Shifting towards Remote Located Virtual Environments for Rehabilitation

Evelyne Klinger
HIT Team, P&I Lab Laval,
Arts et Métiers ParisTech Angers, France
evelyne.klinger@angers.ensam.fr

Patrice L. (Tamar) Weiss
Laboratory for Innovations in
Rehabilitation Technology,
University of Haifa, Israel
tamar@research.haifa.ac.il

Abstract

Improving access to medical rehabilitation service delivery is one of the most challenging issues facing health care research. In parallel, the rapid development of virtual reality (VR) based technologies over the past decade is an asset that can be used to meet this challenge. This paper describes the evolution of VR systems according to two dimensions: the number of users and the distance between the users. We show how single user and locally used virtual environments have recently been expanded to three additional avenues: multiple users in collocated settings, single users in remote location, and multiple users in remote locations. We will finally highlight concerns when adopting remote located virtual environments for neurological rehabilitation.

Keywords: Virtual reality, rehabilitation, remote location.

Introduction

As a result of the need to reduce care costs, the discharge policy in many countries has changed to release patients before they have completed a full program of rehabilitation (Saxena, Ng, Yong, Fong, & Gerald, 2006). Many thus return home with disabling deficits and less than optimal functional performance. Considering recent evidence supporting the effectiveness of intensive therapy for at least the first six months following stroke (Liepert, et al., 2000; Nudo, 2007), improving access to home-based care and extending the reach of medical rehabilitation service delivery is a major challenge in health care research. In parallel, the rapid development of virtual reality (VR) based technologies over the past decade is an asset for neuro-rehabilitation (Rizzo, Schultheis, Kerns, & Mateer, 2004). These novel technologies provide interactive, functional simulations with multimodal feedback that enable clinicians to achieve traditional therapeutic goals (Holden, 2005; Rose, Brooks, & Rizzo, 2005). They also lead to the creation of novel clinical assessment and intervention paradigms. For example, the virtual Morris Water Maze combined with fMRI has been use to increase the understanding of the role of the hippocampus in spatial memory (Shipman & Astur, 2008).

In recent years, we have observed a push-pull phenomenon which is leading to an increase in the application of VR technologies for rehabilitation (Crosbie, Lennon, Basford, & McDonough, 2007; Weiss & Klinger, in press). The “push” emanates from the continuous development of novel technologies, their more ready availability in clinical settings, and lowered costs. The “pull” stems from clients, clinicians and third party payers who recognize the need for treatment that goes beyond conventional therapy.

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In this paper we will describe progress from virtual environments (VE) designed to support single users in local settings for rehabilitation to those that enable multiple users to interact in both local and remote locations (Figure 1).

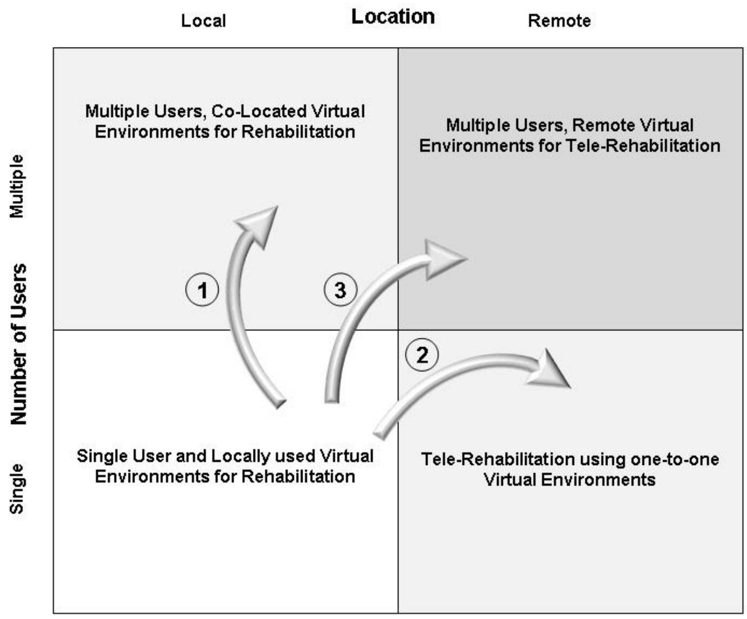

Figure 1. Shifting towards remote located virtual environments for rehabilitation

We begin by showing an example of the original approach (lower, left quadrant in Figure 1): a single user (i.e., designed for and used by one clinical client at a time) used locally within a clinical or educational setting. We then expand to three additional avenues: multiple users in co-located settings (Arrow 1), single users in remote locations (Arrow 2) and multiple users in remote locations (Arrow 3). We will finally highlight the assets of remote located VEs for rehabilitation that have led to the concept of tele-rehabilitation.

Single User Approach

Replicating the therapist-patient relationship in traditional therapy, the first VR-based applications were used with a single user (patient) who engaged in a particular VE in the presence of the therapist; this is what we refer to as the single user and locally used (lower, left quadrant in Figure 1). The description of the Virtual Action Planning - Supermarket (VAP-S) will illustrate the clinical attributes of such systems (Klinger, Chemin, Lebreton, & Marié, 2006).

The VAP-S was developed in order to meet the need for a clinically feasible and ecologically valid tool for cognitive planning assessment (Klinger, Chemin, Lebreton, & Marié, 2004; Marié, Klinger, Chemin, & Josset, 2003). The VAP-S original paradigm is based on the “test of shopping list” (Martin, 1972). It proposes a series of actions, described as a task, and allows an analysis of the strategic choices made by clients and thus their capacity to plan. It simulates a fully textured, medium size supermarket with multiple aisles displaying most of the items that can be found in a real supermarket (Figure 2).

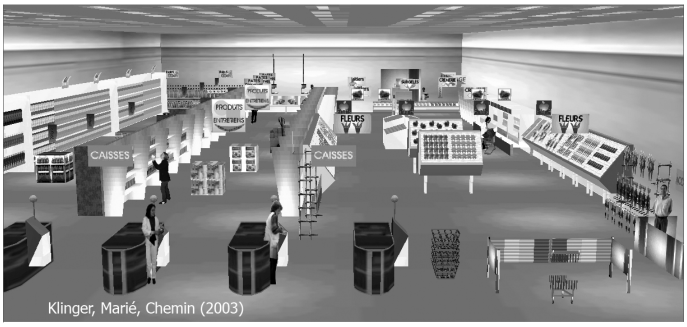

Figure 2. The Virtual Action Planning – Supermarket (VAP-S)

The test task is to purchase seven items from a clearly defined list of products, to then proceed to the cashier's desk and to pay for them. Following a familiarization session, participants complete the task without any time limitations. Twelve correct actions (e.g., selecting the correct product) are required to completely succeed in the task. Various outcome measures (position, times, actions) are recorded while the participant executes the task; they allow the calculation of at least eight variables, of which the total distance traversed by the user. A review of the performance is available from a "Bird's eye view", i.e. from above the scene (Figure 3).

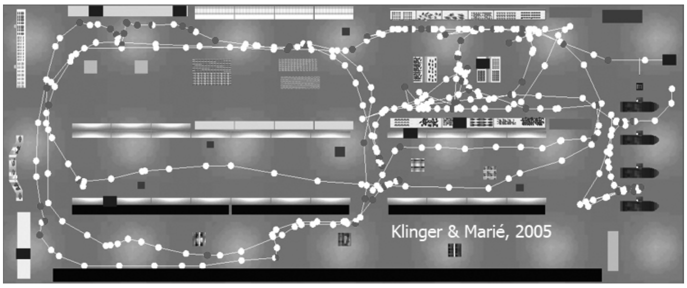

Figure 3. A typically trajectory of a patient with Parkinson's Disease

The initial design of the VAP-S was carried out in the context of research on Parkinson's Disease and the elderly (Klinger, et al., 2006). This system is now applied to other clinical populations including the exploration of executive functions of post-stroke patients (Josman, et al., 2006; Klinger, et al., 2008). These studies confirmed the feasibility of the VAP-S for use with persons suffering from the dysexecutive syndrome and examined the relationships between performance within the VAP-S and standard outcome measures of executive functions.

Clinical researchers have foreseen the need to go beyond the single user, local location environment, and have begun to develop more complex VR-based approaches that advance along the two dimensions shown in Figure 1: the number of users and the distance between the users. With regard to the dimension of number of users (Figure 1, arrow 1), issues related to the role that additional users will play in a VE arise. They may be involved in an assistive role (e.g., a therapist may help the patient perform the activity or task), or in a positive or negative collaborative role (e.g., patients may be involved in a common activity to achieve a task). In order to illustrate the second aspect, we next describe the use of collaborative tables among children with autism (Gal, et al., in press).

Co-located Multiple Users Approach

Active Surfaces are an emerging class of devices and applications (Zancanaro, et al., 2007). They are shared, co-located systems that are based on large interactive surfaces placed horizontally ('tabletop' devices) or vertically ('wall displays') on which a specifically designed interface is displayed or projected. The StoryTable examines interaction pattern in pairs of typically developed children when narrating a joint story using an the interface that "enforced" joint actions (Figure 4) (Zancanaro, et al., 2007). Inspired by the methodology of Cooperative Learning (Johnson & Johnson, 1999), our 'enforced cooperation' paradigm aims to support and promote cooperation within small groups by requiring that designated actions and manipulations at the interface be physically performed together by the group participants. The nature and distribution of those multi-user actions can be varied to affect the degree of cooperation among the group members.

The StoryTable paradigm was used with high functioning Autistic Spectrum Disorder (ASD) to evaluate the effectiveness of a three-week intervention in which a computerized, co-located touch table interface combined with Cognitive Behavioral Therapy (CBT) intervention guidelines (e.g., self instruction, problem solving) (Gal, et al., in press; Gal, et al., 2005). Results demonstrated progress in three major areas of social behaviors. First, the participants were more likely to initiate positive social interaction with peers after the intervention. Second, the level of shared play of the children increased from the pre-test to the post test and they all increased the level of collaboration following the intervention. Third, the children with ASD demonstrated lower frequencies of autistic behaviors while using the StoryTable in comparison to the free construction game activity. This preliminary study revealed the effectiveness of the integration of technology to enforce collaboration integrated with CBT framework.

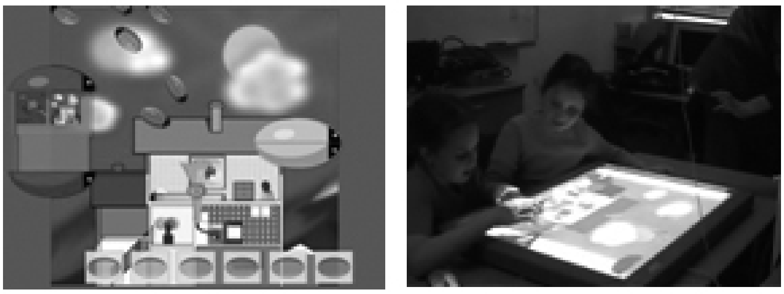

Figure 4. The StoryTable. Left panel shows screen shot of one story telling background. Right panel shows two typically developed children engaged in a multi-touch activation.

Remote Located Single User Approach

In order to improve access to care and to extend the reach of medical rehabilitation service delivery, several VEs have evolved that add distance between the patient and the therapist leading to what is known as tele-rehabilitation (Figure 1, arrow 2). The clinical attributes of such systems will be evoked with the description of upper extremity function rehabilitation in patients with stroke (Holden, Dyar, Schwamm, & Bizzi, 2005).

Holden et al. (2005) proposed a tele-rehabilitation system that is an enhancement and expansion of their VR-based motor training system for upper extremity, originally developed as a single user and locally used VE (Holden, Dyar, & Dayan-Cimadoro, 2007). The system provides real-time interactive training sessions at the patient's home with a therapist who is located remotely at a clinic. Each partner (patient and therapist) uses two computers, one for the display of the VR program (VE display) and one for communication via video-conferencing. The computers are connected via a high-speed Internet connection. Motion-capture equipment transmits information about the patients' arm movements to both VE displays (patient and therapist), and video cameras allow video-conferencing. The movements are performed within the context of a virtual situation which requires from the patient to imitate a pre-recorded movement. The therapist can direct and control the activity in real time from the remote clinical setting. This system has been used to train a wide variety of arm movements in any place at the UE workspace. A study, carried out with 11 subjects with stroke, demonstrated the feasibility the system deployment in home-based environment and the efficacy of this kind of training in the context of stroke (Holden, et al., 2007). Results showed significant improvement in the upper extremity function following 30 VE treatment sessions (one-hour each, delivered 5 times per week) as measured with standard clinical tests. The changes were maintained, for the most part, at a four-month follow-up test.

Remote Located Multiple Users Approach

The obvious next step in the evolvement of VEs for clinical use is to expand jointly in both dimensions (numbers of users and location) as shown in Figure 1, arrow 3. Indeed, researchers have recently begun to develop and evaluate the use of "multiple users and remote VE" for tele-learning and tele-therapy. This phenomenon is supported by the continuous development of robust technologies such as faster, more secure Internet connections and the growing popularity of the social networks (Boulos & Wheeler, 2007). In order to illustrate this trend, we next describe some medical and health applications based on Second Life.

Second Life is an Internet-based virtual world launched in 2003 by Linden Lab (http://lindenlab.com). Second Life provides an advanced level of social interaction while allowing users, called residents, to participate in individual and group activities, and to create and trade items and services. About 38,000 residents are logged on to Second Life at any particular moment. Second Life currently features a number of medical and health educational projects including Nutrition Game, Heart Murmur Sim, Second Life Virtual Hallucination Lab, Gene Pool, Occupational Therapy at the Virtual Neurological Education Centre (Boulos, Hetherington, & Wheeler, 2007; Gorini, Gaggioli, Vigna, & Riva, 2008). All these initiatives focus primarily on the dissemination of medical information and the education of therapists and patients.

However a few Second Life VEs, called private islands, have been created for therapeutic purposes. For example, Brigadoon (Lester, 2005) was specifically designed for patients with Asperger's syndrome. Brigadoon is a controlled environment where users are encouraged to feel comfortable and learn socialization skills at their own pace. This simulation is less fearful for people because it does not involve local interactions, yet, due to the representation of actual users via avatars, it retains the flavour of real social situations. Its ability to teach social skills that are effective in real world situations remains to be evaluated.

Concerns when Adopting of Remote Located Approaches

Future applications of tele-rehabilitation (remote located) systems, designed to further improve and prolong healthcare after disabling events, must provide robust systems that are easy to operate by home-based users, are relatively inexpensive, yet retain the assets found to be essential in hospital-based virtual reality. Selection of a platform (VR system), for example, that is capable of providing real-time feedback (both knowledge of performance and knowledge of results) to the user as well as to the remote therapist is essential. The selection and implementation of VEs for both assessment and intervention purposes must be capable of execute optimal therapeutic objectives. These may include off-the-shelf games wherein virtual control is "translated" into simple or complex limb movements or specialized functional environments programmed within public domain software such as NeuroVR (http://www.neurovr.org/). Consideration of how to model the patient within the VE (e.g., via an avatar or letting him view himself) is also important. Finally, therapist control over the environment with full two-way documentation is crucial. For example, a therapist needs to be able to specify and calibrate the system such that any given environment will respond with programmable levels of difficulty or will respond only to a specific limb (e.g., the patient's weak hand) or will respond to any body part.

Conclusion

Single user, locally operated VR-based technologies will continue to play a major role in providing rehabilitation within a clinical or educational setting. Due to the considerable technical barriers it is only in recent years that remote located systems to support home-based rehabilitation have become feasible. The literature, to date, has focused on descriptions of system development and reports of small pilot studies (Brennan, Mawson, & Brownsell, in press). We anticipate that the coming two years will see the publication of evidence that begins to demonstrate the effectiveness of remote therapy as well as the identification of "best practice" guidelines concerning its implementation.

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