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Transformation of flow in rehabilitation: The role of advanced communication technologies

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Authentic rehabilitation requires the active participation of patients and their involvement with opportunities for action and development. Within this framework, in this article we outline the possibility of using two emerging computing and communication technologies—ambient intelligence (AmI) and virtual reality (VR)—for a new breed of rehabilitative and clinical applications based on a strategy defined as *transformation of flow*. Transformation of flow is a person's ability to exploit an optimal (flow) experience to identify and use new and unexpected psychological resources as sources of involvement. We identify the feeling of *presence*—the feeling of being in a world that exists outside oneself—as the theoretical link between the technology and rehabilitation. AmI and VR are used to trigger broad empowerment processes induced by a strong sense of presence, leading to greater agency and control over one's actions and environment.

The International Classification of Functioning, Disability, and Health of the World Health Organization (2004) defines disability as a "condition in which people are temporarily or definitively unable in performing an activity in the correct manner and/or at a level generally considered 'normal' for the human being." According to this definition, disability is considered a specific situation in which a person is not able to fully exploit his or her relationship with everyday contexts rather than a characteristic of the individual. For these reasons, technological rehabilitative tools have to move from a specific activity-centered approach to a general user-centered one. In particular, the focus of technology should be the improvement of the quality of the life of the individual, through its effective support of his or her activity and interaction (Glueckauf, Whitton, & Nickelson, 2002).

In this article, we consider the role of two emerging technologies—virtual reality (VR) and ambient intelligence (AmI)—in rehabilitative care. These technologies may be capable of enhancing quality of life for a variety of rehabilitation populations because of their ability to enhance the user's feeling of *presence*, defined as the "feeling of being in a world that exists outside the self" (Riva, Waterworth, & Waterworth, 2004, p. 408). More specifically, VR and AmI can be used for a new breed of rehabilitative applications focused on a strategy described as "transformation of flow." Debilitating illnesses such as Alzheimer's disease often draw individuals into themselves, and to counteract this tendency VR and AmI technologies are used to evoke a feeling of presence or engagement in the external world. The flow experience (Riva et al., 2002; Riva et al., 2004) is one of feeling highly engaged with the world, a feeling that many diverse groups report as empowering (Csikszentmihalyi, 1990).

Virtual Reality and Ambient Intelligence: Two Presence-Enhancing Technologies

VR can be considered the leading edge of a general evolution of communication interfaces such as television, computers, and telephones (Riva & Davide, 2001). Unlike historical communication interfaces, VR provides full immersion of the human sensorimotor channels (auditory, visual, and kinesthetic), thereby creating a vivid and global experience (Biocca & Levy, 1995). VR is an advanced human–computer interface that has recently been used in rehabilitation to allow people to "interact with and become immersed in a computer-generated environment in a naturalistic fashion" (Schultheis & Rizzo, 2001, p. 210). Subjectively speaking, it is the feeling of presence that

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distinguishes VR from other interface technologies (Ruggeroni, 2004).

These aspects of VR offer two main advantages to rehabilitators (Morganti, 2004; A. Rizzo, Schultheis, Kerns, & Mateer, 2004). First, patients receive immediate feedback about their performance in a variety of forms and sensory modalities. This allows for the creation and provision of more *ecologically* valid assessment and rehabilitation scenarios. Furthermore, it allows the provision of "cuing" stimuli or tailored sensory modality presentations designed to improve availability of assessment and rehabilitation. In other words, the creator of the VR environment has the capability to build in systematic assessments that provide ongoing feedback regarding improvements over base-rate performance. Second, the therapist/rehabilitator using VR can create and control a dynamic and interactive 3-D scenario within an immersive environment. Thus, VR allows for complete performance capture and the availability of a more naturalistic/intuitive performance record for review and analysis. Furthermore, it offers the capacity to pause assessment, treatment, and training for discussion and/or integration of other methods.

In a computer-generated environment such as VR, the full range of behavior—including overt behavior as well as physiological measures such as heart rate and galvanic skin response—can be captured and correlated with the subjective experience of research participants.

In summary, VR provides a new human–computer interaction paradigm in which users are no longer simply external observers of images on a computer screen but are active participants within a computer-generated 3-D virtual world (Riva, 1997; Riva, Alcañiz, et al., 2003; Riva, Wiederhold, & Molinari, 1998). In a particular virtual environment created with VR technology, the patient has the possibility of learning to manage a problematic situation related to his or her diagnosis in a more realistic and ecologically valid context than is typically provided in most clinical settings (Mendozzi, Motta, Barbieri, Alpini, & Pugnetti, 1998; A. A. Rizzo & Buckwalter, 1997).

The term *ambient intelligence* refers to a specific vision of the Information Society Technologies Advisory Group (ISTAG) of the European Community according to which humans will be surrounded by intelligent interfaces supported by advanced technologies distributed everywhere and embedded in everyday objects such as furniture, clothes, vehicles, and roads (ISTAG, 2002). Although the term *ambient technology* may be specific to the ISTAG, its concepts, methods, technologies, and interfaces are shared by different groups all over the world. Some examples are the *smart medical home* concept introduced by the Center for Future Health, the notion of *pervasive human-centered computing* proposed by the Oxygen MIT project, and the *ubiquitous computing* vision detailed by Georgia Tech. For example, the Smart Medical Home Research Laboratory is a five-room house equipped with infrared sensors, computers, biosensors, and video cameras. The goal is to develop an integrated personal health system where all technologies are integrated seamlessly, allowing people to maintain health, detect the onset of disease, and manage existing diseases. To illustrate, the Center for Future Health provides a video of an older person asking the system whether or not she can take an aspirin and what may be causing her headaches. The system asks her questions about her condition, recalls her physician's advice, and notes that headaches may be a symptom of her other medications.

On the practical side, AmI may be roughly described as the flip side of VR: VR puts people inside a computer-generated world, and AmI puts the computer inside the real world to help us. If combined with mobile technologies, AmI may enhance the activity of a mobile user by embedding one or more interactive AmI objects (e.g., holograms, videos, images, texts, sounds) in his or her clothes, automobile, or even a bicycle (Rosenblum, 2000). Through "tangible user interfaces," it is possible to employ physical objects, surfaces, and spaces as specific embodiments of digital information (Ullmer & Ishii, 2001). For example, one can imagine an AmI interface built into a bicycle that provides information about the grade of upcoming hills, traffic approaching from all directions, and rider fatigue, and makes recommendations to the rider or even occasionally assists with pedaling. Following this paradigm, we can embed an active interface in any assistive device, helping the user to understand how to use it effectively. In this way, tangible interfaces may transform the ambient environment (e.g., walls, desktops, ceilings, doors, windows) into an active interface between the user and his or her activity. According to the AmI metaphor, people will live in enriched environments in which the technology is sensitive to their needs, personalized to their requirements, anticipatory of their behavior, and responsive to their presence. Considering the AmI-enhanced bicycle described above, such an interface would need not only to sense objective conditions such as hill grade and weather conditions, but also to assess the subjective preferences of individual riders at each particular moment. Different riders are likely to find different kinds of information useful and be more or less willing to receive help at different times. Presumably, this assessment is made on the basis of a combination of previous experience with specific riders, sensory inputs from the present environment, and judicious questioning of the rider.

Recently, Riva (2005) introduced a psychological definition of AmI based on the experience of the user: "AmI is the effective and transparent support to the activity of the subjects through the use of information and communication technologies" (p. 20). This definition suggests that the role of AmI in rehabilitation is related to its ability to support action. It also identifies effectiveness (defined as attainment of the objective of the activity) and transparency (defined as an absence of breakdowns during the activity) as the main characteristics of any rehabilitative AmI system. Following this vision, the most important reason for developing AmI assistive tools lies in their potential to *compensate or expand the activity of users* through new forms of human–computer interaction (Morganti & Riva, 2005; Riva, 2003).

For instance, an AmI system may identify the impairment of a blind man and signal him by voice the instructions presented on a wall. Furthermore, AmI assistive tools may use gaze analysis to expand possibilities of interaction in paralyzed subjects.

Presence and Agency

We argue that the key feature of both VR and AmI technologies is that they offer an effective support to the activity of the subject by activating a stronger sense of *presence* (Riva, Davide, & IJsselsteijn, 2003). Presence is usually defined as the "sense of being there" (Steuer, 1992) or the "feeling of being in a world that exists outside the self" (Riva & Waterworth, 2003; Riva, Waterworth, & Waterworth, 2004). A growing group of researchers considers presence as a neuropsychological phenomenon, evolved from the interplay of our biological and cultural inheritance, whose goal is to increase emotional fidelity and perceptual accuracy to produce a strong sense of agency and control (Alcañiz, Baños, Botella, & Rey, 2003; Mantovani & Riva, 1999; Moore, Wiederhold, Wiederhold, & Riva, 2002; Nova, 2005; Retaux, 2003; Riva & Davide, 2001; Riva, Davide, & IJsselsteijn, 2003; Schubert, Friedman, & Regenbrecht, 2001; Spagnolli & Gamberini, 2002; Spagnolli, Varotto, & Mantovani, 2003; J. A. Waterworth & Waterworth, 2001, 2003; Zahoric & Jenison, 1998).

Some VR researchers consider the subjective sense of presence in VR worlds simply a "perceptual illusion of nonmediation" (Lombard & Ditton, 1997). However, recently some VR researchers have conceptualized presence more broadly (Baños et al., 2005; Rettie, 2005; Riva, Waterworth, & Waterworth, 2004; Spagnolli & Gamberini, 2005) to address the question of why people feel a sense of presence in any setting, computer generated or otherwise (Timminis & Lombard, 2005). In these works, presence is conceptualized as a continuous variable, so that individuals may feel different degrees of presence in different situations depending on the degree of meaning experienced in an environment. Thus, an inhabitant of the Amazon rainforest, rich in ethnobotanical knowledge, may feel a fuller sense of presence while walking through the forest than might an urban visitor admiring the beauty. Similarly, a computer-literate person may feel a greater sense of presence while surfing the Web than might a computer novice. From this point of view, presence has a simple but relevant role in our everyday experience: *It is the control of agency through the unconscious separation of "internal" and "external."* The sense of presence allows the nervous system to differentiate between internal and external states. As infants develop, they learn that some aspects of their perceptual worlds (such as the movements of their arms) are part of the "self" and that other aspects of the environment (such as the movements of a mobile) are not "self." Were it not for the development of the sense of presence, it would be impossible for the nervous system to reference perceptions to an environment beyond our boundaries. As we will see below, the meaning of "internal" and "external" is related not only to the body but also to the social, emotional, and cultural space (situation) in which the self is embedded. If this sounds far-fetched, consider the subjective experience of driving a car. For experienced drivers, the car becomes an extension of the self. Statements such as "she's too close to my rear" or, worse, "he hit me" reveal the subjective sense of internalizing the dimensions of the car. This subjective recalibration of boundaries facilitates the greater sense of control experienced by good drivers.

From this point of view, it is important to distinguish between *presence as process* and *presence as feeling*. Presence as process is the continuous activity of the brain in separating "internal" and "external" within different kinds of afferent and efferent signals. As emphasized by de Vignemont and Fourneret (2004),

> the double sense of agency depends on the same mechanisms of action control: It results from the unconscious comparison between different kinds of afferent and efferent signals. Therefore, these monitoring systems allow one to automatically distinguish one's own actions and those of the other. (p. 15)

Thus, presence as process can be described as a sophisticated form of monitoring of action and experience, transparent to the self but critical for its existence.

As Russell (1996) further clarified,

> Action-monitoring is a subpersonal process that enables the subjects to discriminate between self-determined and world-determined changes in input. It can give rise to a mode of experience (the experience of being the cause of altered inputs and the experience of being in control) but it is not itself a mode of experience. (p. 263)

For this reason, presence as feeling is not separated from the experience of the subject but is related to the quality of our actions. It corresponds to what Heidegger (1959; translated by Macquarrie & Robinson, 1962, p. 5) defined as "the interrupted moment of our habitual standard, comfortable *being-in-the-world.*" Subjectively, a higher level of presence as feeling is experienced by the self as a better quality of action and experience (Marsh, 2003; Zahoric & Jenison, 1998). However, sometimes we become aware of presence as a feeling of being separate from our being-in-the-world, as during either breakdowns or optimal experiences. Winograd and Flores (1986) refer to presence disruptions as *breakdowns*: A breakdown occurs when, during our activity, an aspect of our environment that we usually take for granted becomes part of our consciousness. If this happens, we shift our attention from action to the object or environment in order to cope with it. To illustrate, imagine sitting outdoors engrossed in reading a book on a pleasant evening. As the sun sets and the light diminishes, one continues reading, engrossed in the story, until one becomes aware that the light is no longer suitable for reading. In such conditions, before any overt change in behavior, what we experience is a breakdown in reading and a shift of attention from the book to the light illuminating the book.

It is interesting to consider why we experience such breakdowns. Our hypothesis is that breakdowns are a sophisticated evolutionary tool used to control the quality of experience, which ultimately enhances our chances of survival. As a breakdown occurs, we experience a lower level of presence as feeling, which reduces the quality of experience and leads us to confront environmental difficulties.

On the other end of the spectrum are optimal experiences. According to Csikszentmihalyi (1975, 1990), individuals preferentially engage in opportunities for action associated with a positive, complex, and rewarding state of consciousness known as *optimal experience* or *flow*. There are some exceptional situations in real life in which the subject's activity is characterized by an unusually high level of presence. In these situations, the subject experiences a full sense of control and immersion. When this experience is associated to a positive emotional state, the result is the feeling of flow. An example of flow is the case in which a professional athlete is playing exceptionally well (positive emotion) and achieves a state of mind in which all attention is focused on the game (high level of presence). For Ghani and Deshpande (1994), the two main characteristics of flow are total concentration on an activity and the enjoyment that one derives from the activity. Significantly, these authors identified two other factors that affect the experience of flow: a sense of control over one's environment and the level of challenge relative to a certain skill level.

Technology, Presence, and Flow

A critical corollary of our vision of transformation of flow in rehabilitation are design-technologically-mediated situations that elicit a state of flow by activating a high level of presence (Morganti & Riva, 2005; Riva, 2005; E. L. Waterworth et al., 2003). In particular, we argue that VR and AmI are the best technologies for facilitating optimal flow experiences. In this section, we will explain the rationale behind this claim.

Immersive VR is the medium most capable of activating the highest level of presence and allowing flow when connected to positive emotional experiences. The work of Gaggioli (2004; Gaggioli, Bassi, & Delle Fave, 2003) supports this vision. Gaggioli (2004) compared the experience reported by a user immersed in a virtual environment with the experience reported by the same individual in daily situations. To assess the quality of experience, the author used a procedure called the *experience sampling method*, which is based on repeated online assessments of the external situation and internal personal states of consciousness (Csikszentmihalyi & LeFevre, 1989). Results showed that VR experience was the activity associated with the highest level of optimal experience (22% of self-reports). Reading, television viewing, and the use of other media—in the contexts of both learning and leisure activities—yielded lower percentages (15%, 8%, and 19% of self-reports, respectively) of optimal experiences.

The successful use of VR exposure in therapy highlights the possibility that a high level of presence elicited by the use of technology may help facilitate rehabilitation. VR has been used in a number of therapeutic contexts, including therapy for phobias (Rothbaum, Hodges, Anderson, Price, & Smith, 2002; Rothbaum, Hodges, Smith, Lee, & Price, 2000; Vincelli et al., 2003; Wiederhold & Wiederhold, 2003), posttraumatic stress disorders (Hodges et al., 1999; Rothbaum, Hodges, Ready, Graap, & Alarcon, 2001; Roy, 2003), and pain reduction in burn patients (Hoffman, Patterson, & Carrougher, 2000; Hoffman, Patterson, et al., 2004; Hoffman, Richards, et al., 2004; Hoffman, Richards, Coda, Richards, & Sharar, 2003). AmI could be a powerful tool for increasing the level of presence in natural environments. This can be achieved by providing tools or cues that directly or indirectly support the action of the subject. AmI offers the user new tools or targeted cues that make his or her action simpler (e.g., an interactive map to make it easier to reach the clinician's office in the hospital). It also offers indirect support by providing cues that improve the meaning given to the situation (e.g., a narrative describing the history of a church we are visiting, along with the times of church services and information about the congregation).

Authentic rehabilitation implies the active participation of patients in their contexts, their exposure to opportunities for action and development, and their freedom to select the opportunities that they perceive as most challenging and meaningful (Gaggioli, 2005; Gaggioli et al., 2003). In response to this vision, a critical asset potentially offered by VR to the rehabilitation process is the possibility of triggering optimal experiences (J. A. Waterworth, 2003). Optimal experiences cultivate individual development within a given skill domain. As Massimini and Delle Fave (2000) noted, to replicate a flow experience,

> a person will search for increasingly complex challenges in the associated activities and will improve his or her skill, accordingly. This process has been defined as *cultivation*; it fosters the growth of complexity not only in the performance of flow activities but in individual behavior as a whole. (p. 28)

This process can also be activated after a major trauma. As Delle Fave (1996) explained, to cope with dramatic changes in daily life and in accessing environmental opportunities for action, individuals may develop a strategy defined as *transformation of flow*: a person's ability to build upon optimal experiences to identify and exploit new and unexpected resources and sources of involvement.

We hypothesize that it is possible to use VR and AmI to activate a transformation of flow to be used for rehabilitative purposes. The proposed approach begins with identification of an enriched environment that contains *functional* real-world demands. The use of real-world demands is critical to creating a connection between subjective experience and true agency. Then, we use the technology to enhance the subjective level of presence in the environment and to induce an optimal experience. Linking agency and presence promotes cultivation by linking an optimal experience to particular abilities. This transformation of flow not only provides positive experiences but also guides and motivates fuller engagement beyond the scope of particular VR sessions.

It is interesting to note that the proposed approach can be considered an advanced technological version of the multisensory environment approach used in the rehabilitation of the learning disabled and of older people with dementia (Hope, 1998; Thompson & Martin, 1994). Multisensory environments are

> purpose-built units or rooms utilized for the application of multisensory stimulation, whose goal is the stimulation of the primary senses to generate pleasurable sensory experiences in an atmosphere of trust and relaxation without the need for intellectual activity. Exposure to multisensory stimulation occurs through the agency of the care provider, nurse or therapist who facilitates the development of a relaxing and supportive environment. (Hope & Waterman, 2004, p. 58)

The results from a recent randomized controlled trial ($N = 50$) showed the efficacy of this approach in the treatment of older people with dementia (Baker et al., 2001). In particular, the use of a multisensory environment appeared to have a greater influence on aspects of communication in comparison with one-to-one activity, and also appeared to lead to improvement in behavior and mood at a 4-week follow-up. We hypothesize that the VR experiences we propose will have a greater impact because they rely on the agency of the participant rather than on that of the care provider.

To verify the link between advanced technologies and optimal experiences, the V-Store project was recently carried out to investigate the quality of experience and the feeling of presence in a group of 10 patients with frontal lobe syndrome involved in VR-based cognitive rehabilitation (Castelnuovo, Lo Priore, Liccione, & Cioffi, 2003). On one hand, during the project the experience sampling method (Csikszentmihalyi & LeFevre, 1989) was used for repeated online assessments of these patients' external situations and the emotional, cognitive, and motivational components of their daily experience during 1 week, which included traditional cognitive rehabilitation and sessions of exposure to the V-Store VR environment. On the other hand, after the VR experience the ITC-Sense of Presence Inventory (Lessiter, Freeman, Keogh, & Davidoff, 2001) was used to evaluate the feeling of presence induced by the VR sessions. Findings highlighted the association of VR sessions with both positive affect and a high level of presence. In particular, during the VR sessions "spatial presence"—the first scale of the ITC-Sense of Presence Inventory—was significantly correlated with the positive psychological feelings of "being free" ($r = .81, p < .01$) and "being relaxed" ($r = .67, p < .05$).

The transformation of flow may also exploit the plasticity of the brain, producing some form of functional reorganization (Johansson, 2000). Optale and his team (Optale, 2003; Optale et al., 1999; Optale et al., 1997) used a transformation-of-flow approach to treat male erectile disorders. They found that 30 of 36 patients with psychological erectile dysfunction and 28 of 37 clients with premature ejaculation maintained partially or completely positive response at a 6-month follow-up. The most interesting aspect of their work is the PET scan analysis. Optale et al. (1998) used PET scans to analyze regional brain metabolism changes from baseline to follow-up in the experimental sample. The analysis of the scans showed different metabolic changes in specific areas of the brain connected with the erection mechanism. These findings suggest that this approach may hasten the healing process and produce lasting neurological changes. The relationship between VR-based therapy and neurological functioning is an exciting avenue for further research.

Recent experimental results from the work of Hoffman and his group in the treatment of chronic pain (Hoffman, Patterson, & Carrougher, 2000; Hoffman, Patterson, et al., 2004; Hoffman, Richards, et al., 2004; Hoffman, Richards, Coda, Richards, & Sharar, 2003) also might be considered to foster this vision. Few experiences are more intense than the pain associated with severe burn injuries. In particular, daily wound care—the cleaning and removal of dead tissue to prevent infection—can be so painful that even the aggressive use of opioids (morphine-related analgesics) cannot control the pain. However, it is well-known that distraction—for example, having the patient listen to music—can help to reduce pain for some people. Hoffman, Doctor, Patterson, Carrougher, and Furness (2002) conducted a controlled study of the efficacy of VR as an advanced distraction by comparing it with the efficacy of a popular Nintendo video game. The results showed dramatic reductions in pain ratings during VR in comparison with those during the video game. Furthermore, using an fMRI scanner, they measured pain-related brain activity for each participant during conditions of VR and without VR in a study in which order was randomized. The team studied five regions of the brain that are known to be associated with pain processing: anterior cingulate cortex, primary and secondary somatosensory cortex, insula, and thalamus. They found that during VR all these regions showed significant reductions in activity. In particular, they found direct modulation of pain responses within the brain during VR distraction. The degree of reduction in pain-related brain activity ranged from 50% to 97% (Hoffman, Doctor, et al., 2000).

Discussion

In this article, we suggest the possibility of using two emerging communication technologies—AmI and VR—for a new class of rehabilitative applications based on a strategy described as "transformation of flow." The vision underlying this concept arises from positive psychology (Seligman & Csikszentmihalyi, 2000). According to this vision, existing professional treatments should include positive peak experiences because they serve as triggers for a broader process of motivation and empowerment. Within this context, *transformation of flow* can be defined as a person's ability to draw upon an optimal experience and use it to marshal new and unexpected psychological resources and sources of involvement.

We identified the feeling of "presence"—the feeling of being in a world that exists outside the self—as the theoretical link between the technology and transformation of flow. The technology is used to trigger a broad empowerment process within the flow experience induced by a strong sense of presence. Two emerging technologies, VR and AmI, may facilitate these processes. By inducing a feeling of presence, VR and AmI may support a person's actions, allowing a greater subjective sense of personal efficacy (Morganti et al., 2003).

An avenue of research that we are currently exploring concerns the use of this technologically based transformation-of-flow protocol to fight the onset of Alzheimer's disease (Optale et al., 2001). In particular, we hypothesize that this approach could be used to target mild cognitive impairment (Burns & Zaudig, 2002), a pathological state that differs from normal aging characterized by objective evidence of memory impairment. However, despite the significant advances in computer and graphic technology and the development of different VR and AmI applications, their rehabilitative use is still limited by the maturity of the systems available today. No off-the-shelf solutions are currently available. Our experience is that rehabilitation research with VR and AmI requires much patience for dealing with conflicting hardware and software. Nearly every VR system requires a dedicated staff or at least one computer technician to keep the system running smoothly. Testing the available technology is an important and ongoing process, so therapists and researchers must continue to investigate the application of these tools to their day-to-day research and clinical practice. Finally, it is still the case that in most circumstances, today and in the foreseeable future, the clinical skills of the rehabilitator are the key factor in the successful use of any technology.

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