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Avatars in Clinical Psychology: A Framework for the Clinical Use of Virtual Humans

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ABSTRACT

Early applications of virtual reality (VR) technology in psychological assessment, treatment, and research have yielded promising results. In particular, an increasing number of studies analyze the unique features of the experience made by patients during their exposure to virtual environments. However, the majority of these studies explore how patients navigate in the virtual spaces and interact with virtual objects. Only a few of them investigate the features of inhabited virtual environments, where real people and autonomous virtual humans are able to interact and to cooperate. In particular, there is a lack of discussion of the role that such autonomous virtual humans could have in VR-aided psychotherapy. The main goal of this paper is to identify a framework for future research in this area. Three levels of analysis are identified. The purpose of the first two levels is the identification of the key "physical" features (e.g., appearance, structure) and "internal" characteristics (e.g., behavior, degree of autonomy, perceptual capabilities) needed by an effective simulation. The third level is concerned with the evaluation of the interaction characteristics required for a successful relationship between the patient and the virtual human.

INTRODUCTION

IN THE PAST DECADE, medical applications of virtual reality (VR) technology have been rapidly developing, and the technology has changed from a research curiosity to a commercially and clinically important area of medical informatics technology".[1] In general, virtual reality is described as "a collection of technologies that allow people to interact efficiently with 3D computerized databases in real time using their natural senses and skills".[2]

However, there is a growing recognition that VR can play an important role in clinical psychology, too. One of the main advantages of a virtual environment for clinical psychologists is that it can be used in a medical facility, thus avoiding the need to venture into public situations. In fact, in most of the existing applications, VR is used to simulate the real world and to assure the researcher full control of all the parameters implied. VR constitutes a highly flexible tool that makes it possible to program a variety of procedures of intervention on psychological dysfunctions. The possibility of structuring a large amount of controlled stimuli and, simultaneously, of monitoring the possible responses generated by the user of the program offers a considerable increase in the likelihood of therapeutic effectiveness, as compared to traditional procedures.[3]

In this sense, 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 three-dimensional virtual world. The key characteristics of virtual

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environments for clinical professionals are both the high level of control of the interaction with the tool without the constraints usually found in computer systems, and the enriched experience provided to the patient.[4]

Applications of VR technology to psychotherapy and rehabilitation have addressed a variety of pathologies such as phobias,[5–8] anxiety disorders,[9] eating disorders,[10] sexual disorders,[11] and neurological damages.[12]

Virtual environments represent an effective assessment tool as well. In fact, this technology offers mental health professionals the opportunity to manipulate complex test *stimuli* along with more precise measurement of participant responses. In this manner, VR has the potential to improve the ecological validity of measurement of psychological variables by simulating "real world" functional testing environments.[13]

One major challenge faced by researchers and designers interested in VR-aided psychotherapy is to improve the efficacy of this innovative methodology. This can be achieved by increasing the quality of the interaction between the patient and the VR interface, by enhancing the realism of the rendered scenes and by adding multiple sensorial cues to virtual environments. The goal is to enhance the level of "presence," which can be defined 'as "the observer's subjective sensation of 'being there' ".[14] For this goal to be achieved, a key issue is understanding how human beings—as well as other aspects of the real world, including technological artifacts, stones, plants, trees, and animals—should be represented in the virtual scene. The problem is demanding since human beings are not visually perceived as "ordinary" *stimuli*, but as particular, "privileged" entities. This cognitive ability, called social perception, refers to the processing of sensorial information that culminates in the accurate analysis of the dispositions and intentions of other individuals. Thus far, most research has focused on the face as the primary communication channel of human emotional expression. Accordingly, several neuroimaging studies have been carried out to define whether there are neural subsystems specialized for the social perception process. Such studies have evidenced that specific brain areas carry out at least initial stages of the social perception process. For example, in monkeys and humans, the superior temporal *sulcus* is activated both by static images and by movements of the eyes, mouth, hands and body, suggesting that this region is sensitive to *stimuli* that signal the actions of another individual. Subsequent analysis of socially relevant *stimuli* is carried out in the amygdala and orbitofrontal cortex.[15]

Given the perceptual relevance of individuals for the brain, the first critical issue is concerned with the *physical* appearance of virtual humans in clinical-oriented VEs: how much visual fidelity is necessary? A second key area relates to the realism of the virtual human in its environment with regard to its behavior (in a broad sense) rather than its rendering or visualization. For the modeling of behaviors, the goal is to build intelligent autonomous virtual humans with adaptation, perception and memory. Virtual humans should be able to act freely and emotionally. They should be conscious and, to some extent, unpredictable. But how conscious and how unpredictable? Have such features the potential to be effectively used for assessing and treating mental disturbances? How do we expect to represent these concepts in the clinical setting?

Until now, these questions have been almost neglected. As a result, "the presence of virtual humans within virtual environments has been and is for practical purposes nonexistent. When used, they predominantly serve the role of propos, rather than humans".[16]

In order to stimulate and to guide further investigations, we will try to discuss these issues in a systematic way, by providing examples of existing applications of virtual humans in clinical psychology.

CHARACTERISTICS OF VIRTUAL HUMANS: WHAT SHOULD THEY LOOK LIKE?

Modeling the human body is one of the most demanding problems in computer graphics and animation. An open question, in particular, is how much visual realism is needed for representing virtual humans in clinical-oriented virtual environments. Developers of environments that contain virtual humans must make hard tradeoffs, compromising visual fidelity in the service of other pragmatic demands. For example, increasing realism can lead to significant decrease in frame rate, but this should be avoided, as VEs need to respect real-time processing constraints. The rendering cycle of a VE system ideally works at 25–30 Hz. Under this threshold, it becomes difficult or even impossible to sustain the illusion of physical reality. This problem is well known by VEs developers and many researches have targeted the creation of visually appealing components with as low a polygon count as possible. One of the techniques used to accomplish this requirement is Level of Detail (LOD), that allows components to be represented by successively more detailed models as the user approaches them.[17] The LOD technique suggests that a simple, but cost-effective method to decrease computational efforts is to display only those details that can be resolved by the human visual system. Along this line of thinking, designers of VEs try to determine the appropriate level of photorealism by analysing the features of the virtual scene on which the attention of the patient will focus. Such an optimization scheme requires a detailed user task analysis.[18,19] By describing what the patient is expected to do in the virtual environment, the task analysis can provide valuable insight that can be used to increase or decrease photorealism of an object. Figure 1 shows the main steps of the design and implementation process.

In the following section, we show that the appropriate level of photorealism of virtual humans is not fixed, but rather it is dependent on the clinical task perfomed by the patient. In other words, we can imagine a *continuum* of visual realism (Fig. 2). At one end of the *continuum* (high visual fidelity), we place VR clinical applications where the focus of the patient is on virtual human's physical features. At the other end (low visual fidelity), we place clinical applications where the focus of the patient is on the virtual environment.

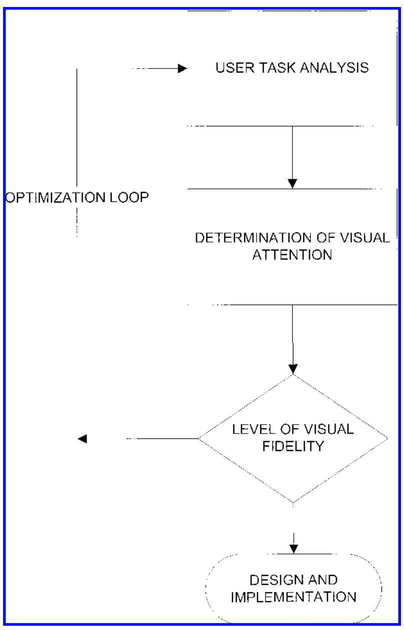

FIG. 1. Optimization scheme for determining the appropriate level of visual fidelity.

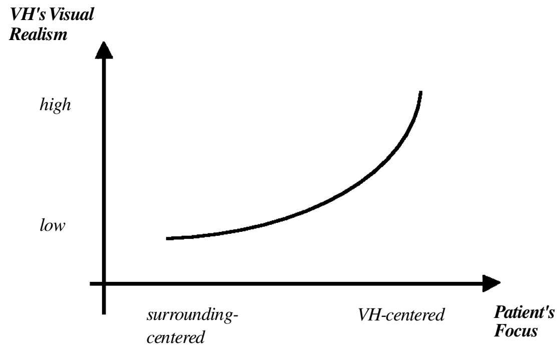

FIG. 2. The relationship betweens virtual human's visual realism and patient's focus.

The first application considered is a clinical tool that uses virtual humans for assessment purposes in eating disorders and represents an example where photographic realism of virtual human is a critical issue. Then we consider VR treatment of phobias, where the focus of the patient is not centered on rendering or visualization of virtual humans, but rather on the features of the anxiety-producing *stimuli*.

High visual realism: the Body Image Virtual Reality Scale

Eating disorders (EDs) are clinical disorders characterized by an altered eating behavior that is determined by efforts that patients make to control their weight and shape. Body-image disturbance (a distorted picture of the body that is formed in a patient's mind) is what essentially distinguishes EDs from other psychological conditions that occasionally involve eating abnormalities and loss of weight. For this reason, the construction of measurement procedures for the assessment of body image has proliferated in the recent years. Traditional methods have used movable calipers, silhouette tests, distorting mirrors and other techniques. BIVRS–Body Image Virtual Reality Scale was the first clinical tool using Virtual Humans for assessment purposes in eating disorders. Developed by Riva and his research team within the EU-funded project VREPAR (Virtual Reality Environments for Psycho-neuro-physiological Assessment and Rehabilitation, DGXIII–Telematics for Health Care–HC 1053), BIVRS is a software consisting of a non-immersive 3D graphical interface through which the patient is able to choose between nine figures of different size, which vary from underweight to overweight (Fig. 3). Subjects are asked to choose the figures that they think reflects their current and their ideal body sizes. The discrepancy between

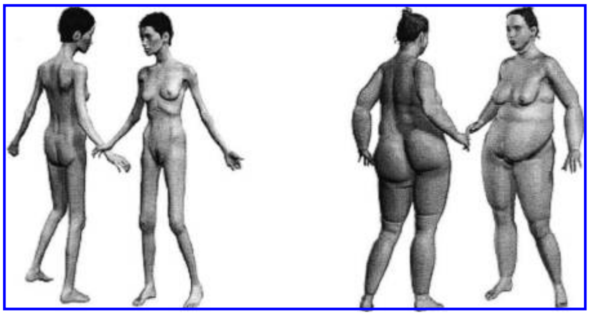

FIG. 3. Possible virtual humans for body image assessment.

these two measures is an indication of their level of dissatisfaction. The software was developed in two architectures, the first (a) running on a single user desktop computer equipped with graphical development software, such as VREAM or Superscape™, and the second (b) split into a server accessible via Internet and actually running the same virtual environment as in (a) and a VRML client (many are available for free on the Internet), so that anyone can access the application.

According to Riva,[3] one main advantage of using virtual humans is that the third dimension added to the body size silhouettes presented in the test can improve its effectiveness. In fact, using 3D makes it easier for the subject to perceive the differences between the silhouettes, especially for specific body areas (breasts, stomach, hips, and thighs).

Since BIVRS does not include the ability for real-time modification of specific body areas according to a patient's criterion, Alcaniz and colleagues have recently presented a new method for accurate 3D deformation of a human body model that uses a reduced number of parameters. The algorithm chosen by the authors is based on a series of boxes around the geometry parts to be changed. Any change in the position of a box vertex is converted to geometry deformation and eventually to opportune displacement of the neighbor boxes. As discontinuities have to be avoided, all boxes have a field of deformation decreasing in intensity as distance increases. To achieve a high degree of realism, a set of user photographs taken from several angles are positioned at the head of the mannequin. Depending on the position of the user, one of the photographs is selected and oriented towards the user. With this method, the model can express several aspects of the way the patients perceive their bodies. According to these authors, initial clinical results have been very promising.[20]

BIVRS is a clear example of a clinical application in which realism of virtual humans is a critical issue. In fact, in this assessment tool, a high degree of visual fidelity is necessary to allow patients to discriminate between different figures.

Low visual realism: virtual humans for the treatment of phobias

In the previous paragraph we have emphasized that visual fidelity can play an important role in assessment tasks that require the patient to evaluate fine anatomical details of the virtual human's body. However, in most clinical applications the goal is not to provide the patient with realistic rendering of the virtual human's body, since the task requires the patient to focus the attention on other kinds of objects. In VR treatment of phobias, for example, the goal of the therapist is the desensization of the patient's behavioral response (fear) through a gradual exposure to the anxiety-producing *stimuli*, which can be represented by animals, places, social situations etc. In order to maximize the efficacy of the exposure, the feared *stimuli* (i.e., a spider, in the case of arachnophobia) must be rendered with good realism. On the other hand, visual fidelity of surrounding details can be reduced, in order to limit computational efforts and to avoid side effects determined by decreasing of frame rate.

In such clinical applications, the inclusion of virtual humans is useful for giving the patient the impression of being in a real place. In fact, a virtual scene—beautiful though it may be—is not complete without people. However, many designers of VR clinical applications make often use of impostors instead of building more realistic (but also computationally expensive) 3D geometric models. These simple forms of virtual humans are often static and are not able to interact with patients although in some cases an audio feedback is provided. When they are animated, motion is driven by external animation of the body surface rather than by internal activation of the body structure. They are often used to simulate crowds, or as a low-level LOD node. Many intermediate techniques between impostors and medical-based 3D models have been experimented (e.g., Sprites, humanoids with rigid skeleton) for game engines or VR simulation.

CHARACTERISTICS OF VIRTUAL HUMANS: HOW SHOULD THEY BEHAVE?

The requirement of "behavioral realism" means that virtual humans should move and respond like a human. Moreover, they should be believable, both through the actions of the agents themselves, and their interaction with others. This means the development of "virtual actors" that should be able to play a specific role in a pre-defined scenario. But how do we expect to represent the concept of "intelligent virtual human" in the clinical setting? Which are the appropriate degrees of intelligence, autonomy and adaptation that such virtual humans should have in interacting with patients?

In analogy with the problem of visual fidelity discussed above, we could represent behavioral realism on a continuum. At one end of this continuum there are clinical scenarios that engage the patient in complex social interactions with virtual humans (i.e., the participation in a group therapy session with some virtual humans simulating other patients). The simulation of such a complex social interaction would require the implementation of high-level cognitive abilities like comprehension and production of natural language, planning, decision making, learning, as well as the incorporation of knowledge representation.

At the other end there are clinical scenarios in which the complexity of the social interaction is lower (i.e., the patient is instructed by the therapist to speak to a virtual audience, as in the case of social phobia[21]). In this case, the focus of the patient is more on believable physical, "exterior" behavior than on virtual human's "internal" states. In such scenarios, important features are realistic movement and physical interaction with the environment, in addition to body language, gesture and facial expression (Fig. 4).

Ideally, of course, virtual humans should be capable of fully realistic movement and physical interaction as well as human-like cognitive abilities. In reality, as noted by Aylett and Luck,[22] "both involve solving many hard problems so that there is a tendency for researchers to place their emphasis at one or other end of the spectrum."

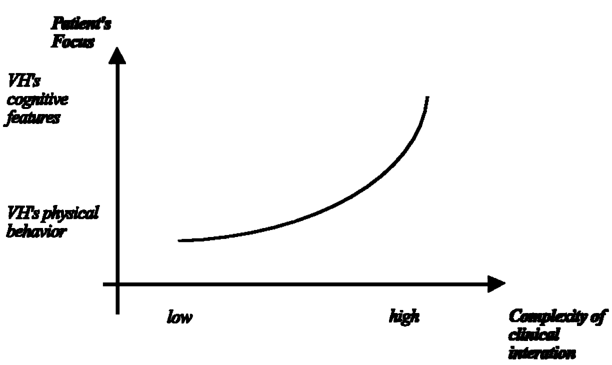

FIG. 4. The relationship between complexity of clinical interaction and patient's focus.

The following paragraphs examine with more detail the particular concerns relevant to the physical and cognitive ends of this continuum.

Autonomy and reactivity

The Merriam-Webster dictionary defines autonomy as "the quality or state of being self-governing." In the case of virtual humans, this means allowing them to select and to decide their own behavior. In clinical applications, the need to have autonomous behavior for virtual humans arises from the consideration that autonomous human-like behavior is necessary in order to maintain the illusion in the user that the environment is real. This implicates that they are to behave in a way that is convincing to the patient, for example showing the same limitations in interacting with objects (i.e., noticing and avoiding) that human beings have in the real world.

A field of psychotherapy that could significantly benefit from the implementation of this feature is the treatment of social anxiety disorder. Social axiety disorder, better known as social phobia, is an intense fear of becoming humiliated in social situations, specifically of being embarrassed in front of other people. This pathology significantly limits people from forming relationships by generating severe phobic responses at the prospect of human social contacts, causing sufferers significant impairment of their professional and private lives. Complications include alcohol addiction, drug abuse and depression. VR therapy of social phobia is based on the exposure of sufferers to a simulated seemingly threatening social situation in such a way that it becomes easier to face.

Early experimentations of VR therapy and assessment of social phobia have been made with fear of public speaking, which is a kind of social anxiety disorder. Jo and coll., for example, have developed a public speaking simulator for the treatment of this phobia. The virtual environment was a seminar room populated with eight virtual audiences. Patients were asked to speak in front of these virtual audiences and the therapist could control motions, facial expressions, sounds, and voices of each virtual audience.[21] In a similar study, Slater et al.[23] constructed, as a virtual reality modelling language (VRML) model, a virtual seminar room populated with an audience of eight avatars seated in a semicircle facing the speakers, as if for a talk held in the real seminar room. The authors also simulated eye contact by enabling the avatars to look at the speaker. Also, they could move their heads to follow the speaker around the room. Facial animation allowed the avatars to display six primary face expressions together with yawns and sleeping faces. Avatars could stand up, clap, and walk out the seminar room, cutting across the speaker's line of sight.

According to the authors, results of this pilot study were encouraging. In particular, they found that human subjects do respond appropriately to negative or positive audiences, even when these are entirely virtual.

As noted by Pertaub,[24] virtual human exposure therapy can be effectively used to treat sufferers of social phobia provided that patients will respond to virtual humans (avatars) in a virtual social setting in the same way they would to real humans. If someone is extremely anxious with real people, he would also be anxious when faced with simulated people, despite knowing that the avatars are computer generated. In this sense, providing virtual agents with a sufficient degree of autonomy could be helpful to generate in the patient the feeling of facing a real audience by improving naturalness of virtual humans' behavior. For example, the avatars should continuously display random autonomous behaviors such as twitches, blinks and nods designed to foster the illusion of life.

Perception

In order to implement perception, virtual humans should be equipped with visual, tactile, and auditory simulation. The virtual human–environment interface, or the virtual sensors, constitutes an important part of a behavioral animation system. From the behavioral point of view, the virtual human must give the real humans the illusion that it has a perception. This is fundamental to increase in the patient the impression of facing a real person. For example, the "look-at" action consists in moving the head in the direction of the object to look. The virtual human does not need to "look-at" to know the position, colors and other features of the object. But the execution of this action is necessary to convince the patient that the virtual human is looking at the object. Perceptually based behavioral capabilities would also allow the virtual human to activate appropriate patterns of actions as the patient triggers them by watching him or approaching him. This could avoid the situation where only the virtual agents under the therapist or experimenter direct control are active while the others stay in inanimate poses. Further, perception could avoid that the virtual human performs actions that could seem "magic" or unnatural to the patient, for example touching fire or walking through walls.

Memory

Memory is the retention and ability to reproduce or recall information, personal experiences, and procedures (skills and habits). As noted by Nadia and Daniel Thalmann,[25] to implement a concept of memory into a virtual human is not very complex, as already memory is a key concept in computer science. Thus, the problem is rather to understand how to make an effective use of this feature in the context of a clinical application. In our opinion, allowing the virtual human to store things learned and retained from his experience would be a powerful new feature that could be of great interest for clinical applications.

The virtual human could be able to modify the structure of his behavior according to the previous experience with the real patient. This would allow the therapist to introduce the concept of "past" in the virtual environment and to avoid that the patient feels that his experience of the simulated world is somehow "frozen" in a timeless dimension. In a possible therapeutic scenario, for example, the virtual human could keep track of the answers of the patient in a given situation and then choose the most appropriate feedback on the basis of the information stored.

Emotion

Most people have little problem in recognizing and identifying when we are having an emotion. However, emotion is one of the most difficult concepts in psychology to define. In fact, there are at least 90 different definitions of emotion in the scientific literature. A simple definition of emotion is that it is a response by a whole organism, involving physical arousal (as anger or fear), expressive behaviors, and conscious experience.

For our purposes, the possibility to implement emotion in virtual humans would be tremendously worthwhile. Apart from making the virtual humans more realistic, visible facial emotions on the part of the avatar could provide the therapist with a direct way of affecting the patient's own emotional state.

Most attention in regard to this issue has focused on the face as the primary communication organ of human emotional expression. For this reason, several techniques have been developed to capture the complexity of facial emotional expression. In the last years, the field of emotion rendering has produced very sophisticated programs, which are able to emulate emotions at a highly detailed level, such as the model of vascular expression in facial animation.[26]

CHARACTERISTICS OF VIRTUAL HUMANS: HOW SHOULD THEY INTERACT?

In the context of clinical-oriented virtual environments, communication between the virtual human and the patient is a critical issue. As pointed out by Thalmann and Thalmann,[27] this interaction requires a two-way communication between them at the geometric level (i.e., through 3D devices such as SpaceBall or a DataGlove), at the physical level (i.e., through a force transducer), and at the behavioral level.

For our purposes, the most important level of the interaction is the behavioral one. At this level, we can consider emotional communication between the patient and the virtual human. For instance, even if virtual environments so far fail to convey eye contact, facial expressions, and real body images of people, some of the effort in their design is focused on the development of tools for the creation of faces. This choice reflects the considerable societal attention on the face as a medium for expression and information display. Particularly, facial expressions exceed verbal reports to enhance context comprehension. As explained above, the difficulty here is not the fidelity of emulation of a particular emotion on the part of the virtual human, rather it is the ability to use the facial expression of this emotion as a feedback to specific patient's actions. This is true for the body as well, considering that the body is a highly communicative instrument, just as is the face.

A more intriguing way to accomplish interaction at the emotional level would be to allow the virtual human to model the patient's emotional responses. This could be done, for example, by using as input the physiological correlates of the psychological states of the patient. In this way, the virtual human could tune its behavior according to the psychological responses of the patient and take appropriate decisions to reduce eventual undesired symptoms. For example, the virtual human could recognize the physiological data pattern correlated to fear and activate a special set of "stereotyped" behaviors finalized to teach the patient how to manage panic.

As noted by Alessi and Huang, what is required to allow effective interaction between the patient and the virtual human is the ability for a program to capture and assess the emotional status of a viewer, translate this, taking into consideration cultural, educational, psychosocial, and cognitive aspects, and then give an appropriate response that would potentially include speech, facial, and body emotional expression.[16]

According to this vision, the key step for an effective interaction is the interpretation of the situations which actors are involved in. So, the most effective way of clarifying the meaning of messages is to connect them to a shared context of meaning. To reach this goal, virtual humans should provide task appropriate information representation, using their appearance, behaviors, and communicative actions.

Designers play a key role in defining these characteristics. In order for a virtual human to interact effectively, the patient has to have some idea about what the virtual human expects and can handle, and the environment has to incorporate some information about what the virtual human's goals and behaviors are likely to be. These two aspects, the user's "mental model" of the virtual human characteristics and the designer's "understanding" of the user, are just as much a part of the interface as its physical and sensory manifestations.[28]

When a patient is trying to shake the hand of a virtual therapist (task) in the virtual environment using a dataglove, he/she manipulates an iconic representation of both the hand and the therapist that are designed to stand for the real ones in his/her internal model of what he/she is doing. For most users, moving the hand in the virtual environment to shake the hand of the therapist is a quite straightforward action, analogous to moving the "real" hand on his/her "real" environment.[29] In this sense, the role of the designer is to make the patient believe that what he/she does when he/she moves the hand is an analog to moving the "real" hand.

Expanding this point, Churchill and Snowdon[30] recently identified a series of key issues a developer has to face for supporting the interaction process in a virtual environment:

- *The transition between shared and individual activities*: The patient should know what is currently being done and what has been done in the context of the task goals.
- *Flexible and multiple viewpoints and representations*: Tasks often need the use of multiple representations, each tailored to a different point of view and different subtasks.
- *A shared context*: The shared context is composed of symbolic references that allow patients to

orient and coordinate themselves. It includes the shared knowledge of each others' current activities, shared knowledge of each others' past activities, shared artifacts, and shared environment.

- *The awareness of others*: This awareness includes both the knowledge of shared task-related activities and the sense of co-presence.
- *The support of communication activities*: Negotiation through face-to-face talks is important for collaboration. In fact, conversation analytic studies of negotiation at work have detailed how subtle verbal and non-verbal cues contribute to such negotiation.

CONCLUSION

The use of virtual humans in clinical practice is a new and emerging area that is still relatively immature. In fact, almost all VR applications in psychotherapy research are "one-off" creations tied to a proprietary hardware and software. This makes it difficult to use them in context others than those in which they were developed.[31] To support further research in this area, three levels of analysis were identified. The purpose of the first two levels was the identification of the key "physical" features (e.g., appearance, structure) and "internal" characteristics (e.g., behavior, degree of autonomy, perceptual capabilities) needed for creating an effective clinical simulation. The final level was focused on the interaction characteristics required for a successful relationship between the patient and the virtual human.

Even if the results of our review are very promising, there are some issues that limit the actual use of virtual humans in clinical psychology.

The first problem is concerned with safety issues. Considerable caution should be exercised before patients are introduced to virtual reality and specifically when they are allowed directly to interface with virtual representations of human beings. In this sense, the therapists should be allowed to maintain a significant level of control on the virtual human's behavior, in order to be able to stop it in case of a patient's unexpected negative feelings or reactions.

All the issues related to the user interface should not be disregarded as well. The essence of virtual reality is the ability to interact with a three-dimensional computer-generated environment.

If this technology has to become an effective research tool in clinical psychology, the goal is to build applications that allow patients to interact with the virtual humans in a naturalistic fashion. In conclusion, our main goal was to provide mental health professionals who are interested in virtual reality some examples of the value of virtual humans for increasing the power of treatment and assessment. Moreover, we tried to define a framework to be used for stimulating further investigation on this topic. Despite current technical and methodological limitations, the opportunities for rapid advances are marked. Indeed, if a closer interaction among researchers in the fields of computer graphics, artificial intelligence, and psychology can be encouraged, the chances of overcoming the critical issues will be enhanced.

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REFERENCES

1. McCloy, R. (2001). Science, medicine, and the future. Virtual reality in surgery. *British Journal of Medicine* 323:912–915.
2. Székelly G. (1999). Virtual reality in medicine. *British Journal of Medicine* 319:1305.
3. Riva, G. (1997). Virtual reality as assessment tool in psychology. *Studies in Health Technology and Informatics* 44:71–79.
4. Schultheis, M.T. (2001). The application of virtual reality technology in rehabilitation. *Rehabilitation Psychology* 46:296–311.
5. Botella, C., Baños, R.M., Perpiñá, C., et al. (1998). Virtual reality treatment of claustrophobia—a case report. *Behaviour Research & Therapy* 36:239–246.
6. Carlin, A.S., Hoffman, H.G., & Weghorst, S. (1997). Virtual reality and tactile augmentation in the treatment of spider phobia—a case report. *Behaviour Research & Therapy* 35:153–158.
7. North, M.M., et al. (1997). Virtual reality therapy for fear of flying. *American Journal of Psychiatry* 154:130.
8. Rudzki, K. (1996). Virtual reality could cure phobias. *Search* 27:298.
9. Rothbaum, B.O., & Hodges, L.F. (1999). The use of virtual reality exposure in the treatment of anxiety disorders. *Behavior Modification* 23:507–525.
10. Riva, G., Bacchetta, M., Baruffe, M., et al. (1998). Experiential cognitive therapy: a VR based approach for

the assessment and treatment of eating disorders. *Studies in Health Technology and Informatics* 58:120–135.
11. Optale, G., et al. (1997). Multimedia and virtual reality techniques in the treatment of male erectile disorders. *International Journal of Impotence Research* 9: 197–203.
12. Rizzo, A.A., & Buckwalter, J.G. (1997). The status of virtual reality for the cognitive rehabilitation of persons with neurological disorders and acquired brain injury. *Studies in Health Technology and Informatics* 39:22–33.
13. Rizzo, A.A., & Buckwalter, J.G. (1997). Virtual reality and cognitive assessment and rehabilitation: the state of the art. *Studies in Health Technology and Informatics* 44:123–145.
14. Freeman, J., Avons, S.E., Pearson, D.E., et al. (1999). Effects of sensory information and prior experience on direct subjective ratings of presence. *Presence Teleoperators & Virtual Environments* 8:1–13.
15. Allison, T., Puce, Q., McCarthy, G., et al. (2000). Social perception from visual cues: role of the STS region. *Trends in Cognitive Sciences* 4:267–278.
16. Alessi, N.E., & Huang, M.P. (2000). Evolution of the virtual human: from term to potential application in psychiatry. *CyberPsychology & Behavior* 3:321–326.
17. Reddy, M., Watson, B., Walker, N. (1997). Managing level of detail in virtual environments—a perceptual framework. *Presence Teleoperators & Virtual Environments* 6:658– 666.
18. Nielsen, J. (1993) *Usability engineering*. New York: Academic Press.
19. Shepherd, A. (1985). Hierarchical task-analysis and training decisions. *Programmed Learning and Educational Technology* 22:162–176.
20. Alcaniz, M., Perpiñá, C., Banos, R.M., et al. (2000). A new realistic 3D body representation in virtual environments for the treatment of disturbed body image in eating disorders. *CyberPsychology & Behavior* 3:433–439.
21. Jo, H.J., Ku, J.H., Jang, D.P., et al. (2001). The development of the virtual reality system for the treatment of the fears of public speaking. *Studies in Health Technology and Informatics* 81:209–211.
22. Aylett, R., & Luck, M. (2000). Applying artificial intelligence to virtual reality: Intelligent virtual environments. *Applied Artificial Intelligence* 14:3–32.
23. Slater, M., Pertaub, D.P, & Steed, A. (1999). Public speaking in virtual reality: facing an audience of avatars. *IEEE Computer Graphics and Applications* March/April:6–9.
24. Pertaub, D.P., Slater, M., & Barker, C. (2001). An experiment on fear of public speaking in virtual reality. *Studies in Health Technology and Informatics* 81:372–378.
25. Thalmann, N.M., & Thalmann, D. (1994). *Creating artificial life in virtual reality*. New York: John Wiley.
26. Thalmann, K.P., & Magnenat-Thalmann, N. (1994). Modeling of vascular expressions in facial animation. In: Thalmann, N.M., Thalmann, D. (eds.). *Computer Animation*. IEEE Computer Society Press, pp. 50–58.
27. Magnenat-Thalmann, N., & Thalmann, D. (1991). Complex models for visualizing synthetic actors. *IEEE Computer Graphics and Applications* 11.
28. Laurel, B. (1990) Interface agents: metaphors with character. In: Laurel, B. (ed.). *The art of human–computer interface design*. Addison-Wesley, pp. 355–365.
29. Mantovani, G., & Riva, G. (1999). "Real" presence: how different ontologies generate different criteria for presence, telepresence, and virtual presence. *Presence, Teleoperators, and Virtual Environments* 8:538–548.
30. Churchill, E.F., & Snowdon, D. (1998). Collaborative virtual environments: an introductory review of issues and systems. *Virtual Reality* 3:3–15.
31. Riva, G. (1998). Virtual environments in neuroscience. *IEEE Transactions on Information Technology in Biomedicine*. 2:275–281.

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