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Cognitive Engineering of a Military Multi-Modal Memory Restructuring System

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ABSTRACT

Several methods have been proposed to treat combat veterans with posttraumatic stress disorder (PTSD). Still, a recent review reports on high drop-out and non response rates. This has motivated work into the design of a software application to support and to increase the appeal of traditional face-to-face trauma-focused psychotherapy. The research followed a situated cognitive engineering approach, which included a domain analysis, scenarios and claims analysis based on experts reviews (N=10), user evaluations, and a case study. This resulted in the identification of nine core application functions: (1) provide a flexible way of storytelling, (2) provide a structured way of storytelling, (3) prevent losing track of changed and added events, (4) ensure patient trust, (5) ensure usage for therapists with different backgrounds, (6) ensuring awareness of treatment, (7) provide a personal approach, (8) prevent unexpected exposure to emotional material, (9) and ensure appealing and motivating approach throughout the therapy. These functions formed the basis for the design of a military multi-modal memory restructuring (Military - 3MR) system, which focuses on restructuring and relearning of past events. The system allows patient and therapist to visualise past events using personal photos, narrative text, online geographical maps, webcam snapshots, and patient created 3D virtual worlds. Results of the usability evaluation (N=18) suggests key design features such as the time line, content manage, and the 3D world editor, of an acceptable perceived usability level. Results of a storytelling experiment (N=18) between telling an autobiographical story with or without Military-3MR system, found that with the system, time referencing and event description were more precise, and a smaller time period in the story was covered. In the case study, the veteran suffering from combat-related PTSD was pleased with the system and felt encouraged talking about his past events.

Keywords

PTSD, trauma-focused psychotherapy, memory, multimedia, restructuring, reappraisal, 3MR, 4MR, cognitive engineering, mental health system.

1. INTRODUCTION

Warriors that served in combat or peacekeeping operations have often witnessed or experienced traumatic events, such as attacks, serious personal injuries, and the death of comrades or civilians including children. On their return from deployment these warriors can suffer from Post-Traumatic Stress Disorder (PTSD). For example, a survey (Hoge, et al., 2004) among members of four US combat infantry units found that between 12%-20% of them reported PTSD symptoms a few months after their duty in Iraq or Afghanistan. Similarly, in another survey (Milliken, Auchterlonie, & Hoge, 2007) among US Iraq war veterans 17%-25% exhibited PTSD symptoms three to six months after their return. Several methods have been proposed to treat patients with PTSD ranging from pharmacological approaches to Cognitive-Behavioural Treatments (CBT), with exposure therapy currently considered the first-line treatment for PTSD (Cukor, Spitalnick, Difede, Rizzo, & Rothbaum, 2009). Still a recent review (Schottenbauer, Glass, Arnkoff, Tendick, & Gray, 2008) of 55 studies on empirically supported treatments for PTSD reported that drop-out and non response to the treatment are often high. While dropout rates ranged widely from 0% up to 54%, a 50% non response rate was not uncommon to find. This has motivated the work reported here into the design of a military multi-modal memory restructuring (Military - 3MR) system, a software application to support, and increase, the appeal of traditional face-to-face therapy. The application focuses especially on helping the patient to restructure and relearn memories about events of their past deployment.

One of the symptoms of PTSD as indicated by DSM-IV-TR is the inability to recall an important aspect of the trauma. For example, Clark and Beck (2010) discussed the case of Edward, a 42-year-old man with 20 years of distinguished service in Canadian infantry who after several deployments is diagnosed with PTSD. Especially his experience of his 6-month United Nation peacekeeping Rwanda tour in 1994, they reported to include traumatic events. One of these traumatic events that Edward experienced was the apparent murder of a 5-year-old orphaned girl and her friends by soldiers of the Rwandan Patriotic Army (RPA). Edward’s beliefs were based on his last visit to the orphanage, when the children were no longer there, instead a RPA soldier was there, smiling and gesturing by sliding his hand across this throat. However, when they studied his recollection in depth they noticed inconsistency with other information such as: (1) there was no indication from the caretaking nuns that children had been taken away and murdered; and (2) the incident would have taken place after the genocide had stopped when many children returned to their village. Reports on perceptual and memory distortion of high stress events, sometimes referred to as critical incident amnesia (Grossman & Siddle, 2001) are not uncommon. For example, a study of police officers involved shooting incidents (Artwohl, 2002) reports the case of an officer that saw a suspect suddenly point a gun at his partner. As the officer shots the suspect, he saw his partner go down in a spray of blood. When the officer ran over to help his partner, he found him standing unharmed. In fact the suspect never fired a shot. Critical incident debriefings have been suggested (Grossman & Christensen, 2008) as a vital method to reconstruct the events, learn from it and help those involved to come to terms with it. As everyone involved is brought together, potential memory loss, memory distortion, irrational guilt etc can be addressed. The absence of such debriefing can have a large impact on someone's life. As an example Grossman and Christensen discuss the case of Tim, a Vietnam veteran, who for over 20 years never told anyone about an event in which he thought he had abandoned his man at an observation point when it was overran by North Vietnamese soldiers. Only after telling his story with pain and tears in his eyes to a group of West Point psychology students, Grossman explained to him that with his actions he had actually saved every man in his company, by ordering his man at the observation point to open fire and afterwards running back to the company's defensive position on a hilltop. Tim had never realised this. An important element of cognitive therapy for PTSD is therefore directed toward evaluating and restructuring the traumatic memory (Clark & Beck, 2010).

As is pointed out in the 'collaborative cycles for the design and evaluation of technology for mental health interventions' (Coyle, Doherty, Matthews, & Sharry, 2007), research into the design of technology of talk-based mental health intervention often follows a two stage approach. Where stage one focuses on design and development of the technology, the second stage focuses on clinical evaluation. The work reported here should be seen as part of this first stage. In this stage, because of ethical constraints, access to patients is often limited, and the focus of this stage is to evaluate and establish confidence about the usability of the technology for the target end users group. Furthermore, to design a software application to support therapies for combat-related PTSD, the situated cognitive engineering (Neerincx & Lindenberg, 2008) approach was applied. Instead of working from a pre-set of requirements, this approach recognises the complexity and situational dependence of a working domain, and the need for exploration of technological innovations to establish a set of testable claims that can drive a design solution. The work went through several iterations where the requirements baseline was continuously refined as new insights were acquired through prototype evaluations and reviews with therapists. The first iteration of this approach was to do a thorough domain analysis. This was done in multidisciplinary meetings with cognitive engineers and a psychiatrist experienced in treating veterans suffering from a combat-related PTSD, which eventually led to the establishment of an inventory of human factor knowledge, operational demands, and envisioned technology. This knowledge was used to create several scenarios and prototypes. PTSD experts reviewed these scenarios and discussed various possibilities and limitations. In addition, cognitive engineering experts reviewed the prototypes on their usability. In a following iteration, the system was empirically tested with users on its usability and its ability to support storytelling. The actual use of the system was eventually studied in a small case study with a veteran suffering from a combat-related PTSD. The paper gives an account of all these iterations, and concludes with summarising the contributions made by this study and discussing directions for future work.

2. DOMAIN ANALYSIS

Designing a useful mental health care system requires a multidisciplinary approach (Coyle, et al., 2007). Besides studying the literature, an important element of the domain analysis therefore were several follow up brainstorming sessions between cognitive engineers and a military psychiatrist. An important patient characteristic which was found in this analysis and which would later play an important role in the design and implementation of the system was the availability of personal material. Many of the patients who were treated at the medical centre kept personal photos, pictures and various related documents related to their past dispatches at their homes. Although this material may not directly be related to a problematic stressor, it could still contain information necessary for the treatment or it could be used for reappraising the past dispatch as a whole.

2.1 Operational demands

Several operational demands were identified as relevant for the design of the system. First, the patient's memories play an important role in addressing fears and stressor. A system should therefore support therapist and patient to organise various memory elements. Patients exposed to their memories of past events will remember more facts and details of the traumatic stressors (Foa & Kozak, 1986). Biographic material could be useful in accessing these memories. However, patients might not be in possession of this material, therefore a system should also offer other facilities to support recollection. Second, there seem remarkable differences in the selected treatments between therapists and between patients. Some treatments only focus on imagery-based treatment, while others focus on cognitive reappraisal or restructuring. While a single system might not support all these different types, a system that would have features that could support various treatment methods would be more attractive for more therapists than those that only support one single method. Third, the setting of a session can vary from individual home work, individual face-to-face session with a therapist, to a group session with other patients. Next, patients in a group session do not necessarily have participated in the same deployment. Managing these different experiences in a group can be difficult. Currently, a flap-over was used in the therapy, but not so often. After a session the drawings would be lost and rarely mentioned again. Fourth, patients that better understand their treatment are less likely to terminate their treatment (Clark & Beck, 2010). Therefore, psycho-educational features in the system could make the progress in a treatment more insightful.

2.2. Human factors knowledge

Although often research on mental health systems focuses on the patient side on issues such as efficacy and acceptability, the therapist side also requires considerable attention addressing human factor issues as workload and usability (Brinkman, van der Mast, Sandino, Gunawan, & Emmelkamp, 2010) and the interaction between the patient, the therapist and the system (Wrzesien, Burkhardt, Alcañiz Raya, Botella, & Bretón López, 2010). As part of the domain analysis a People, Activity, Context, and Technology (PACT) analysis (Benyon, Turner, & Turner, 2005) was conducted that identified the following three main human factors: trust, emotion, and cognitive task load. As traumatic events might involve moral judgement or have legal consequences for those involved, treatment has to be set in environment patients can trust. Because of the perception of stigma still associated with receiving mental health services among soldiers (Hoge, et al., 2004), the patient privacy is an important issue, especially, when considering using autobiographical material of the patients. If data is stored, patients should be aware that data is handled correctly. A technology solution should not endanger the patient-therapist relationship as this is a key factor of a therapy (Rizzo & Kim, 2005). Trust also involves the reliability and confidence with which therapists use a system. As was reported (Brinkman, et al., 2010) in the case with a system to treat people with a fear of flying, therapists were less confident using a system if they fear that it would crash during a session and shatter patients' trust in their ability to control a situation.

Emotion was also identified as an important human factor as the autobiographical material could trigger memories of traumatic events. As these can be very upsetting for patients, unintended exposure should be avoided. Additionally, in a group session, some patients do not like to be stared at during exposure and others might feel uncomfortable looking at the person in a distressing state. Finally, additional cognitive task load the system placed upon the therapist and patient should be limited. High task load can potentially hinder treatment. It would divert therapist's attention away from the patient and the treatment. For the patients, it would divert their attention away from their memory exposure and restructuring activities.

2.3. Envisioned Technology

Considering the work and the success of others on virtual reality exposure therapy systems, such as virtual Vietnam environment (Rothbaum, 2006), Virtual Iraq environment (Pair, et al., 2006), Bus world (Josman, et al., 2006), World Trade Center environment (Difede, Cukor, Jayasinghe, & Hoffman, 2006) and the clinical results (Wood, Wiederhold, & Spira, 2010), the project was initially set out to develop a virtual environment tailored for the Dutch combat and peacekeeping operations. However, when exploring various 3D development environments in the first multidisciplinary meeting, it was realised that the very act of creating such a world by a patient might already be part of the treatment, as it might be a visual way of storytelling. For treatment of PTSD the latter has been regarded as a helpful strategy to modify memories of past traumatic experiences, for example in expressive writing (Clark & Beck, 2010), in creative therapies (Johnson, Lahad, & Gray, 2009) or Narrative Exposure Therapy (NET) (Bichescu, Neuner, Schauer, & Elbert, 2007). In NET the generally fragmented, gap-filled reports of the events are transformed into a coherent narrative. This can cause the habituation to emotional responses to reminders of these traumatic events. The memories are included in the patient’s biography in a narrative form, facilitating the reorganization of the autobiographical memory and attribution of meaning. Therefore the first idea was to solely create a 3D virtual world editor, allowing the patients themselves to select 3D objects, such as houses, tanks and other vehicles and placing them on an empty template. To support the group process, a projector would display the computer screen on the wall. This way a patient could explain to other group members what the situation looked like, what they experienced and in which order specific events had occurred. In following multidisciplinary meetings where the first scenarios were discussed the idea evolved into an even more personalised support environment, allowing patients to use multi-media modalities by using besides the 3D world, their own pictures, and consequently the need to structure media elements on a timeline to support storytelling of past experiences. The 3D world editor remained initially the main storytelling feature.

3. SCENARIOS AND CLAIMS

Scenario-based design (Carroll, 2000) emphasizes on exploring the use of a system before it has actually been developed and this method has been successfully used in establishing design requirements for other mental health systems (Paping, Brinkman, & van der Mast, 2010). Therefore a set of use scenarios were created to describe and discuss possible situations in which the envisioned application was presented. The gathered knowledge was later used to establish a preliminary requirements baseline. By creating these scenarios several assumptions had to be made explicit. The assumptions were linked to possible effects on the involved actors and were therefore important to analyze. A claims analysis was done with experts to reflect on possible effects as either pro or cons, and to establish a more elaborate understanding of the claims and assumptions without already verifying them empirically.

3.1 Use Scenarios

The scenarios described three possible situations in a therapeutic setting in which the system could be used: (1) the general use of the system showing all the major features of the application, (2) the use of the 3D editor as a feature of the system, and (3) modifying or extending data related to an event discussed in a previous session. To explain these scenarios better, they were transformed into three separate movie clips showing actors using a first low-fidelity prototype of the envisioned application.

3.1.1. Scenario A: Start of a session and general use of the application

Scenario A showed general use of the application and introduced the idea of personalisation, a timeline, and a progress bar. This scenario started with two therapists preparing the group session (Figure 1.a). The therapists had different roles during the session; one led the session and interacted with the patient, while the other operated the system. The session started with focusing on one patient and his experience (Figure 1.c). The therapist asked the patient to place the pictures he had brought on the timeline and explain what could be seen on the pictures. Two main claims examined in this scenario were that (1) adding personal photographs and text were sufficient enough for a patient to restructure and relearn past deployment events; and (2) the usage of the timeline would help the patient to organize various memory elements.

(a) Two therapists: one focuses solely on the patient, the other on the technical aspects of the application

(b) Group session starts and the patients enter the room

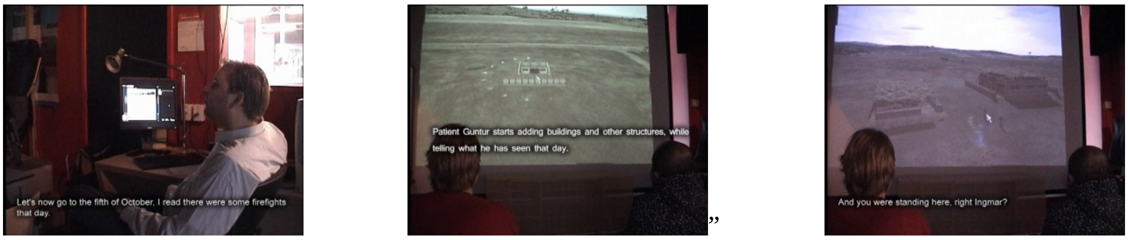
(c) "Can you label the pictures by putting them on the timeline?"

(d) "Allright, what do you still remember of that specific day?"

Figure 1: Stills of the scenario describing the general use of the application.

3.1.2. Scenario B: Using the 3D editor

Scenario B described how a patient used a simple version of the Armed Assault 1 editor to recreate an event in the 3D environment (Figure 2.b). The scenario showed that both group members and the therapist can interrupt the patient when recreating the event, asking him questions or giving their view on his story and the situation (Figure 2.c). The main claims examined here were that a patient could create such a world, and that editing work can be paused, and a patient can talk, or be calmed down by a therapist.



(a) “Let’s now go to the fifth of October. I read there were some firefights that day. Can you show me what happened exactly and what the area looked like?

(b) Patient Guntur stars adding buildings and other structures, while telling what he had seen that day.

(c) “And you were standing here. Right Ingmar?”

Figure 2: Stills of the scenario describing the 3D editor.

3.1.3. Scenario C: Returning to a previously edited day

The last scenario showed that a patient could continue to work on their story in follow up sessions. It also showed that patients can go back to what they told in previous sessions and add additional details. In the scenario the patients reveals that before the fire fight he had not told his colleague, who got shot, that he had seen someone behind the structure. In the previous session the patient had said that they did not know where the shooting was coming from.

(a) “It has been a week since we last met, let us continue by going to the 20th of October”

(b) “Uhmm, yeah, we can continue but I’d like to go back to the day we edited last time...”

(c) “I was worried and actually couldn’t sleep last week because I didn’t tell you all the details”

Figure 3: Stills of the scenario describing the modification of a previously discussed day.

3.2. Use scenarios evaluation

The three scenarios were used in individual expert reviews with 10 experts, they included therapists working with soldiers, war veterans, and civilians with war traumas; and academics specialised in the treatment of traumatic memory, PTSD and grief. Six were non-Dutch experts, coming from Croatia, the UK, the US, and Poland, attending the NATO Advanced research workshop entitled ‘Wounds of War: Coping with posttraumatic stress in returning group’ that was held in October 2009 in Austria. The experts used several approaches such psycho-dynamics, imaginary exposure, cognitive behaviour therapy and VR exposure. Some worked often in group setting, while others treated patients in one-to-one sessions. During the reviews, each expert was shown the video of the scenario, and asked to comment on the underlying claims to start the discussion.

The overall feedback from the experts was positive and the general idea underlying the envisioned approach was supported. The acquired comments were mainly related to features which could improve the system, including additional options to facilitate memory content, such as adding maps and photos of drawings. Other suggestions, which also caused refinements to the requirements baseline, were (1) the possibilities to personalize the application for an individual patient, (2) the use of keywords to tag or summarize a specific day and (3) methods to manage and store data and session information. Although not presented in the scenario, the latter suggestion came up multiple times during the reviews. Some mention that soldiers might not seek treatment because of the fear of stigmatization and the potential consequences. Not all experts supported the use of the 3D editor, especially experts with a background in psychodynamic and group therapy without exposure. Comments were also made on the set up of the room. In the scenarios the therapist was placed slightly behind the patients. Instead the therapist should be positioned to see the face of the patients and other non-verbal signals. Next, as only the patient that is working with the system needs a table, other group members only need a chair which should be situated in the shape of a circle or the letter ‘U’, creating the feeling of a ‘safe zone’.

4. DESIGN

The results of the domain analysis and scenario-based evaluation led to a list of nine core functions of the Military-3MR system, which formed the requirement baseline for the design and implementation of the system. The design and the evaluation process, reported later, also contributed to the final list shown in Table 1. An iterative approach was followed for the design of the system. Several prototypes were made and reviewed in the meetings of the multidisciplinary team. The story board shown in Figure 4 gives an overview of specific features of the final system and how they are used. The actual system was implemented using two development packages: (1) Adobe Integrated Runtime (AIR) for the main application, and (2) Vizard for the 3D world editor feature.

Table 1: Core functions of the Military-3MR system and their underlying claims.

No	Core function
1.	*Provide a flexible way of storytelling*. Restructuring and relearning about a past deployment events can have a positive effect in traditional treatment. Only the patient has access to the various memory elements related to the events and stressors at that time. More efficient and effective results may be achieved by allowing the patient to facilitate memory content in a flexible and motivating way.
2.	*Provide a structured way of storytelling*. Deployments usually cover multiple months. Within these months various events occur. Next to giving the patient the tools to flexibly add and edit memory elements, it might also be important to do this in a more structured environment.
3.	*Prevent losing track of changed and added events*. Currently a physical folder is kept of every patient, containing notes, drawings and other deployment related information. These files can get rather large and it is difficult to keep track of the continuous changes which may occur. Especially if a therapist works with multiple different patients every week.
4.	*Ensure patient trust*. Deployment related stories can contain very sensitive information. This data should therefore be stored securely. Trust might be another problem if the storage of private data is not properly implemented. The look and feel of the system can also be important when establishing trust.
5.	*Ensure usage for therapists with different backgrounds*. Therapists use several methods to treat patients suffering from a combat-related PTSD. If the system does not force the patients to follow one specific procedure, while providing several tools to facilitate memory, the system might be interesting for a variety of different therapists and methods.
6.	*Ensuring awareness of treatment*. Besides the restructuring and relearning element, a psycho-educational element can be introduced to give the patient more insights about the treatment in general. Details of sessions, including information about recent changes, future goals and accomplished goals may help patients learn and cope with their disorder.
7.	*Provide a personal approach*. The patient should feel comfortable using the application. Personal preferences should be respected, making the application look and feel like a helpful companion throughout the treatment.
8.	*Prevent unexpected exposure to emotional material*. During the first review with an actual patient, one of the suggestions was to implement an option to 'tag' photographs that are linked to very emotional situations. For example, a patient may not like the idea of being greeted with a very emotional memory when starting the application or navigating through the timeline.
9.	*Ensure appealing and motivating approach throughout the therapy*. One of the problems with current treatment is the high drop-out rates. Keeping the patient motivated and aware of the progress may prevent the patient to quit the therapy too early.

As ensuring patient trust was identified as core function, the system supported three types of installations set up: (1) full USB-stick installation; (2) full therapist computer installation; and (3) photo separation installation. In the first installation the software application is installed on USB stick (or another external memory device), and a folder is created on the USB stick where prior to a session photos can be copied to. During the session, the application is run from the USB stick and internal recordings such as text element, snapshot of maps, are stored on the USB stick. After the session, the USB stick can again be taken out of the computer. The USB stick could be locked up in a physically safe place or given to the patient. If the therapist regards it appropriate, the patient can also be given as homework assignment the task to continue working on the timeline at home in preparation of the next session. The full therapist computer installation on the other hand ensures that the application is only used in the session with the therapist as the application and autobiographical material is stored on the computer of the therapist. A folder has to be created on the therapist's computer to copy the photo brought by the patient into. An alternative would be to install everything on the patients' laptop on which their autobiographical material is stored. In this way patients are in complete control of the access to their material which might enhance their trust. The last installation type is a combination of the previous two. The application is installed on the therapist's computer, but the photo material is kept in a folder on USB-stick of the patient. Only when the USB-stick is plugged into the therapist's computer, will the photos be accessible for the application. This installation avoids patients to work unsupervised on their timeline, but gives the patient assurance that they are still in control of their own photo material.

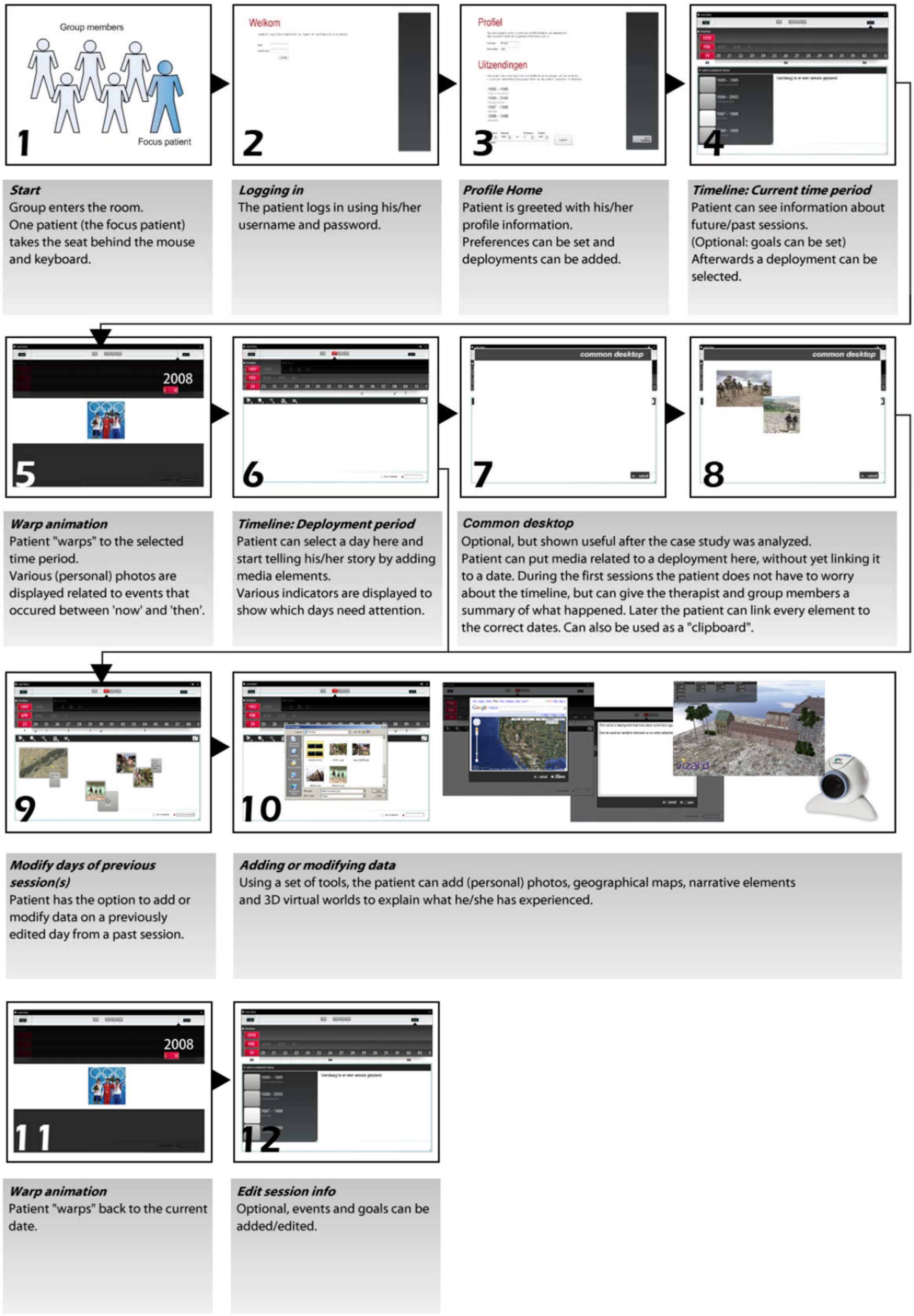


Figure 4: Story board describing the use of the Military-3MR system.

4.1 Timeline

Patients' intrusive recollection of traumatic events is among other things caused by their fragmented and poorly elaborated memory structure of these events (Clark & Beck, 2010). Providing a structured way of storytelling was therefore identified as another core function. A key element in the Military-3MR system to support this is the timeline which is a chronological visual representation of the events in the patient's life. This idea is not entirely new. For example, the life-chart method (Osuch, et al., 2001) provides a graphical presentation of events in patients' life and their treatment interventions with an aim of visualising the longitudinal course of the illness. In the Military-3MR system the purpose of the timeline however is (1) to help patients to structure their memory, (2) to enhance their awareness of the relatively small time scale of the traumatic event compared to their entire life, and (3) to enhance their awareness that the traumatic events that dominate their current life all happened in the past. The overall timeline is presented at the top of the screen (Figure 5) what is referred to as the lifeline of the patient. It shows which year the patient was born, the deployments, and current & future events. When a deployment is selected (Figure 4 step 5) the indicator moves back to the year of the deployment. As the years are counted back, photos are shown of a memorable event of each year. To emphasize even more that the deployment occurred in the past, the photos in the warp animation start in full colour, but become more grey when year lay further in the past. The timeline slider (Figure 5 at left), allows patient to select a specific date. The symbols below the days indicate whether discussion of that day has been complete, or is still in progress. To avoid the patient only to focus on past events, the application also supports the creation of events in the now or the future. Here patient can be encouraged to talk about the present and set goals for the future.

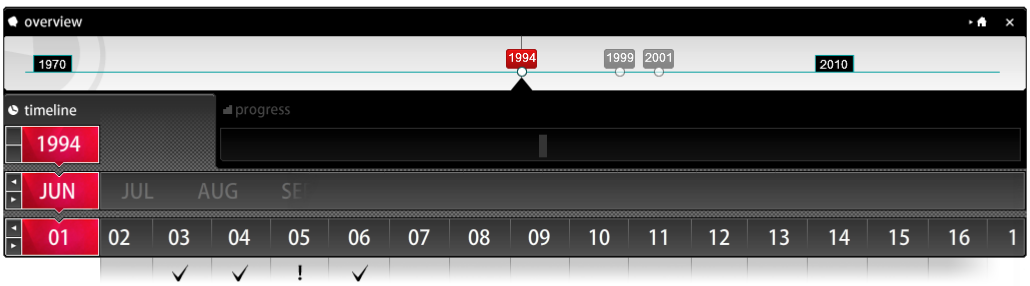


Figure 5: Timeline.

4.2. Photo, Text, Maps, and webcam

The system provides five different features to facilitate memory. The patient has the option to add (1) images or photographs, (2) geographic maps using Google Maps, (3) story text, (4) webcam snapshots and (5) virtual representations of a situation using the 3D editor. When the patient adds an image, a webcam snapshot or a map, the system creates an interactive thumbnail and puts this thumbnail on the content panel. Clicking on these thumbnails gives the patient the option to display the picture on the full size screen, to remove it, and to hide or unhide it. The hiding option avoids unwanted exposure of emotional material. After the case study, a common desktop function was also added. This is a clipboard on which photos and text can be placed temporally, and copied to the content panel of specific days. With non recent deployments, patients might not own digital photos, but only printed photos of their deployment. In these cases, the patient can digitised these photos by taking a snapshot of them with the webcam. The webcam can also be used to take pictures of drawings made in the session, or documents or objects brought by patient. It could also be used to make pictures of recreated situations with physical objects. For example, Playmobil has been used successfully to recreate accident events to study emergency responses (Gunawan, Ooms, Neerincx, Brinkman, & Alers, 2009).

4.3. 3D world editor

The 3D world editor allowed the patient to create a simple 3D world by selecting objects such as buildings, trees and vehicles from a menu. Besides placing and rotating the objects, the patient can also change the camera position using the mouse and some keyboard keys. The patients can therefore look at the world from different angles (Figure 6) to help them reflect on the event from multiple perspectives.

Figure 6: 3D world editor.

5. EVALUATION

Besides the expert reviews of the system design and its underlying claims as discussed previously, another core activity of the situated cognitive engineering approach is the evaluation of the system with users. In this study, the evaluation of the system focussed on three issues: (1) the usability of the system, (2) the effect of the system on storytelling, and (3) practical use of the system in the field. All these issues were empirically evaluated.

While only the last issue was evaluated with an actual veteran suffering from combat-related PTSD, the other two issues were evaluated with participants that did not suffer from combat-related PTSD.

5.1. Usability analysis

The usability of the system was evaluated using both an analytical method, i.e. heuristic evaluation, which involves designers to critically analyse the design, and an empirical method, i.e. a usability test, which involves testing the system with users. This approach allowed that potential generic usability problems were identified and gave direct input on how potential users would use and perceive the usability of the system.

5.1.1. Heuristic evaluation

Several prototypes and evaluations were conducted before the final Military-3MR system was developed. Once the first set of core functions and requirements were defined, a first high-fidelity prototype was created. The ten principles for user interface design (Jakob & Rolf, 1990) also known as the ten heuristics, were used to obtain feedback on this high-fidelity prototype. Six MSc students, trained in the field of cognitive engineering, were all asked to complete, individually, a form containing several questions related to the ten heuristics. Later, a part of this group participated in a follow-up group evaluation that aimed at identifying possible usability issues present in the high-fidelity prototype. The obtained feedback from both evaluations mainly concerned: (1) the state of the system, which was not clear, (2) system behaviour, as it did not follow common Graphical User Interface standards, and (3) clarity of the icons and buttons.

A formative usability evaluation approach was chosen to address these issues and to continuously acquire more feedback of the rapidly generated prototypes in a period of four weeks. During this phase various elements of each prototype were inspected by the cognitive engineering team, which included the six students and two lecturers. During this time multidisciplinary meetings were also held to improve the requirements baseline, and a small interview was conducted with a patient suffering from combat-related PTSD to review the prototype. The reviews and the small interview resulted in two of the core functions (Table 1): providing a personal approach and preventing unexpected exposure. Eventually the evaluation reached a point where no usability issues were reported anymore. This last prototype, referred to as the final Military-3MR system, was now considered suitable to be used in a usability test with users and a case study with a veteran suffering from combat-related PTSD.

5.1.2. Usability test

The evaluations of the previous prototypes led to several refinements regarding both the usability and the functionality of the system. With the final prototype finished, a users based usability test was conducted, in which 18 individuals (12 males, 6 females) participated, none suffering from a combat-related PTSD. The age varied between 21 and 59 (M =36.2, SD = 15.1) years. The participants had never worked with the final prototype before and none were given instructions beforehand. To evaluate the perceived usability of timeline navigation, content manager, and the 3D editor, a component-based usability questionnaire (Brinkman, Haakma, & Bouwhuis, 2009) was used, as component-specific measures have been reported (Brinkman, Haakma, & Bouwhuis, 2008) to be on average statistically more powerful than overall usability measures. The questionnaire asked participants to rate the usability of each of these interaction components on six statements. Before participants were asked to complete the questionnaire they were asked to complete a number of tasks: select a specific deployment, navigate through the timeline to pick a date and eventually add, modify and delete content elements. In addition the participants were asked to create a virtual world based on a screenshot provided to them. Participants were not provided with any additional instructions or help material.

The individual component measures, each based on six 7-point Likert scale statements, received an acceptable level of reliability with Cronbach's alpha ranging from 0.73 to 0.81 (Table 2). The average of the scores on these six items was therefore taken as a usability measure for the component. One-Sample *t*-tests showed that all three measures deviated significantly from the norm value of 5.29 (Brinkman, et al., 2009). As Table 2 shows all means were above the norm value, suggesting that the perceived usability of these components were more comparable with the perceived usability of easy-to-use components in the norm set than the perceived usability of difficult to use components in the norm set. The questionnaires also allowed participants to add additional comments and suggestions. One reoccurring issue was that of the 'maps' icon; a large number of participants thought that the 'maps' icon was actually the icon to open up an internet browser. Because there were not many other options, everyone still managed to add the map, but some found this a bit confusing. A suggestion made by multiple participants was to add the ability to drag and drop objects in the 3D world editor. No other usability issue was found. All participants stated that they were very pleased with how the application worked, and most of them also mentioned that the user interface looked appealing.

Table 2: Result reliability analysis and One-Sample *t*-test with test value 5.29 on component-based usability questionnaire data.

Component	*α*	*M (SD)*	*t*	*df*	*p.*
Timeline	0.81	6.37 (0.43)	10.58	17	<0.001
Content manager	0.70	6.08 (0.45)	7.37	17	<0.001
3D world editor	0.73	5.62 (0.57)	2.44	17	0.026

5.2. Storytelling analysis

After participants in the usability test filled out the component-based usability questionnaire they were asked to tell two different autobiographic stories of six minutes each. One story they were asked to tell using the Military-3MR system, the other story they were asked to tell without the system. To control for possible learning or fatigue effects, the order of these two conditions was counterbalanced. The events, for example a holiday or business trip, should have taken place at least three years in the past. The order between the time of the events was also counterbalanced, i.e. half the participants started with describing their more recent event, while the other half started with describing their less recent event. While talking they could use photos they had specially brought with them for the experiment. At the start of the session, the experimenter selected only a small set of phones they could use, to reduce the chance that prior to experiment, participants would have mentally rehearsed a specific story line.

During the storytelling, voice recordings were made of both stories, resulting in a total of 36 different audio clips. Each sentence was coded for five non-mutually exclusive categories (Table 3) reference to (1) time, (2) an event or (3) a location. All references in a told story were counted so it could be used for a statistical analysis. Only 24 recordings were used in this analysis, as six participants used the text feature to write about their stories without saying what they were typing. These voice recordings did not contain any relevant information and could therefore not be used. For each story the number of references for each category was counted, the difference between the stories told with or without the system was analysed by Wilcoxon Signed-ranks tests. As Table 3 shows, participants significantly more often made precise date references and used significantly less often a less precise time frame when they used the system. The system, therefore, seems to have encouraged participants to place their story in a specific time. This was also supported by the analysis of the number of months covered in a story. With the system (*Mdn* = 0.13) this was significantly ($Z = -2.43$, $p. = 0.015$) shorter than without the system (*Mdn* = 0.5). Once they picked a starting date for their story, they seem to continue telling more about this day by adding events. Furthermore, they seemed to talk about days that were close together. This was not the case when participants did not use the system. In some cases these stories even covered several months. Table 3 also shows that participants made significantly more often detailed event descriptions and made significantly less often general event descriptions when using the system. This seems to suggest that the system encouraged participants to be more specific in describing the events in their story. Although the online geographical maps functionality was expected also to have an effect on the number of reference made to specific location, no significant difference was found. This however might have been an artefact of the story topic e.g. a holiday or business trip, where the location and the geographical setting might be less relevant than for events in a combat situation.

Table 3: Results Wilcoxon signed-rank test on sentence analysis for story told with or without the system.

		Median frequency			
No	**Category**	**With system**	**Without system**	***Z***	***p.***
1a	*Precise date reference*; e.g. "12th of March"	2.5	0.0	-2.96	0.003
1b	*Less precise time frame*; e.g. "the summer holidays" and "my second vacation that year"	1.5	4.0	-2.77	0.006
2a	*Detailed event description*; e.g. "buying a cola at the supermarket", "picking up the phone", and "getting in the car"	4.0	3.0	-2.56	0.011
2b	*General event description*; e.g. "going on a business trip", "leaving town", and "taking care of the pets".	1.5	3.0	-2.46	0.014
3	*Reference to location*; e.g. "the bank in the same street as the hotel we resided", "...I saw someone in my kitchen...", "...so we moved my furniture to the Weimarstraat..." , "Right before the small town which name I've forgotten..."	4.0	3.5	-1.51	0.130

Another observation was the individual difference between participants in how they told their story with the system. Although it might be caused by the six minute time constraint, some participants only used the text feature to write about past events and what they saw, even when they brought a photo book with them containing pictures which may have supported the storytelling. However, others were very dependent on the images and photographs. Two participants even did not mention any events that were not seen on the pictures.

After the story telling participants were also asked to rate statements on a 7-point Likert scale about their attitude towards the system's ability to support storytelling. Table 4 shows the results of One-sample *t*-tests comparing the score with the middle point of the scale, e.g. four. Overall the participants' attitude seems to lead towards the more positive side of the scale, in favour of the system to support storytelling. Interesting was that participants did not seem to agree with the statement that the system encouraged them to add media. This could be interpreted that they felt in control of their storytelling, not being dominated by the system to add content. Participants seem to find that they were also significantly ($t(17) = 4.91$, $p. < 0.001$) more able to tell everything they wanted with the system compared to without the system.

Table 4: Result One-Sample *t*-tests, with test value 4, on attitude questionnaire towards storytelling support

No	Statement	*M(SD)*	*t*	*df*	*p.*
1	I prefer a timeline, such as the one in the application, to tell my story	5.50 (1.30)	4.92	17	<0.001
2	I found the story telling with the application more enjoyable	5.28 (1.27)	4.25	17	0.001
3	I was able to tell everything I wanted (story telling **without** the application)	3.78 (1.59)	-0.59	17	0.562
4	I was able to tell everything I wanted (story telling **with** the application)	5.50 (1.25)	5.10	17	<0.001
5	I think I put more details in the story told with the application	6.00 (0.67)	12.37	17	<0.001
6	By using the application, I was encouraged to add media such as text, maps or pictures to explain things better	4.39 (1.79)	0.92	17	0.369
7	Comparing the two stories, I found that more memories came back with the application	5.94 (0.80)	10.28	17	<0.001

5.3. Case study with a Veteran

The usability analysis and storytelling analysis was conducted with people not suffering from a combat-related PTSD. However, actual experience with a system by a person actually suffering from this disorder might be different. Therefore, a small case study was conducted to get an insight on how a patient would interact and experience the system. The patient that participated in the case study was a Dutch veteran that had experienced stressful event during his deployments in the Former Yugoslavia: 1994 - Dutchbat I stationed Srebrenica; 1999- SFOR 6 operating in Bosnia; and 2001 - Task Force Harvest operating in Macedonia. The patient was already receiving outpatient PTSD treatment at time of the case study. In January 2010 two sessions were observed that took place in the office of the psychiatrist in Central Military Hospital, in Utrecht, The Netherlands. Prior to the session the psychiatrist informed the patient about ideas underlying the design of the system, the purpose of the case study, and the presence of an observer during the sessions. Figure 7 shows the office where the session took place and the set up of the system, which included a projector, a laptop on which the application ran, and a cell phone with Bluetooth which facilitated the internet connection needed for the online geographical maps. The patient was located behind the laptop and the psychiatrist was sitting at the right of him both facing the wall on which application was projected.

Figure 7: Office and set up of the Military-3MR system.

The first session took around an hour, and started with a few minutes introduction of the system and allowing the patient to explore the system. After this the patient started with creating his profile including his deployments. Once this was done the psychiatrist decided to work on the first 1994 deployment. Although the patient understood the idea of warp animation, he suggested the option to switch this off as it would be annoying to see this at each session. After the timeline was set at the starting day of the first deployment, the patient loaded all the images that he had brought on USB-stick on to this first day, with the intention to sort the images later on to specific days. In the reflection discussion after the session both patient and psychiatrist agreed on the need for a common desktop function to store images temporary, to copy them from here to specific days. After the images were uploaded on to screen, the psychiatrist asked the patient to discuss in detail these photos and suggested to add text element to them. As the psychiatrist entered the text, the patient was able to read back his comments on the screen and added details. Besides the photos, the webcam feature was also used to take a snapshot of a situation drawing made in a previous session with the patient, and again text was added to this snapshot. Often the patient also used the online geographical map function to look up specific places and buildings he remembered from his deployment. Again the psychiatrist encouraged the patient to explain in detail his recollection. The patient talked about his experiences and also how things had changed since then. Access to the online geographical map took relatively long because of limited internet connection. Interestingly, the download waiting time was used to let the patient tell more about the event that had happened.

A week later the second session took place, which lasted around 40 minutes. It started with a small reflection about the first session. The patient pointed out that talking and presenting his memories in this visual way was very appealing, and he considered it also useful for him. He had the feeling that this application helped him to become aware of events that had happened, and he felt in control of his own treatment, working on his own timeline. The patient also indicated that the year indicators of each deployment on the timeline should be clickable to allow jumping between time events. This was not implemented on purpose, to focus the discussion at one deployment at the time, and to avoid memories from different deployment to be mixed. Table 5 shows a summary of his comments. After this reflection, the remaining time of the second session was devoted discussing a document the patient had brought with him. This document was related to the events discussed in the first session, and the patient thought that this would help with specifying events on the timeline discussed in the previous session. The main interaction in the second session was directly between the patient and the psychiatrist without the use of the system.

Table 5: Summary of patient feedback on the use of Military-3MR system.

No	Feedback
1	The application makes you aware of the time-related events
2	It is positive that you working on your own deployment, you are more in control to add story elements yourself
3	Normally everything is done mainly verbal, now treatment is done with visual aids, which more appealing
4	Might also be good for group session, but also for individual session
5	Going back to these past events is painful, but it is still important to do so

Although during the sessions the 3D editor was not used, both psychiatrist and patient were hopeful that this feature would contribute in elaborating on complex stressful events. Later on, this was also confirmed in a review by a US soldier who had just returned from Iraq. This soldier was a behavioural health specialist stationed in the US Tripler Army Medical Center in Hawaii. After reviewing the Military-4MR system he wrote down that with the 3D editor soldiers would be able to draw a clearer image for the therapist. He thought that this would be beneficial for both therapists and patients as therapists would no longer need their own imagination to try and recreate what patients are trying to explain. With this clearer understanding, therapists would be able to help patients more. Interestingly, his comments also related to the need for personalisation of these worlds, as he wrote down that the 3D editor currently provided too few objects to recreate events in Iraq, missing objects such as Humvees[1] and MRAPs[2] vehicles, and Iraq style buildings. Overall he considered the 4MR-system a potential helpful tool for soldiers that have been avoiding anything that reminds them of what they went though. The system could also help to identify what exactly upsets a specific patient if this was unclear.

6. CONCLUSION AND DISCUSSION

Several conclusions can be drawn from the presented study. First of all, after several design and review cycles the Military-3MR system now seems to have established an acceptable usability level, without major usability problems, and with key design features such as timeline, content manage, and 3D editor being received as easy to use. Second, the system seems to facilitate storytelling as time referencing and event description become more precise, and smaller time periods are covered. Third, the case study with the veteran showed that he enjoyed working with the system, giving him a sense of control and a visually appealing way of talking and reflecting on past experience. Besides these points, the nine core functions identified are put forward as scientific contributions.

A practical limitation of the current system is the use of internet for online geographical maps, or the use of personal files such as digital photos. Due to security risks involved, military environments often limits the use of internet and do not allow plugging in a USB-stick into a military computer. At the moment, a solution seems the use of a standalone computer not connected to the military network, but instead connected to a public internet provider using a mobile phone or USB internet dongle. Another limitation is the limited involvement of patients in this study. No general statement can yet be made about the response of a treatment which used the Military-3MR system. An extensive randomized controlled trail would be needed for this, with a validated treatment protocol.

In the case study, no use was made of the 3D editor feature. Probably the effort involved creating a 3D world suggests that this feature should mainly be used to recreate specific traumatic and stressful event to reflect on the patient's recollection of these events. Future work might also look at the possibility of combining the Military-3MR system and a Virtual Reality Exposure Therapy (VRET) system, whereby a VRET system could be used to expose patients to generic 3D worlds, but also to the highly personalised 3D worlds created by

[1] Refers to High Mobility Multipurpose Wheeled Vehicle

[2] Refers to Mine Resistant Ambush Protected vehicles

patients in the Military-3MR system. Exploring the use of generic material might also include using generic picture databases of combat and peacekeeping operations, or using historical event databases such as online newspapers databases or Wikipedia. This might help the patient to remember personal events and place them in the context of major news events of that day. Instead of relating to a specific date, generic material could also include music popular at the time of the deployment or iconic video material. For example, historic video material of Saddam Hussein, as an US army clinical psychologist at Tripler Army Medical Center wrote down in his review.

Although the Military-3MR system was designed for the treatment of patients with combat-related PTSD, the identified core functions and possibly parts of the Military-3MR system might also be considered relevant for the treatment of non combat-related PTSD patients with traumatic events that stretch over a longer period of time, for example civilians in war situations, child abuse, or rescue workers that respond to natural disasters. In these and in military context the 3MR system might help patients to restructure and relearn their traumatic events as part of their treatment for PTSD using autobiographic multi-modal memory cues.

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