Do we need high-scale flexibility in virtual therapies?

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ABSTRACT

Virtual reality (VR) offers a wide range of applications in the field of cognitive neuropsychology both in diagnosing cognitive deficits and in treating them. An optimal diagnostic method is the on-field test, which provides an opportunity to apply VR-based simulations. VR is also a useful tool for skill-building and training by setting up a virtual setting, which imitates the real environment including the attributes to be trained. Moreover, it provides a graded approach to problem-solving and the feeling of safety and it excludes the negative elements which are detrimental to the learning process. To further extend the effectiveness of VR applications it is necessary to refine VR environments and adapt them according to the specific needs of selected target groups and the real-time control of virtual events. Following the principle of flexibility we prepared two virtual environments: 1) an Adjustable Virtual Classroom (AVC) for the treatment of fear of public speaking in a primary school task-solving setting, and 2) a Virtual Therapy Room (VTR) designed for use with aphasic clients. Due to their flexible nature, a large number of elements can be customised in both of these settings including spatial organisation, textures, audio materials and also the tasks to be solved. The real-time control over the virtual avatars by the supervisor, i.e. therapist to guide the social interactions in the virtual world also allows him/her to follow-up on the user's reactions and therapy performance. By focusing on the details of the therapy room, we would like to demonstrate the relevance of the flexibility of the software in the development of innovative therapy solutions for aphasic clients.

1. INTRODUCTION

Virtual reality offers a wide range of applications in the field of cognitive rehabilitative medicine. The research area we are interested in is rehabilitation in the field of cognitive neuropsychology and in particular language therapy for persons with aphasia. In this area, the most significant application of VR is in the therapy environment as a tool for intensive structured practice for the patient. However, it also has its merits in diagnosing neuropsychological deficits. As stated by Pugnetti and colleagues (1998): "VR will probably change some of the diagnostic procedures that are still used after decades have passed from their introduction". For this reason, various neuropsychological test procedures should be adapted according to innovations in the field of VR. On the other hand, Shallice (1991) considers the on-field tests to be the best tool for diagnostic purposes, because they provide valid patient information regarding the use of VR-based simulations.

The issue of cost/benefit ratio is the first to address when considering applying VR solutions in this field. This has actually been done, at least with reference to neuropsychologists' being willing to open up to this new technology. They are well aware of the fact that VR technology does not consume an immeasurable amount of money, since most of the applications suitable for their purposes are based on low-cost technology and off-the shelf components (cf. Pugnetti et al, 1998).

Botella and colleagues (1998a) also view VR as a "research laboratory setting for clinical psychology", where emotions, thoughts, and behaviour of patients can be studied through imitating a situation, an atmosphere in which the persons reactions are available for monitoring. Obviously, VR is not suited for the treatment of every type of cognitive deficit or mental disorder. However, for example in the case of phobias, the patients can be exposed to the virtual version of their fears and the clients can profit from this exposure.

As the well-known application of VR in the field of rehabilitative medicine is concerned, namely a therapeutic environment allowing direct practice for improvement of skills, numerous publications report positive results, e.g.: in the treatment of acrophobia, fear of flying and claustrophobia (Botella et al., 1998b; North and North, 1996, Rothbaum et al., 1995; Laky and Sik Lányi, 2003; Sik Lányi et al., 2004, etc.).

The environmental enrichment theory – a well known theory in neuroscience - also supports the importance of situational exercises, which is clearly associated with VR-based simulation. With regard to studies with nonhuman subjects, the term 'enriched environment' refers to an environment with numerous playthings for the animals and less food intake inducing competition among the animals. Renner and Rosenzweig reported (1987) that when laboratory animals were exposed to an enriched environment, they showed a significant improvement in their behavioural patterns. They were superior to their non-enriched counterparts with respect to complex learning and problem solving tasks. Their advantage increased with an increase in the complexity of the problem to be solved. It was observed that enrichment induced changes were evident in several parts of the brain as demonstrated by an increased number of neuron combinations, a heavier cortex, which is deeper and greater in surface area. Kempermann and colleagues (1997) indicated that these factors contribute to increased performance.

Similar result have been found for primates. Therefore, the application of this theory for neurological patients is well-grounded. Tinson and colleagues (1989) observed that stroke patients tend to spend most of their time disengaged, with inactive tasks. Thus, brain damage can lead to a reduction of activity and a withdrawal from participating in social activities. In this context, Rose and colleagues (1998) view VR as a means for producing an enriched environment, which can even overcome some practical problems of real environments.

2. VIRTUAL REALITY

In the area of cognitive rehabilitation VR systems are becoming more sought after because they provide a flexible means to address the aforementioned practical problems. Foremost, virtual reality replaces a real environment with its virtual counterpart, which eliminates the need for leaving the clinic to experience various situations. This is not only important for in-patients, it is even more important in the chronic stage for clients still in need of intensive therapy to cope with situation in daily life. Being able to remain in the wider environment of the clinic, and stressing the non-real nature of the virtual world imparts an underlying feeling of safety, even in case of being confronted with less positive albeit possible daily situations. This kind of acting without feeling threatened is a key factor in therapies (Botella, 1998).

VR also allows the design of environments which are specifically adapted to the basic requirements for a particular type of therapy. This also involves the possibility of excluding unwanted, negative aspects or effects and emphasising beneficial ones which can further strengthen the abovementioned feeling of safety.

In addition to these attributes, VR applications allow for the tackling a critical situation or problem in a graded fashion. For example, in the case of phobias, the formidable nature of the possible situations can be organised according to a graded chain of growing intensity, through which the patient can progress from the easiest tasks to the most difficult ones. Such a gradation is difficult to reproduce in an on-field exercise. In real life situations there is much less control over possible random, unwanted, negative incidents.

Role-playing is a basic exercise in many forms of therapeutic intervention and therapy settings. In such a situation VR can assist the therapist and in doing so it almost becomes another participant in the play besides the patient. This latter case is also one of the best examples, in which the attribute of flexibility can be highlighted. The crucial role of flexibility, which is a central theme of this paper, is also prevalent for both of the aforementioned main applications, namely for diagnostic and therapeutic purposes.

If we conceptualize a virtual environment with bounded surroundings, in terms of its geometry, texture, sounds, it limits the appearance generated by the software. Turning to the dynamics of this artificial world, pre-programmed events lead to the anticipation of the whole situation, i.e. the plot, which heavily influences the behaviour of the patient. Together with the former bounded appearance this could also make the whole exercise very boring for the patient and he/she would lose every motivation for participating.

The design of this type of virtual environment lacks flexibility, which is the crux of the problem. It will result in some sort of standardisation, based on statistical evaluations. It results in standard situations, environments to be displayed, but also standardised patients and human needs. All in all, it appears to match the requirements for a majority of members of a given group, for example the whole community of patients with a particular type of aphasia all over the world. But is it really the case? Or, does it match the needs of a non-existent standard human?

On the other hand, a virtual environment enhanced by flexibility enables us to even depict the users very own real life environment in addition to artificial ones designed by the therapist in user friendly way. Regarding the dynamics of such worlds, there is the possibility of not only customising plots, but also having a real-time control over the entire therapy session, i.e. throughout the therapy process. In summary, we can state that an appropriate level of flexibility allows us to refine the program according to the specific needs of each individual patient. It provides a detailed, accurate display of the actual problem, thus providing the therapist with a tool for developing adequate diagnostic environments or therapy sessions. Such a flexible tool allows for on-line follow-ups of the findings and performance during single sessions and over time in the recovery from aphasia. The whole process becomes more pleasant for the patient.

3. CONCEPT OF THE VIRTUAL CLASSROOM AND VIRTUAL THERAPY ROOM

Following the idea of the virtual classroom put forward by Rizzo (2004) and his colleagues, who measured distracting factors during class-work, we dedicated our class to the treatment of the fear of public speaking in primary schools. Stage anxiety was the topic of another software development which was investigated by Slater and colleagues (1999). They prepared a virtual conference room with a number of avatars and assessed the reaction of the user while presenting to various audiences. One audience paid no attention to the speaker throughout the whole presentation; another audience reacted in a negative manner; and a third audience changed from negative to positive at halfway through the presentation. The authors concluded that co-presence, i.e. the feeling of being with others, seemed to amplify both the negative and the positive sentiments of the situation. More importantly, a higher perceived interest from the audience reduced the anxiety experienced when speaking in public.

Our virtual environment, titled Adjustable Virtual Class (AVC) (cf. Geiszt et al., 2006) was designed on this basis. AVC is characterized by its high degree of flexibility. The situation consists of solving a task on the blackboard, while a living classroom of classmates and a teacher comments on the users' actions. This software package consisted of two essential components: an Editor to set up the classroom with regard to its spatial organisation, textures, sounds and tasks, and a Viewer to immerse the prepared environments. As opposed to Slater's abovementioned work, the avatars in our program are under real-time control of a supervising trainee, and are able to perform four speech utterances accompanied by basic gestures. A valuable potential application of the program is its use as a direct learning tool through adequately designed blackboard tasks.

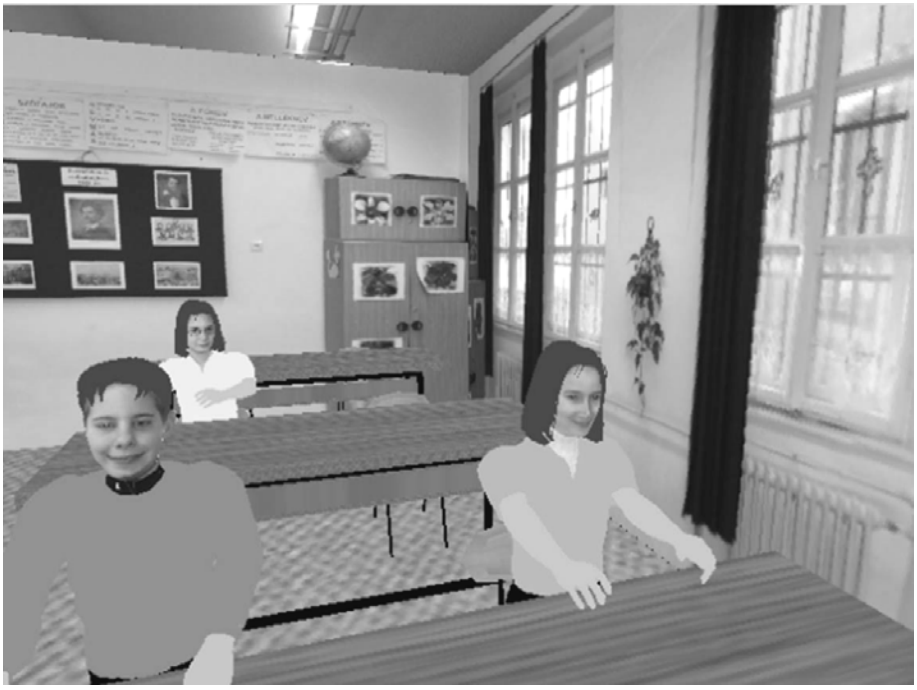

Figure 1. *Virtual students sitting in the Adjustable Virtual Classroom.*

The Virtual Therapy Room (VTR) is our second software based on the principle of flexibility. It follows the pattern laid out in the AVC. Its aim is to serve as an innovative procedure for the provision of language therapy to single aphasic clients or to several clients in a group therapy situation and for developing and testing language tasks to be performed in a VR setting. The VTR requires a different concept for the design of the environment and the situations to be displayed.

The target group for the VTR applications consists of brain-damaged persons who after having suffered a stroke present with a language impairment termed 'aphasia'. The clinical description of the aphasic symptoms varies according to the type – Broca's, Wernicke's, anomic, global - and the degree of severity of the acquired language impairment.

The traditional language rehabilitation process for aphasics involves single patient and group therapy sessions designed to address each aphasic's specific language processing difficulties. VR applications of language therapy for both single patients and group therapy are being developed in our program. In both cases, the therapist can build up an environment with the Editor part, then the patient can immerse in it with a head mounted display. During experiencing the virtual environment he/she has to answer questions appearing on the blackboard. The questions are accompanied by picture stimuli. The picture stimuli used for all of the language therapy tasks are taken from *The Everyday Life Activities (ELA) Photo Series* (Stark, 1992, 1995, 1997, 1998 and 2003). The therapist monitors the aphasic client's doings via a display and switches between the tasks and controls and changes the actions of the present virtual persons.

Figure 2. *Initial version of the Virtual Therapy Room layout.*

The group session is similar to that of the AVC setting, but there is a more direct interaction between the single users and the virtual group members in the form of cooperation or even competition among the members. Although all the members of the virtual community are sitting around a round table, each member has his/her turn to answer a question appearing on the blackboard. If a certain amount of time passes without a solution being provided by the participant whose turn it is, other members are free to answer or to provide some cues or prompts. Thus, in our software the supervising therapist can make them perform those actions.

This competition-type motivation is not part of the single patient session, since here the focus is on situational exercises, i.e. systematic, linguistically structured tasks, for which the patient is alone with the virtual therapist. Thus, it obviously follows that the real supervisor controls only the virtual therapist and the tasks, although the interaction is more intensive between the user and the virtual therapist than in the virtual group therapy setting.

A further extension of the task is to enhance the learning process and thus strengthen the language stimulus for each task item. This is done by shifting of the viewpoint from first person view to a side view after every correct answer is given. In this shifting of viewpoint the user observes his/her own avatar giving the correct answer.

4. DEVELOPMENT

The development of such an environment comprises the preparation of elements from which a world is built up. These elements (or building blocks) of the virtual world are selected according to the needs of the persons who will participate in the VR therapy. Then by way of observation, movement in this world has to be programmed. Lastly, in the case of the Virtual Therapy Room, the program records data for long-term evaluation of the performance of the individual users. In the following, we will concentrate on the development process of this program.

The most important part for the creation of building elements is the modelling process, which can be divided into two parts on the basis of the type of the object modelled: character modelling and the preparation of the inanimate surroundings. The first was done with Poser 4.0, preparing a number of characters, while the second was carried out with 3D Studio Max. Due to the fact that every little motion - from the standpoint of a virtual world - requires a great deal of computation in order to build up the part of the environment which is on view, we had to reduce the number of polygons used in the objects. This was done mostly manually, especially during the pre-sketch of the inanimate objects, while in the poser-generated figures, we used the older 4.0 version of the software due to the lower number of polygons used in that version instead of than in the new 6.0 version.

The second step was the refinement of texture-maps with UVMapper Classic, and for the pictures with PhotoShop 6.0.

Other pre-made elements contain recorded audio materials for avatar utterances and background noise, photos for texturing the models prepared or giving support through illustrating tasks.

The task of the frame software is not only of building up the virtual environment from the prepared models, textures, animations, audio material, and putting it into motion, but also providing a way to prepare and save custom therapy rooms, and save data including audio record of the patients' speech utterances while immersed in the virtual world. It was programmed in C++ language with the help of Irrilicht 3D Game Engine.

In spite of its name, this latter is not an engine for games but rather a so-called library: it is a collection of a number of inbuilt functions, procedures, which aid in the preparation of 3D applications. It is a platform-independent library, thus, it can work with both versions of Linux and Windows. Irrilicht 3D is freeware and can be freely modified.

Most important, from our point of view, is that Irrilicht supports a high number of 3D file types, including the standard object (.obj), Microsoft DirectX (.x), both of which were suited for our development process. The structure of the building elements comprising a prepared therapy room are saved with the help of XML in a properly structured form.

5. USE OF THE VIRTUAL THERAPY ROOM

As it was mentioned before the program has a dual structure. In the first part, i.e. Editor, there is an array of adjustable features. The options menu is divided into two sections: the General settings, comprising attributes of visualisation and room set-up, and the User menu in which the patient data-management is processed.

In the General settings section, the usual entries can be found including screen resolution, colour depth, version of DirectX, etc., and the language of the Editor interface. At present, it is able to communicate in both Hungarian and English.

Under these settings, a list of features concerning the avatars can be found. The model itself and the textures can be imported from files, as well as the audio material for a total of five speech utterances. The suggested picture format is JPEG, while for the audio it is WAW.

The Exercises section of the General settings menu is responsible for the setup of the task to be solved by the user while 'acting' in the virtual environment. Both the question and the answer can be accompanied by text and with a picture appearing simultaneously or following the written presentation on the blackboard of the virtual classroom. Audio material can be imported and associated to the task item presented on the virtual blackboard. The text of the question and the answer is limited to 200 characters.

The therapy room section is responsible for setting up the community. The floor plan itself is listed here as well as the number of the patients and therapists along with their whole representation (model with textures and voice). The entries concerning the spatial structure of the room itself are also listed here. A pre-made model can be selected for the room, in which the coordinates of the main objects must also be given.

One of these objects is the blackboard the position of which is very important, because the position of the written texts depend on it. The text includes e.g.: instructions, a task item or question and the responses to chose from (4 picture multiple choice). The position of the therapists and the patients must also be given. Particular attention is paid to their order, since this determines their identifier number. Lastly, the initial position and direction of the camera is also set up here. The therapy room was conceptualized according to an actual therapy room. It was structured this way in order to accommodate both single and group sessions. The therapist selects whether a single session or a group session will be carried out.

The User menu covers the data-management of the users' classified under self-chosen nicknames for avoiding any possibility of violation of human rights. This nickname is used for identification of a person, whose allocated set of data contains gender, type of aphasia, time post onset of aphasia and the audio records.

The task of the Viewer part is to display the virtual therapy room settings which were determined in the Editor. While the user is immersed in the virtual environment by means of a Head Mounted Display, a therapist can follow his/her actions in the virtual class through the monitor and the therapist can give instructions, comments, feedback. In addition, the therapist is able to control the virtual environment as it was mentioned before. Numerous shortcuts are offered by the software or the control of the environment.

Figure 3. *A language therapy task in the Virtual Therapy Room.*

For example the function keys from F1 to F6 select the virtual patients with the corresponding number, while F12 stands for the virtual therapist. If an avatar is selected, by pressing the numbers 1 to 5, an activity, which was set before in the Editor part, is associated with the avatar, and this activity starts immediately..

Another set of keys is related to the handling of tasks. Numeric + and – shows or hides an exercise, while the right and left cursor keys move on and back in the list of tasks and the down key selects one randomly.

Through these options the supervising therapist can build up any situation she/he wants, and can control it in real time. Due to the fact that the aphasic patients tend to require more time to respond, the supervising person has enough time to plan for the upcoming interaction and to direct the communication in a specific direction. Even dynamic group work can be built up without any additional physical members besides the supervising therapist and the single user.

These features are particularly important for the group sessions, where the aforementioned competition and support-like interactions set stronger group dynamic and social interactive factors into motion, and motivate and/or encourage the user to participate more actively in the problem-solving activity. In this way the aforementioned enriched environment can be guided and enhanced. This is a crucial factor in the case of stroke patients suffering from various types of aphasia (Broca's, Wernicke's, anomic) with varying degrees of severity of impairment (moderate, mild, minimal).

6. PILOT TEST OF THE VIRTUAL THERAPY ROOM

Following the development of the program, items for three language tasks were incorporated in the VR system: sentence comprehension, a single word processing task consisting of providing definitions to presented stimuli and a picture description task. The first two tasks consist of items of varying complexity. The number of tasks and the number of task items (n=20) will be expanded on as more tasks are developed. For this pilot study, five aphasic clients (NE, EK, WS, HW and TH) were selected for testing the preliminary version of the VR system in a single therapy setting and in the group setting. The clients were selected from aphasics who attend the 'Aphasia Club', at the Department of Linguistics and Communication Research of the Austrian Academy of Sciences. Aphasic clients with global aphasia were not included in this project, because their language impairment was too severe for them to understand the instructions to the tasks.

In single sessions each of the aphasic clients were asked to participate in this pilot study and were extensively instructed on the new method. They were acquainted with the Head Mounted Display and given adequate time to get used to this new device. After they felt comfortable wearing the Head Mounted Display the program was started. The three language tasks were carried out in a single session. Following this each client was asked for his opinion of the whole procedure. In a second session the group therapy program consisting of more interactive language tasks and addressing such pragmatic issues as turn-taking in a dynamic, group situation were performed by all five aphasics. (It must be stressed that the language tasks currently included in the VTR application are provisional and require adaptation based on the preliminary applications.)

7. SUMMARY

The two programs proved well on pilot testing: the AVC was tested in two primary schools, one with average and one with students with special needs. It is already in use in primary schools in Veszprém, Hungary. The participating teachers claim that the program is more than just a good support for their work, while the children found it to be great fun. With regard to the virtual therapy room, the initial applications of this innovative approach resulted in a high acceptance by the participants of the pilot study. The VR applications with these language impaired clients, who had received only traditional language therapy to date, revealed interesting findings regarding the language therapy process itself and also with respect to using the VR equipment. These include very different responses by the participants in the learning process in a completely different therapy situation. The results are presently being analyzed for adaptations to the applications and for future VR developments. Overall, the therapists participating in the pilot study responded to the new therapy setting positively. The fact that they could build up customized situations for group therapy sessions, ranging from friendly, cooperative ones to competition-based situations with real-time control over each virtual participant also created a learning situation for them. Interestingly, this learning aspect for both the therapist and the aphasic client relativised their 'client' versus 'therapist' role in the therapy process.

Due to its flexibility, the large number of customised elements, the virtual therapy room is an appropriate tool for both diagnosing and providing therapy for specific cognitive deficits, although the latter was the focus of our work. In summary, flexibility not only plays a crucial role when providing systematic linguistically based language therapy to aphasic clients on a one-to-one basis, it is also an important feature of VR therapy applications for aphasic clients. Future developments of the AVC and VTR - with particular emphasis on expanding the flexibility of the various components - will result in innovative procedures for providing language therapy and for diagnosing specific neuropsychological deficits in the future. Thus, returning to the title of this paper: Yes, we do need high-scale flexibility in virtual therapies.

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