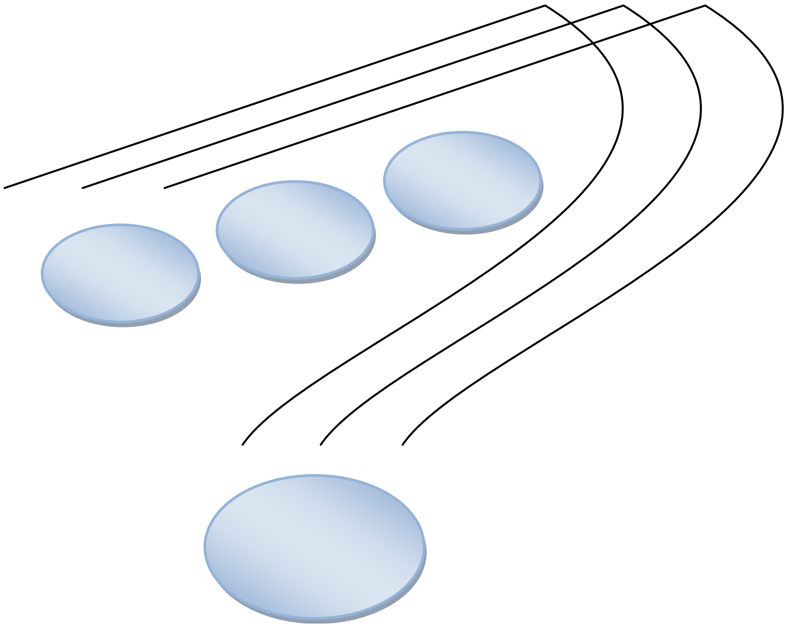
A literature survey to a multiple patient VRET system



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TUDELFT 19-05-2009
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1 Introduction

TU Delft is working on virtual reality exposure therapy (VRET). This is a project using head mounted displays (HMD) to treat patients for various phobias like acrophobia, claustrophobia and agoraphobia [1]. In its current configuration, it is possible for the therapist to treat one patient at the time [2]. This literature survey explores the possibility of one therapist treating two or more patients simultaneously with the VRET.

There are numerous reasons why exploring a multiple patient setup could be useful. First of all therapies are expensive and it could be possible that one therapist treating multiple patients in parallel could be a way to reduce the cost of the treatments. It could also be possible that fewer therapists can assist more patients, thus increasing the efficiency and accessibility of the treatments.

There are many different elements that are involved with the design of a multiple patient setup. Questions range from very practical, like where the patients will be located, does the patient need help putting the HMD on, to theoretical and psychological problems. For example, what are good ways for the therapist to cope with multiple patients at the same time and what factors influence the quality of this type of therapy.

Working with multiple patients simultaneously can eventually mean that the therapists might need assistance focusing their attention between patients. This could be done by implementing a computer system, between the patient and therapist, that continuously monitors the patients and warns the therapist if a patient needs attention. There is even the option of extending this system with modules that can take over specific tasks from the therapist if necessary.

1.1 Goal of this literature survey

The goal of this literary survey is to get a fundamental understanding of the principles involved when creating a multiple patient VRET system. This paper focuses on two facets that are necessary for creating such a system. Firstly the exploration of the excising VRET system and expanding it to a simple multiple patient setup. This also includes looking at the communication between the therapist and patient and understanding how this can change in a multiple patient setup.

Secondly this survey will look at the workload of the therapist and explore how the therapist could cope with two or more patients at the same time. Looking at the tasks and user-interface of the therapist could help with this. Assuming the therapist can only assist one patient at the time, there needs to be software that warns the therapist if another patient might need immediate attention.

There could be a need for a more complex system; where the computer has the option to take over tasks from the therapist. There could be need to know how a computer could take over these tasks and assist the patients autonomously. It could be possible that there is a need for additional software which determines when and what task will be taken over from the therapist (Adaptive automation).

The goal of this literary survey is to understand witch elements are necessary for a treating two or more patients with virtual reality. It is key to get a basic understanding how these elements should work and interact with each other.

1.2 Approach of this literature survey

There are many different ways to approach the design of a multiple patient VRET system. One way is to begin with the therapists and ask them to create a therapy especially designed for a simultaneous multiple patient setup. This therapy will dictate what kind of communication will be necessary in this situation. This could lead to the design of software for supporting this. The consensus with the therapist is very important, they should feel that it is a trustworthy system which will suit their own needs and the patient's.

This literature survey starts with looking at general communication and usability problems and tries to apply them on a multiple patient situation. Later it will explore how known interaction and workload models can be used to create software assisting the therapist.

The first chapter starts by looking at existing information on current VRET systems and how the communication between the therapist and the patient could take place. Working with multiple patients simultaneously means that the therapist might need another communication method than when working with one patient. It could also imply that there is a need for sensory data from the patient, which the therapist but also software could use for monitoring. This rapport will also look at known therapy communication methods to gain a better understanding of the different types of therapist-patient interaction. This information could be used to design suitable methods of interaction for a multiple patients VRET system.

The second chapter of this paper looks at the models behind creating a computer system suited for assisting a therapist with handling two or more patients simultaneously. It is important for therapists having all the information they need. This survey then explores the therapists' switching between tasks and patients and how could the computer assist the patient when the therapist is focused on another patient. It will also explore how and when to interrupt the therapists if the second patient needs attention.

As a conclusion this rapport tries to explore the therapist and patient component that might be needed when dealing with a multiple patient VRET system. Also the communication between the components is discussed.

2 Communication between the system, patient and therapist

In a single patient VRET setup communication between the therapist and the patient is very direct. The therapist talks directly to the patient, gets direct vocal feedback and can watch the postures and moves of the patient to monitor their state of mind. In a multiple patient setup communication becomes more complicated. The therapist need a way to interact with multiple patients separately. This can mean it is necessary to use less direct methods of communication between the therapist and the patients. Also if there is a need for a system that assists the therapist, this system will need to acquire information about the therapist and the patients.

2.1 Possible communication setups

The following chapter will first discuss the existing communication setup as described by Schuemie [2] secondly it will explore a setup where the patients and therapist are separated, this setup should be able to handle treatment of two or more patients at the same time.

2.1.1 Existing communication setup

In the single patient VRET communication setup as described by Schuemie [2] (see Figure 2.1). The therapist can control the virtual environment (VE) of the patient by using either keyboard or joystick and can view the VE on the screen. Furthermore, the computer system can generate sound, which both therapist and patient can hear. The patients can see the images in the HMD, they can change their viewpoint in the VE by moving their heads, a tracker will monitor these movements and adjust the virtual view of the patient.

Interaction can be split into two separate elements. First there is the therapist control, this is the interaction between the therapist and the virtual environment of the patient. The therapist can alter the state of a therapy session and manipulate the VE of the patients. The second element is direct communication, which can act bidirectional. In the current case this exists of vocal communication and visual feedback. Which means that changes in the posture of the patient are directly observed by the therapist and can be used to determine the patient's experience.

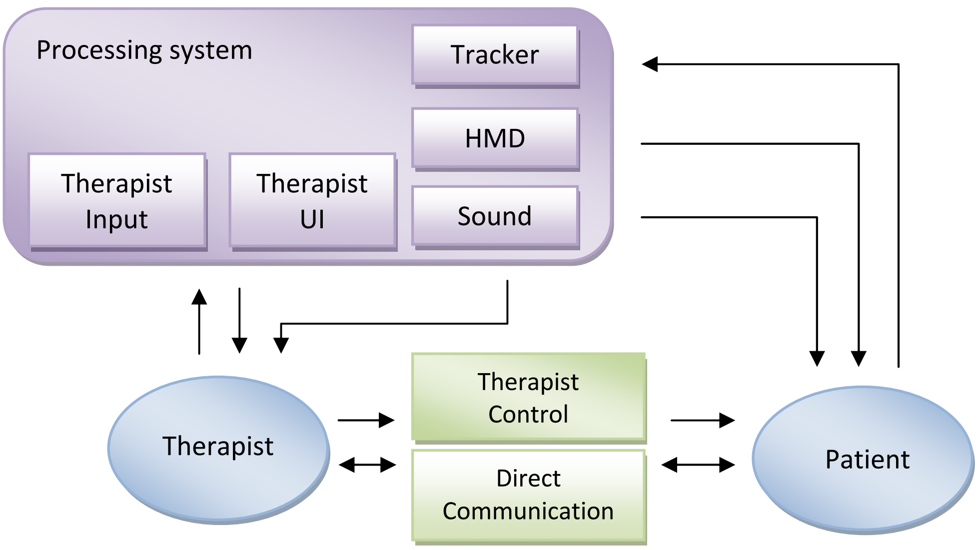

Figure 2.1: *Overview of the communication methods available for the users in the VRET situation extended from Schuemie [2]*

The location of the therapist and the patient are clearly defined in single patient VRET, they are both in the same room. This makes it easy to communicate vocally and easy for the therapist to watch the postures of the patient. When trying to create a multiple patient setup, is it uncertain if the therapist can stay in the same room with the patient. When a therapist gives a patients their own separate treatments, it is not preferred to have interference from other patients. This means that all patients need to be in separate locations, and that they only need to communicate with their therapist.

2.1.2 Split communication setup

When treating two or more patients parallel of each other, all patients will need their own processing system which handles the VE, head tracking and HMD. The therapist also needs a processing system, containing the user-interface and input device controls. To give treatment to the patients the therapist need both a communication channel with the patient as well as a way to modify the state of the patients therapy and VE.

A great advantage with the current system is that all the processing for the therapist and the patients are done on separate computers [3]. These computers communicate with a basic TCP/IP protocol. This means that it is easy to separating these systems and move them to different locations, even very remote locations are possible.

Because direct communication within a multiple patient setup seems not possible, there is need to replace this element with a remote communication module. Both patient A, patient B and the therapist need a two-way remote communication system. The more patients the therapist is assisting simultaneously the more communication lines a therapist must manage.

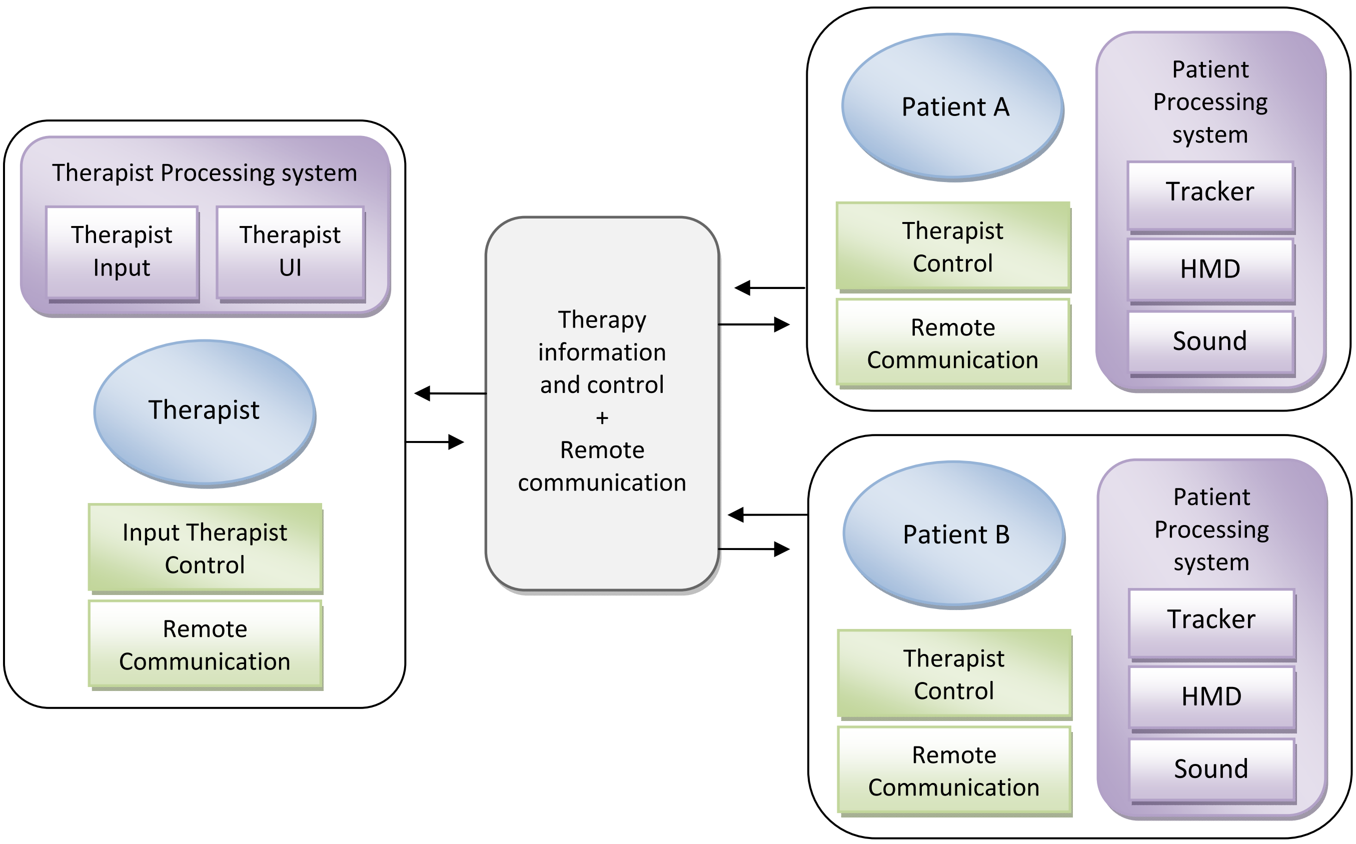

Figure 2.2: *Possible multiple patient setup, a split communication setup with two patients*

Every patients has his or her own remote communication line, so in a multiple patient system, multiple patient communication lines will reach the therapist at the same time. There could be need for some kind of filter to filter the information and communication that will reach the therapist. There is also a option to add more information screens to the system, so that more information and visual communication can be presented to the therapist at the same time. With verbal communication there are also different options. The system can present all the speech channels to the therapist or the therapist can choose which patient they want to listen to.

It can occur that a patient needs assistance, and the therapist is to occupied to become aware of it. A way to assist the therapist with managing all the communication lines is by creating software that can take over tasks from the therapist and can help with monitoring and warning if patients needs extra attention. This will be explored in chapter 3.

There are other facets of a setup that should be considered. Roorda [3] states that the logging of sessions should be available. At this moment only SUD-information and notes are logged and stored into a database, but the complete session should be replayable, including movements, actions and comments. All data must be easily retrievable again from within the VRET application.

VRET is an ever evolving system, which means we need maintainability and extensibility. Roorda also suggests the uses of a modular structure, which will make it possible to change or add parts without touching other modules and especially without touching the main core of the system. Another advantage is that there can be separate research and modifications on different modules without having to recreate the whole framework.

Finally Roorda warns for the security within the system. All data stored in the VRET application is very personal, mainly medically based. This makes security an important aspect. The therapists should be able to access, review and modify their own patients' data within the application, this data must not be accessible from outside the VRET application. The VRET application is an online application, in which a network or internet connection is established between therapist and patient. This connection should be private and inaccessible for non users.

2.2 Direct communication versus remote communication

An important element of a therapy is the ability of the therapist to access the non-verbal information obtained from the direct interaction with patients. This skill is often essential for making accurate diagnoses and in formulating effective treatments [4]. Without non-verbal cues, it is more difficult for the therapists to convey empathy toward their geographically remote patients [5]. Physical separation may also involve emotional separation between patients and therapists.

Because it is assumed that the multiple patients will all have their own separate therapies, it seems necessary to give them their own private treatment area. A consequence of this is that the therapist cannot be face to face with the patients in these areas. This means they are dependent on remote communication with the patients. The following paragraph will discuss how remote communication could be implemented and if it can be sufficient for psychological therapy.

2.2.1 Remote therapy and remote communication

Through better and more divers communication possibilities, the way therapy that can be given is changing. The old "visit to therapist" approach is still there, but new remote variants are starting to be developed. Telephone therapy was already there but now sessions over the internet and even in online worlds are being established [6]. The growth of this so called E-Therapy or tele-treatment still has to be properly defined and has its own ethical and legal issues [7], but research shows there is room for therapy that uses other media then pure face to face communication.

A example of phone and internet therapy is described by Kenwright [8], the communication started by a telephone interview with the therapist. After this the patient was dependent on a computer-aided self-exposure guidance using the internet at home. Every odd week the patient had a 10 minute call with a clinician for extra advice. The results were almost as good as personal therapy. This example shows that computer-aided help is very useful and there is not always need for face to face communication with a personal therapist while having therapy.

Experience with tele-treatment of agoraphobia without VR has previously been reported by Lange at al in 2000 [9] and a more recent example of remote therapy is the study by Riva which discusses Immersive Virtual Telepresence (IVT) as method for treatment [10]. With the IVT concept the therapist and the patient have no physical contact what so ever. The paper describes both the induction of a sense of "presence" or "telepresence" through multimodal human/machine communication in the dimensions of sound, vision, touch-and-feel. It also discusses the use of biosensors (brain-computer interface, psycho-physiological measurements, etc.) and advanced tracking systems (wide body tracking, gaze analysis, etc.). The paper concludes by saying IVT can be an effective therapy, has patient acceptance and is cost effective. Unfortunately, there is still a limited of controlled clinical studies showing significant advantage of IVT over traditional methods.

Remote communication is necessary during a VR session but before an in-between these sessions there could be a option that the patients have consultation with their therapist face to face. This could mean that for the complete therapy the therapists are not fully dependent on remote communication, but they can combine this direct communication.

2.2.2 Verbal communication

During a VR session the VRET patient is wearing a head mounted display, he or she cannot see the therapist, all communication is basically done with speech between the therapist and the patient. As long as there is no physical interaction, this communication could be replaced with voice communication by microphone and headset.

If the direct communication must be replaced, there is a need for suitable hardware and software for setting up a remote communication system. This translates in microphones for both parties, complemented with headphones or a sound system for the therapist. The patients HMD is already equipped with headphones, so it should be possible to add the therapists' comments and feedback to the sounds of the patient's virtual world. A digital connection between the therapists and the patients necessary, but this is also in place with the current setup.

Per patient one communication line will reach the therapist, there are different ways to deal with this. There can be a setup where the therapist listens to all the patient sound lines at the same time. Or there can be setups where the therapist chooses one line to listen to ignoring the others. It could be the preference of the therapist that determents this setup. If the therapist wants to communicate to the patients he or she must first select a patient and to open a line to enable speech from the therapist to reach the patient this means the therapist can only talk to one patient at the time.

2.2.3 Visual communication

In the current VRET setup the therapist can see the patient, they can watch their movement and body language. The HMD could prevent the therapist seeing and interpretation of facial expressions of the patient. In a multiple patient setup we need a system where the therapist cannot only watch one but multiple patients, presumptuously at remote locations.

If the locations are close together it could be possible to watch patient through windows in their own private treatment room, otherwise a camera setup could be used. This setup requires a camera in the treatment room and a monitor for the therapist, to watch the footage. This also implies that there is need for a reliable method to sent over the video data. This can be done independent from other communication lines within the system.

2.3 Communication with the system (Physiological Measurements)

In a multiple patient VRET system therapists should be able to cope with monitoring and assisting multiple patients at the same time. If a computer system can assist the therapist with their tasks, it could be easier for the therapist to manage all the different patients. If a systems has reliable data on the patients' level of fear, it could make more intelligent decisions on how to assist them with their treatments.

It is possible to not only monitor the patient, but it could be useful for the system to obtain data about the therapists' as well. The system could try to measure their stress levels and workload. This can give the system data it may use to determine how occupied the therapist is. When this is combined with the patients' level of fear, the system could use this to determine if the system should interrupt the therapist or maybe take over certain tasks itself.

2.3.1 Patient measurements

The currently used indication of the state of the patient to the therapist is the so called SUD-Score, (Subjective Units of Discomfort) [11] this gives the anxiety level of the patient on a scale from one to ten. One for not anxious at all and ten indicates the highest level of fear the patient can imagine. This SUD score can also be used as indicator for a computer system to determent if a patient needs assistance. In the current system this score is determined by the therapist. Asking the patient about their anxiety. This methods of obtaining SUD-scores can still be used in a multiple patient setup, but it could be useful for the system to acquire SUD-scores by itself without the need of the therapist. This data can then be used so that the system can make more intelligent decisions on how to assist the patients, or when to warn a therapist.

Anxiety or stress is a very complex emotion, but one that is possible to detect in humans. Using only one indicator is mostly very unreliable [12]. But measuring more and then scaling and comparing them gives a more reliable output. There are number of different methods the computer system can use to acquire a anxiety score from a patient, the next paragraph will discuss some options.

Instead of the therapist asking for a SUD-score, the system can do this. There is the possibility of having a computer voice or maybe a bleep at certain intervals, asking the patient what their anxiety level is. The system can use voice recognition software to detriment the score. Research also has been done on obtaining stress levels from the voices of people [13]. This software could be used to determine the patient's anxiety score. For this to work it is necessary that the patient keeps talking to the system. There is also research on software that can recognise stress levels from body posture and facial expressions [14]. Analyzing facial expression could be hard because the patient is wearing a HMD.

A other possibility for the system to determent the patient's anxiety score could be the use of biosensors [10]. Biosensors detect muscle and nerve activity. Currently, biosensors exist that measure physiological activity, muscle electrical activity, brain electrical activity and eye movement. Extracting accurate physiological data from biosensors is often a complex task. In particular, extracting data from different typologies of biosensors will require architecture of great flexibility and the possibility to connected them to different external monitoring devices. The patient monitoring sensors should be easy to attach, an non intrusive. A heart rate meter [20] and a galvanic skin response sensor could be good solutions.

2.3.2 Therapist measurements

Together with measuring the anxiety level of the patients, the system can also monitor the therapists. By determining their stress levels and workload, the system could make better decision on when to interrupt or warn the therapist. When the systems notices the therapist is very busy it could even take over certain tasks from the therapist.

Measuring the therapist is not the same as measuring the patients, with the patients the system needs to determent anxiety levels but with the therapist it needs to look at workload and stress levels. The system can use the user interface input from the therapist itself to gain information about their mental state. The amount and type of actions a therapist is doing can tell something about their mental state. For example if the therapist is only modifying one patients therapy for a long time, it could mean that he or she is extremely focused on that patient, or the therapist ignores all warnings it could mean that therapist has a exceptional high workload at the time. This is also done by measure the *acknowledgement time* (AT) of the therapist [15]. This is the time the users will take before they have reacted to a notification of the system. The longer it takes for a therapist to react to messages from the system, the more likelier the fact that he or she has a high workload.

3 Creating a system that can assist the therapists

When therapists have to assist two instead of one patient their workload will increase. Because different patients do not always require the same amount of attention at the same time, the workload can vary considerably. If it occurs that both patients need a high degree of attention, the therapists could be overwhelmed by the workload. It is possible to use the current task load model described by Neerincx [16] to model the workload and consider ways to optimize it.

3.1 The current task load model

To achieve a better understanding of the increase of a therapists workload, the current task load model can be used (CTL) . The model distinguishes three main load factors that have a large effect on the workload. The first is the *percentage time occupied* (TO), which gives the actual time a user is working on tasks in percentages of the total time. A commonly made assumption is that people should not be occupied more than 70 to 80 percent of the total time available [17]. The second load factor is the level of information processing (LIP). This factor is determined by how fast the user can make decisions. This is done by using the skillrule-knowledge framework of Rasmussen [18] where the knowledge based component involves a high load on the limited capacity of working memory. The last factor is the amount of *task-set switching* (TSS) which is being done. Many switches between different tasks will make the process much more demanding on the user.

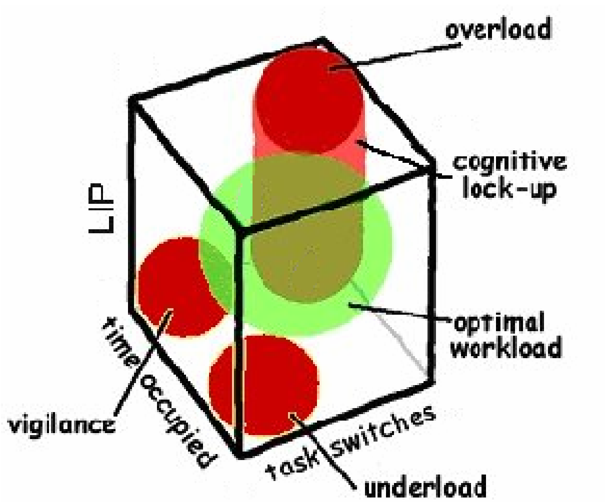

Figure 3.1: *The three dimensions of the task load model. Neerincx [18] distinguished several critical regions*

By plotting the factors above in three-dimensional space the model distinguishes five cognitive states. Figure 3.1 shows a number of expected cognitive states. The five cognitive states are:

1. *Under-load*: When all three factors are low, the user can handle the tasks easily. There is the possibility that the user could lose attention and get bored.

2. *Optimal workload*: The factors are balanced and the user will be able to handle the situation.

3. *Vigilance*: If tasks take too much time it could happen that the user can handle the situation, but on every task they can get a bit behind, losing control in the end. Vigilance can result to stress due to the specific task demands (i.e. the requirement to continuously pay attention on the task) and boredom (carry-over effect) [18].

4. *Cognitive lock-up*: The user has fundamental problems managing their own tasks adequately. Humans are inclined to focus on one task and are reluctant to switch to another task, even if the second task has a higher priority. They are stuck to their choice to perform a specific task [28] and have the tendency to execute tasks sequentially [29].

5. *Overload*: The user will never be able to handle all the tasks given.

All these cognitive states can occur when a therapist is working with multiple patients. When designing a system which supports the therapist, it should be able to deal with under-load, vigilance, cognitive lock-up and overload. The first factor discussed is the level of information processing of the therapist. A way to improve the LIP of the therapists is to make sure the therapists have the correct and proper amount of information to make good and fast decisions (see chapter 3.2). The second factor discussed is the TO by the therapist, this is dependent on the number tasks the therapist has to execute. To lower the workload of the therapist it could be a possibility to let the computer take over certain tasks if the therapist cannot handle them (see chapter 3.3). The last factor is the number of task-set switching. This contains both the switching of tasks within the same patient treatment and the switching between patients themselves (see chapter 3.4).

3.2 Ways to improve the level of information processing

The first factor of CTL is the level of information processing (LIP) of the therapist. Therapists are expected to make decisions based on the information that is presented to them by the system. They need for example to decide on whenever they should adjust a treatment, intervene or should go talk with one of the patients. Two factors are of importance, the speed and the correctness of the decisions. The faster the therapist can make a choice and executes it, the more efficient the system becomes. But if the therapist makes wrong decisions the system will not be very useful.

To make sure that therapists can achieve a proper level of LIP it is essential that they receive the proper information from the system that assists them. If situation occurs where the therapist needs to make a fast decision the system needs to present him or her with all data that is relevant to that decision. A way to assess how and when information should be presented to the therapist, is to look at their *Situation Awareness* (SA). SA is described by Endsley [21] as "The perception of the elements in the environment within a volume of space and time, the comprehension of their meaning, the projection of their status into the near future, and the prediction of how various actions will affect the fulfilment of one's goals."

The two main mediums for the therapist to gain information on the patient are the user-interface presenting information about the patients and their therapies. And a communication link with the patient, which they can use to ask feedback from the patient. This chapter will focus on the user-interface and how and what kind of information should be presented to the therapist.

Neerincx [18] states that in general, user-interface design follows the general top-down and iterative process of software development. This results in user-interface specifications at three abstraction levels. Firstly the *Task level* which contains the users' goals and information needs, the system's functions and information provision. Secondly the *Communication level* describes the control of the functions and the presentation of the information. And lastly the *Implementation level*, where the interface implementation in a specific language on a specific platform is discussed. This last abstraction level is not yet relevant in this stage. The upcoming paragraph will provide a closer look at the specification of the user-interface of the therapist on the task level and communication level.

3.2.1 Task level

A task is a set of behaviours directed towards a task goal. A task or goal can have subtasks or sub goals. For example, the main goal of the therapist is to treat the patients and help them cope with their phobia's. A lot of subtasks can be derived from this main goal. The concepts goal and task are not very different, since tasks and goals in most frameworks have a one-on-one relationship [22]. Actions are the elements of observable behaviour that affect the state of a specific object in the environment [18]. Within VRET there are lot of actions a therapist can execute all having a place within different tasks.

For VRET a task analysis has already take place, a good example is Schuemie [2]. In this paper the main and subtasks of the therapist are mentioned. The subtasks differ per type of treatment, but a lot of treatments have tasks in common. First there is the subtask of determining fear of the patients. This can be done by asking patients for response and by monitoring the patient. The second subtask is change of exposure. This can be done on patient level by instructing the patient. Another way of achieving this is instructing the computer to trigger effects within their virtual world and guiding the patient through this world. The last subtask is to solve ambiguity and making notes and collection data.

What makes a multiple patient setup more complex is the fact that most tasks have to be performed for every separate patient. This not only doubles the amount of tasks and actions, it also introduces new tasks and actions that did not exist before. Guiding two or more patients at once means that communication methods with the patients change (see chapter 2.3.1). An example of a new task that can appear because of remote communication is the opening of a communication link with a patient. New tasks could mean an added task analyses is needed to explore these new tasks and add them to the existing ones.

To make all these tasks manageable there is need to group them in a certain order. A way to do this is not by grouping by type, but by grouping the tasks per patient. All actions regarding a patient should be presented grouped together so it is always be clear to both the therapist and the system on which patient they are working with. The system could be designed to eliminate so called *mode errors [33]*, this are errors where a user thinks he or she is working in one mode but actually working on another. In a multiple patient VRET setup this could mean that a therapist is working with patient A but is actually working with patient B.

3.2.2 Communication level (The user-interface)

Importance in the LIP is the type and amount of data that is presented to the therapist. The therapist should receive the right amount of data to make good decisions, but should not be flooded with too much or not useful data. In a multiple patient setup the amount of data presented to the therapist increases per patient so there could be a need to filter or summarize patient data. A user-interface does not only present information to the user. It also presents a way for the therapist to give actions to the system.

There are many design principles regarding building a user-interface, for example *Ecological Interface Design* (Vicente and Rasmussen) which primary looks at the domain in which the product will be used. Another principle is *user-centered design* (Donald A. Norman) which much more focuses on the user and not only looks at function but does also take tactility and "look and feel" into account. *Human-centered development of interactive systems* [18] requires an iterative design process in which cognitive engineers provide the required human factors input in terms of guidelines, user interface concepts, methods and facilities. It stated that one can distinguish four general design principles to reduce the interaction load that apply to the user interface:

1. *User adaptation*: The user interface design should take account of both the general characteristics of human perception, information transfer and decision-making. But also the specific user characteristics of the user, in our case the therapist, examining their characteristics like education, knowledge, skills and experience.

2. *Goal correspondence*: The functions and structure of the user interface should map, in a one-to-one relation, on users' goals and corresponding goal sequences. Functions that users do not need should be hidden for these users.

3. *Information needs correspondence*: The information that is provided by the user interface should map, in a one-to-one relation, on the information needs that arise from users' goals. Irrelevant information should not be presented to the users.

4. *Use context*: The human-computer interaction should fit to the envisioned use context and/or situation (e.g. a speech interface should not be designed for noisy environments).

The current VRET therapist user-interface

There exists already a lot of research on the user-interface the current VRET is using [3, 11, 23]. The user-interface will keep evolving as research is being continued. The VRET interface consists of different elements based on the kind of therapy it is used for. Main elements are session information, system status, patient's navigation control and a patient view, where the therapist can see what the patient can see. There is an element where the therapist can make notes and an element where the stress levels (SUD-score) of the patients are recorded.

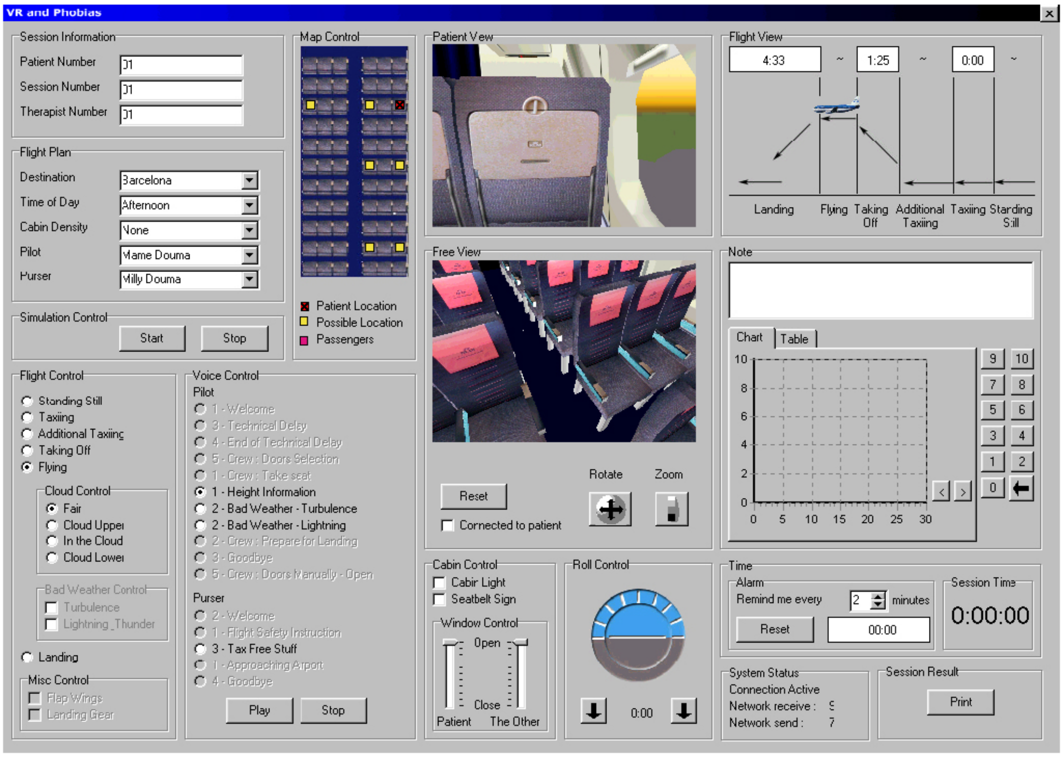

Figure 3.2: *The therapists user interface to monitor and control the airplane world for treating fear of flying. The upper image in the middle is the patients view. The lower image in the middle is the free view, including some controls for looking around by the therapist [23].*

For different types of therapy additional elements can be added, for example an overview map. In completion there are tools for the therapist to modify the VE and thereby the experience of the patient. In the fear of flying therapy these are flight control, voice control, roll control and cabin control (see figure 3.2). At this moment, the user interface is fixed with respect to position, size and lay-out. The more the VRET application will be extended, the more this problem blocks development. With more therapists working with the application, the wishes for a customizable user interface grow [3]. So the therapist can modify it to their personal needs. A newer application could provide a fully configurable user interface, which enables showing and hiding different functionalities and moving them around.

The current user interface is designed in such a way that all information on the patient and their therapy session is presented at one screen. When it is needed to present information on multiple patients at the same time, there are different approaches to how this could be done. One option might be to present all the information of all the patients to the therapist all the time.

3.3 Ways to Improve the time occupied (Adaptive automation)

The second factor of the current task load model is the percentage time occupied of the therapist. This is mainly dependant on the number of tasks the therapist has and how much time each of them will take. There are two main scenarios when a therapist is not likely to be able to cope with the workload. The first one can occur when the therapist has too many tasks (see chapter 3.2.1) and is unable to finish them all in time. The second scenario could occur when a patient needs immediate attention and the therapist is too occupied with another patient.

A way to handle these problems is letting the computer dynamically take over certain tasks. There has already been a lot of research on so called *adaptive automation* (AA): “the dynamic division of labour between man and machine” [24]. It is based on the conception of actively aiding the operator only when human information processing limitations emerge and assistance is required in order overcome bottlenecks and to meet operational requirements.

A possible next step is the use of *augmented cognition* (AC) that extends the AA paradigm by explicitly stating the symbolic integration of man and machines in a closed-loop system whereby the operator’s cognitive state and the operational context are to be detected by the system [25]. For this it is necessary to have systems that reliably augment cognition of the therapist and allows one to cope with unreliability and knowledge about how humans use these systems [12]. Also it is important that the user remains in the loop. Advice should be provided in such a way that the user remains in the loop of the overall activity by interactive involvement in the process of action executions as part of a task procedure.

3.3.1 When should a computer take over

There a number of reasons why the computer should take over certain tasks from the therapist. One reason could be when the therapist cannot handle their workload do to *Vigilance*, *Cognitive lock-up*, or *Overload.* A second reason could occur when a therapist is occupied with one patient and cannot assist the other. It is key that the system can recognize these situations.

The system could have the need for monitoring the cognitive focus of the therapist. The advantage of doing this is, it that the system can know if the therapist is focused on a single patient and is too occupied to monitor other patients. If it then occurs that another patient needs acute assistance the system can choose to warn the therapist or decide to assist the patient itself. For the system to make that decision, it is important to take in account what the workload and cognitive state of the therapist is.

Another situation of AA is described by Arciszewski et al [26]. This paper states that the user rather than the system designer should have the final say as to what level of automation the system is authorized to reach. It describes that you could see the user and the system work together as a team. There is a emphasis on the situation were the user can declare on forehand how the system should react in a case of high workload. Should this be applied to multiple patient therapy, it could mean that the therapist can make working agreements with the system per patient, telling the system how to act in situations with high workloads.

3.3.2 How can a computer take over (Automated Support for the Therapist)

To lower the workload of the therapist, it could be necessary in certain circumstances for the system to take over tasks from the therapist. One of those tasks is proving therapy. So called computer-supported treatment is not new. With it therapists can specify the procedures and constraints of certain modules for self-treatment. For example therapists could individualize homework scenarios and virtual environments for patients. This is discussed within a currently ongoing EMMA project [27].

A multiple patients system that has the option to treat the patient itself can relieve the therapist of many tasks. It should not be needed that the system can take care of all situations, it could be that the system can take care of certain simple tasks that take up a lot of time and are very tedious to the therapist. What tasks the system can take over can be dependent of the type of therapy that is use within the system.

If it is possible to describe a treatment session in terms of steps to be taken under supervision by the therapist, it may be possible to develop an electronic agent which provides advice [23]. This could include some rationales to the therapist about the next possible steps in the actual context of the treatment. It would also seem interesting to provide a planning mode to the therapist to specify some sequential steps for a session just before it starts. The general goal is to provide extra explicit knowledge to the therapist about the progress of the treatment.

The agent can obtain its information from built-in procedures which may be adjusted by the therapist and by measurements of the patients physiological condition. If the systems measures that a patient does not behave within boundaries, The system could pause the scenario or switch to a different scenario which known to relax the patient. How the system exactly should react to different physiological conditions will depend on the type of the therapy.

3.4 Ways to improve the task-set switching

To address the demands of attention shifts, the current task load model distinguishes task-set switching as a third load factor. Complex task situations consist of several different tasks, with different goals. These tasks appeal to different sources of human knowledge and capacities and refer to different objects in the environment.

When giving a VR-therapy the therapist has certain tasks they need to complete. When you add more patients more tasks immerse (see Chapter 3.2.1). These tasks can run parallel of each other making it necessary to actively switch between them. Humans are inclined to focus on one task and are reluctant to switch to another task, even if the second task has a higher priority. They might get stuck to their choice to perform a specific task [28]. So it is could be necessary that a computer system can first warn when a higher priority task occurs and then properly motivates the therapist to switch to the more important task.

It is also known that users have the tendency to execute tasks sequentially [29]. They want to finish the one they work on, before starting on the next. In a multiple patient case this could mean there is need for a system that notifies the therapist and communicates to them that more urgent takes are at hand. This could be done by using the proper methods of interruption and providing the therapists with information on why the switch is deemed necessary. At the end of this chapter we discuss interruption methods, we will first look at the way the therapist could switch between patients and at basic task-set switching design principles.

3.4.3 Switching between patients

When we look at task-set switching in a multiply patients setup, we can distinguish between switching patients and switching tasks within the same patient. The last is also part of single patient therapy and could be handled the same as existing systems. Switching between the multiple patients means that the therapists need to adjust their cognitive state and there could be need for other information presented by the system. If the therapist is remotely talking to a patient or adjusting their VR therapy setting, there should be no ambiguity on which of the patients they are working. A properly designed system should make sure that the therapist can never have confusion between different patients, a so called mode error. Norman [33] argues that the best way to avoid these mode errors, in addition to clear indications of state, is to construct an accurate mental model of the system for the user which will allow them to predict the mode accurately. Another way to deal with mode errors to get rid of the modes altogether and present different interfaces for different modes.

Therapists should always have the possibility to mentally switch between patients. They can choose to switch on their own account or it can occur that the system will initiate a switch. If and when the computer system should initiate a patient switch depends of the predetermined level of automation (LoA) which could be set independently per patient. Arciszewski et al [26] describes five possible levels of automation; *manual, advice, consent, veto* and *system*. With *manual* the user is in full control, with *advise* the user can ask for assistance from the system but the system does not make any initiative. With *consent* the user keeps all the responsibility but the computer system alerts the user to changes in the situation. In the case of *veto* the user delegates the responsibility to the system unless overruled by the user. With *system* the computer system in full control and acts autonomously.

If we use the *Veto level of* automation on a certain patient, the computer system will try take care of the tasks assign to the system for that patient. The system does not interrupt the therapists but they can still interrupt the system. The computer system will for example autonomously modify the therapy of the patient. If we use the *consent level of* automation the system will interrupt the therapist and will notify the therapist if perhaps extra attention is required.

3.4.3 Task-set switching design principles

Switching between tasks also means switching between the information to deal with the task. The tasks can appeal to different sources of human knowledge and capacities and refer to different objects in the environment. If changing to another task goes wrong, the workflow of the user can greatly be disturbed, and lot of extra time is needed to deal with the task and errors in judgment can occur. To make the transmission between different complex task less intrusive, task-set switching support should comply with the following design principles presented by Neerincx [18]:

1 . *Provide an up-to-date overview of the tasks and corresponding actions*, this should including the current status of the activity and the status of each task. It is impotent that the user-interface communicates all the possible actions, tasks and their relations.

2. *The current priority of each task should be shown*. Changes in priority should be communicated to the users, so that they can keep a correct, up-to-date situation awareness. This could be important when switching between patients. It must be well clear to the therapist which patients has the highest priority and why.

3. *The support should enable fast and easy access to the requested information* with adequate orientation cues and state explanation. It should correspond to the optimal search strategy for the specific task and situation, i.e., support several accurate information acquisition processes of users.

4. *It is important that the user remains in the loop*. Advice should be provided in such a way that the therapist remains in the loop of the overall activity by interactive involvement in the process of action executions as part of a task procedure.

3.4.4 Interrupting the therapist

If the system reasons that another patient has more priority then the focus one. It wants the therapist to switch focus between the patients. The system first needs to acquire the therapist attention. Then it needs to communicate to the therapist why the interrupt was necessary and what there next step should be. When an application interrupts a user at an inopportune moment during task execution, the user performs tasks slower, commits more errors and makes worse decisions [30]. Also the user experiences more frustration, annoyance, and anxiety [32, 31] than if it had interrupted at a more opportune moment.

There is an option to use a therapist monitor system to collect data, which can be used to determine if it is a good moment to execute an interrupt. If the data suggests the therapist is very busy with an important tasks, the system can wait with the interrupt for a more opportune time. If the interrupt is so important it goes for anything it should interrupt. This implies that the system needs to judge the interrupts on the level of importance and should be able prioritized according to the current situation. Just telling the therapist there is a problem, is not enough. The interrupt should also always provide information about how to (start to) solve the problem [18] so the therapist can take on the task and continue working.

There is also an option of letting the therapist determine their amount of interrupts themselves. By making so called *working agreements* [26] with the system. These agreements are set by the therapist before starting a therapy session with a patient. An example of one of these agreements is that the therapist wants all warnings from a starting patient, but not from a more experienced patient. Where only in extreme situations the therapist wants a warning message.

There are a lot of methods to let users stop a current task and attract their focus. The VRET system mainly uses a GUI for communication with the therapist, so visual and sound cues are to most obvious. Visual cues can include popup windows, moving objects, screen flashing or partial flashing. Humans are incline to be distracted and focus on moving and flashing objects [32]. Also sound can be a good way to attract attention and warn the user.

There can be different levels of importance of the interrupts, also the system could use different levels of intrusion per interrupt, for example large blinking windows or small moving objects. To make really sure the system gets the attention it can used a so called lock-down. The user cannot take any actions anymore, it can only continue working after the user has acknowledged to the system. It is key to find the right level of intrusion per interrupt. This can be done by an iterative process of design and user testing. Also interruptions can grow more intrusive over time so ignoring the interrupts gets harder every time.

3.5 Overview of possible therapist and patient components

To realize a multiple patient VRET system certain components need to be designed. All patients need their own personal component that can communicate with the therapist component. This should be able to handle both the remote communication and therapy information from all the active patients. (see figure 3.4)

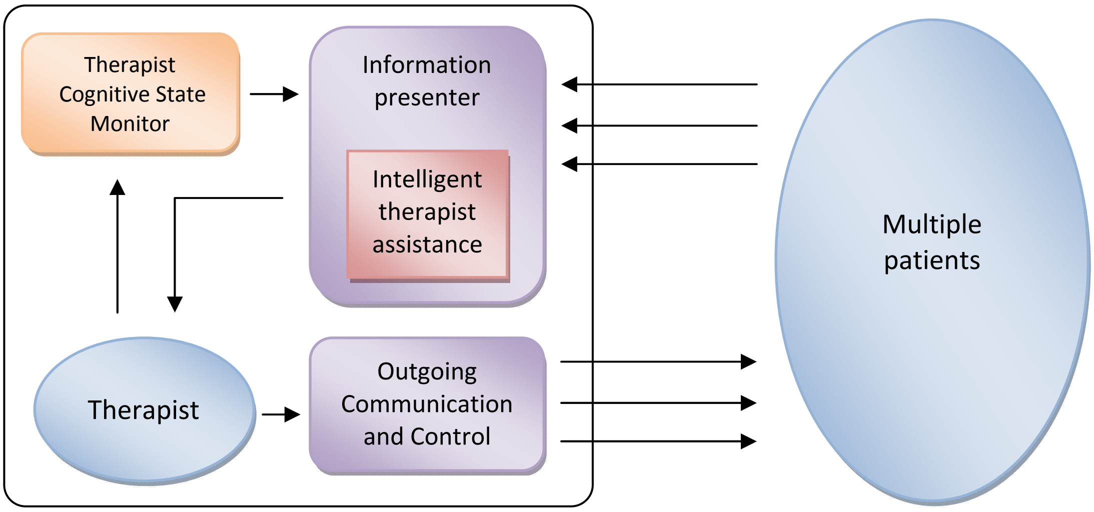

Figure 3.4: *A possible therapist component in a multiple patient VRET system*

Therapist component:

Information presenter
This collects all data from all the patients and presents it to the therapist. This includes both remote communication data like speech and video feeds as well as therapy information like the state of the therapy and VR and background information on the patients. This could be combined with intelligent therapy assistance where a computer system can work together with the therapist. It could take over certain tasks and give warnings to the therapist if necessary.

Outgoing communication and control
Here the therapist can communicate with patients and execute actions. Examples of actions are instructing the computer to trigger effects or guiding a patient through locations within their virtual world. Also here the therapist could make adjustments to the system itself and adjust lines with the different patients

Therapist cognitive state monitor
There is the possibility of adding a therapist cognitive state monitor that acquires data on the therapists stress levels, workload and cognitive state, by using biosensors or feedback from the user-interface (see chapter 2.3.2). This data can be uses by the system to make more intelligent decisions on how to assist the therapist

For a patient component it is important that it can handle the input from the therapist. By adding patient anxiety measurement and a computer session controller, there is an option to give automated support to the patient. (see figure 3.5)

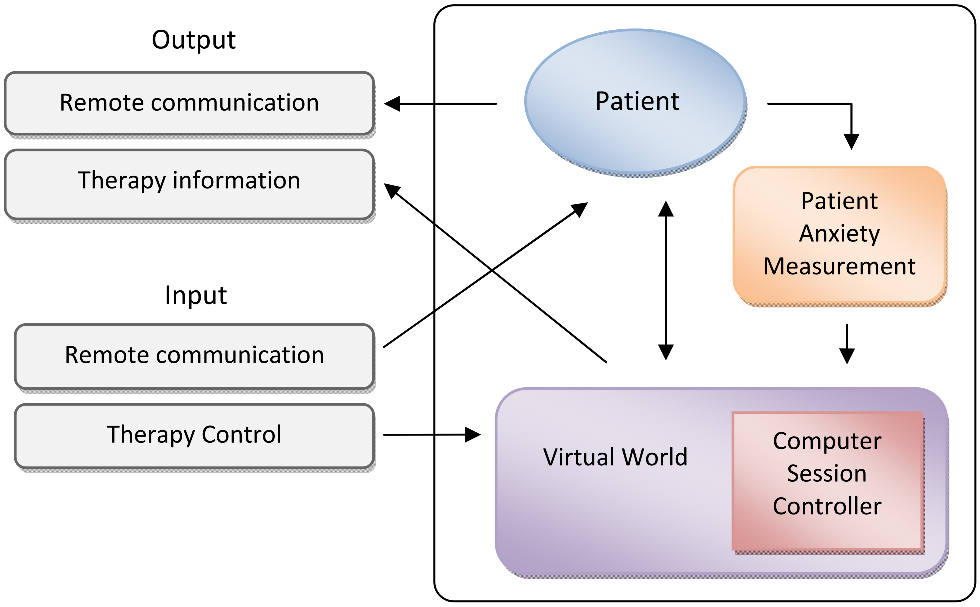

Figure 3.5: *A possible patient component in a multiple patient VRET system*

Patient component:

Patient input and output
At the patient input there is remote communication and therapy control. The remote communication goes directly to the patient and patient can directly communicate back to the therapist. The input from the therapist control can go to the Virtual world and the therapy session controller. With this information the therapist could adjust setting and the therapy of the patient. Any information on a therapy session or patient can be send to the therapist component. This can then present the information to the therapist.

Virtual world and session controller
Every patient has their own Virtual world and matching session controller. This houses the patients virtual environment and gives the visual data to their HMD. It also manages the head tracker of the patients and adjusts there view respectively and also streams sound data to the head phones of the HMD. It should also be able to handles interaction within the VE and run any therapy scenarios. The computer session controller can assist the patient with their therapy by taking data from the patient anxiety measurement and adjusting their scenarios or virtual environment.

Patient Anxiety measurement
By determining the anxiety levels of the patient, with biosensors or other stress sensors (see chapter 2.3.1), the system should be able to make more intelligent decisions on the therapy of the patient. This data could also be send to the therapist possibly warning them that extra assistance is required

4 Conclusion

Creating a VRET system expansion that will provide a platform to treat multiple patients simultaneously is a complex design problem. There are a lot of different aspects that should be looked at, starting with the interaction and communication between the patients and the therapist. There could be need for communication over larger distances, similar to tele-treatment. This could be achieved with a microphone and possibly a camera setup.

A proposed system should be very flexible. It should be scalable from two to more patients and should be able to adapt to a whole range of different therapies. For example fear of heights, claustrophobia but also social phobia's or post traumatic stress disorders.

There could be need for a reliable way to monitor patients for stress levels. This could be done with physical sensors or visual and verbal detectors and then combine their data into a patient anxiety score. A computer system could make decisions based on these scores. These decisions vary over a number of possibilities: interrupting, warning or assisting the therapist or even taking over certain tasks.

If there is need to use adaptive automation to assist the therapist more dynamically, the system needs a way to monitor the therapists and assesses their workload and cognitive state. It could then be able to decide to take over certain tasks from the therapists. At the same time it should work together with the therapists and not hinder them. It is even possible that the therapist has the option to adjust the warning and the assistance level of this system.

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6 Abbreviations

AA	Adaptive automation
AC	augmented cognition
AT	acknowledgement time
CTL	Current task load model
GUI	graphical user-interface
HMD	Head-mounted display
LIP	The level of information processing
LoA	Level of Automation
SA	Situation awareness
SUD	Subjective Units of Discomfort
TO	The percentage time occupied
TSS	level of task-set switching
UI	user interface
VE	Virtual environment
VRET	Virtual reality exposure therapy