Measuring Stress-Reducing Effects of Virtual Training Based on Subjective Response

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Abstract. Training to cope with negative emotions or stress is important for professionals with a high pressure job, such as police officers and military personnel. The work reported in this paper is part of a project that aims to develop a Virtual Reality based training environment for such professionals. As a first step in that direction, an experiment was performed to investigate the impact of virtual training on the subjects' experienced stress responses. A group of 10 participants was asked to rate the subjective emotional intensity of a set of affective pictures at two different time points, separated by six hours. Half of the group performed a session of virtual training in between, in which they were asked to actively apply reappraisal strategies as a form of emotion regulation, whereas the other half did not take part in this training session. The results indicate that the virtual training caused the participants in that group to give significantly lower ratings for the emotional intensity of the pictures.

Keywords. virtual training; emotion regulation; stress response.

1 Introduction

On April 30, 2009, the Dutch national *Queen's Day*, at around 11.50 am, a man drives his car at high speed into a parade which includes Queen Beatrix and other members of the Dutch royal family. The vehicle drives straight through a line of spectators watching the parade, leaving eight people dead and ten injured, after which it nearly misses the open-top bus carrying the royal family and crashes into monument *De Naald* at the side of the road [17].

Due to the unexpected and stressful nature of this event, emergency service workers of the police and fire brigade are immediately faced with very difficult choices. Firstly, they have to make sure the attacker is overpowered, to guarantee the safety of the royal family and other people at the scene. Secondly, many victims of the attack need immediate medical attention. Thirdly, the other spectators need to be calmed down, to avoid any further accidents due to chaos. And finally, while having to decide in a split second which of these actions to pursue, they also have to regulate their own emotional response to the situation, in order to stay calm and avoid developing traumatic stress.

Although this is just one example, it illustrates the difficult choices that policemen and other professionals (e.g., in the fire brigade, ambulance, public transport, security, or military domain) face in crisis situations. Even though they usually have clear instructions about how to act, these security workers often have difficulties in making appropriate decisions, due to a combination of factors [10]. Firstly, crisis situations often require improvisation, i.e., deviation from standard protocols. Secondly, time to make decisions is often limited, which makes that the workers experience an enormous pressure. Thirdly, the extreme circumstances (e.g., many casualties, high danger level) may cause emotions that are not experienced in everyday situations. Consequently, despite extensive training, security workers in crisis situations often make ad hoc decisions that are suboptimal [10, 12].

In addition, even if they make optimal decisions from an external perspective, security workers have an increased risk of developing anxiety related disorders such as Post-Traumatic Stress Disorder (PTSD), especially if the situation involves extreme violence and/or human casualties [2]. Recent evidence indicates that the costs associated with PTSD, both to individuals and to society as a whole, are extremely high [6, 16]. Moreover, even light variants of PTSD may lead to psychological problems, reduced professional ability, or other personal discomfort. For this reason, reducing the number of stress-related disorders in security workers will save extensive costs and discomfort, both at an individual and a societal level.

To conclude, there is a strong need for security workers to be better trained to cope with crisis situations. Such training should ideally focus on two aspects, namely 1) improvement of the quality of decision making and 2) better regulation of the emotional response to traumatic experiences. The current paper focuses on the second aspect, namely to strengthen the regulation of the emotional (stress) response to traumatic experiences. The reported work is part of a larger project that aims to develop a Virtual Reality (VR) based training environment for professionals that have to act in stressful circumstances. As a first step, this paper presents an experiment by which the impact of virtual training on subjects' future stress responses was investigated, in particular on their subjective experience thereof.

The paper is organised as follows. In Section 2, some background of the research is presented. Next, in Section 3 an experiment is put forward that was used to assess the impact of virtual training on stress response. The results of the experiment are discussed in Section 4. Section 5 concludes the paper with a discussion.

2 Background

In this section some background knowledge is briefly described on training of stress management and on the role of REM sleep in coping with stress.

2.1 Related Work on Stress Management Training

Regarding most existing approaches that aim to increase resilience to stress (e.g., [1, 7]), the current project is innovative in the sense that it tries to increase resilience in the earliest possible stage of development of (traumatic) stress-related disorders such as PTSD, i.e., before any traumatic event has actually occurred. The general picture is that existing approaches to increase resilience to (traumatic) stress can roughly be classified into three categories [3], namely approaches to *treat* PTSD once it has already established, approaches to prevent it from developing just after some traumatic event has occurred (*secondary prevention*), and approaches to prevent it before any traumatic event has occurred (*primary prevention*). Approaches for treatment are available, but these are very costly and not always effective. A similar drawback holds for approaches for secondary prevention, such as debriefing. These methods have been found not to prevent long term PTSD symptoms, and may even have negative effects. For these reasons, primary prevention has recently been proposed as a promising alternative. Although few studies have been performed to evaluate primary preventive techniques, recently some evidence has been found for its effectiveness to increase resilience for military professionals [4].

Note that most existing approaches for primary prevention (such as 'stress inoculation' [14]) still target patients who already suffer from PTSD. In contrast, the proposed training environment mainly targets healthy individuals. The assumption behind this approach is that, by assessing the trainee's mental state, a VR system is able to gradually provide appropriate anxiety-provoking stimuli, thereby training her 'mental readiness' [13]. This approach has proved successful, among others, for airline crew [15], to increase preparation for hostage situations.

2.2 Similarities with REM Sleep

Driven by the goal to develop a virtual environment to train mental readiness, a first research question is whether it is possible at all for such an environment to obtain a learned effect of successfully lowering subjects' stress responses in future situations. A second question is what type of instructions should be given to the trainees in order to obtain a successful learning process. Previous research outside the VR domain (e.g., [11]) suggests that the effectiveness of exposure therapy is partly determined by the specific type of therapy and the task instructions (e.g., related to emotion regulation) that are prescribed to the participant. To investigate these questions, an experiment was performed in which participants' reactions to viewing negative pictures from the IAPS picture [8] set were assessed, and the impact of performing reappraisal-based training in a VR environment was studied.

The setup of this experiment, which is described in the next section, was inspired by an experiment by Helm et al. in the context of REM sleep [5]. According to recent cognitive and neurological literature, there are striking similarities between virtual exposure therapy and dreaming. In particular, the process of dreaming makes use of memory elements and their associated emotions to generate 'virtual simulations', and strengthening of regulation of negative emotions is considered an important purpose of dreaming [9]. For this reason, the idea was to test whether virtual training has a similar effect on emotional responses as is reported in [5]'s experiments about REM sleep. More specifically, in that paper, the experimental design displayed in Figure 1 was used. The authors summarise the experiment as follows:

'34 healthy adults (age: 18-30 years) were randomly assigned to one of two groups. Each performed two repeat fMRI tests (test 1, test 2), separated by 12 hr containing a night of EEG-recorded sleep (sleep group, n=18, ten females) or a waking day (wake group, n=16, nine females). During each test, participants viewed and rated the subjective emotional intensity of 150 standardized affective pictures on a 1-5 scale, corresponding to increasing intensity. Importantly, participants viewed the same stimuli at both test sessions, affording a measure of change in emotional reactivity to previously experienced affective stimuli (test2-test1), following wake or sleep. Participants additionally performed a circadian control test at the second fMRI session, involving presentation of a novel set of affective stimuli. This control test allowed confirmation that behavioral and fMRI differences in reactivity identified following wake and sleep were independent of time of day.' [5], p. 2029.

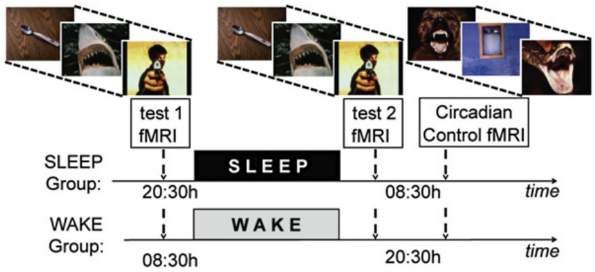

Fig. 1. Experimental Design used in [5].

The results of this experiment showed, among others, that the decrease (between the first and the second test) in subjective emotional ratings of the affective pictures was significantly lower in the sleep group than in the wake group. More specifically, Figure 2 shows both for the sleep group and for the wake group, the relative change in emotional ratings between the first and the second test. For example, the sleep group gave almost 4% fewer 5-ratings (i.e., the highest subjective ratings for emotional intensity) in the second test, whereas the wake group gave a bit more 5-ratings.

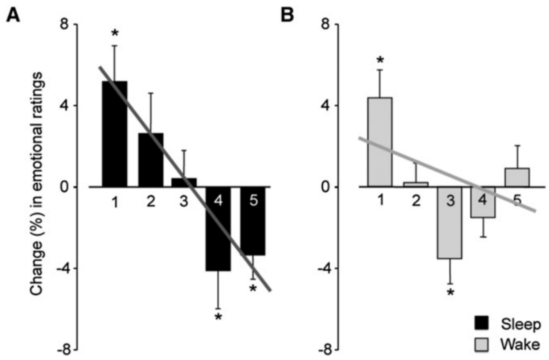

Fig. 2. Relative change in emotional ratings depicted in [5], Fig. 3.

In the next section, our variant of this experiment is described, in which the difference between sleep and wake is replaced by the difference between virtual training and no virtual training.

3 Experimental Design

To study the effect of virtual training on subjective stress response, a variant of the experiment reported in [5] was designed.

Participants

Ten healthy adults (of age between 26 and 32 years, with a mean of 28.2) participated in the experiment, and were randomly assigned to either the 'training' group or the 'no training' group. Three of the participants were female and seven were male.

Setup

The setup of the experiment was similar to the setup used in [5], see also Figure 1. However, the 'sleep' and 'wake' groups were replaced by 'training' and 'no training' groups. Also, no fMRI tests were performed, and no circadian control test was needed (since no sleeping was involved). The participants in the 'no training' group participated in two rounds, separated by a pause of six hours. In these rounds they were presented 5 times 30 pictures from the IAPS picture set [8]. The instances, the order and the duration of the pictures shown were identical to the experiment in [5]. That is, the participants were first shown a black fixation mark for 500ms, after which the image was shown for 2000ms. For 2500ms after the image, a question was shown asking the participants to rate the emotional intensity of the picture on a scale from 1 to 5 (1 being non emotional and 5 being very emotional)[1]. Finally, for another 2700ms a grey fixation mark was shown, followed by the same sequence for the next image and so on. For a total of 150 images, the participants needed approximately 20 to 25 minutes to complete the test. Furthermore, the heart rate and the skin conductance of the participants were measured with the PLUX wireless sensor device (http://www.plux.info/)[2].

The participants in the 'training' group also participated in these rounds, just like the 'no training' group. However, in between these two rounds they performed a virtual training session. This training occurred three hours after the first round and three hours before the second round. The virtual training made use of the same pictures used in the other rounds. However, instead of rating them with a grade the participants were asked to view them while actively reducing their emotional response until they felt comfortable looking at the picture (e.g., by assuring themselves that the pictures were not real). This task was chosen because it is assumed to be representative for the type of virtual training that will be explored in later stages of the project. This type of training will also be focussed on emotion regulation while

[1] Note that this intensity was independent of the 'valence' of the picture (i.e., pos. vs. neg).

[2] The results of these measurements are not further discussed in this paper. They were collected to gain more insight in the relation between the presented stimuli and physiological states, which will be further explored in a follow-up experiment.

processing negative stimuli in a virtual environment (e.g., how to stay calm when a terrorist has just killed your colleague or partner).

Implementation

Both the test and the training environment were implemented using the PsychoPy software (http://www.psychopy.org/). This package provides an API for creating psychological experiments using the programming language Python. In combination with the Python API provided by PLUX, all ingredients for implementing both environments were available. The implementation itself is relatively straightforward, looping through the different images in fixed intervals and recording both the physiological measurements from the PLUX device as well as the manual responses from the participants.

4 Results

The results of the experiment are shown in Figure 3. This figure shows for all 150 pictures (horizontal axis) the absolute change in emotional ratings (averaged over all participants, vertical axis) between the first and the second test, both for the training group and the control group. As can be seen, the curve for the control group is situated around 0 (mean value -0.12), whereas the curve for the training group (mean value -0.60) is much lower. Indeed, a paired t-test confirmed that this difference was significant, with t(149) = 11.96, p<0.001. This indicates that, for this set of participants[3], the training resulted in significantly lower ratings of the images in the second test.

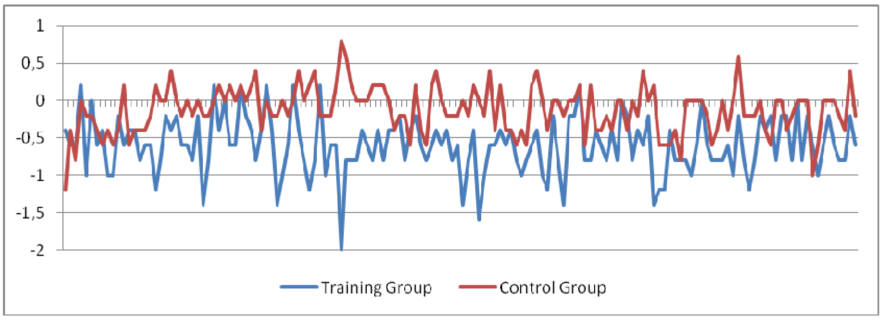

Fig. 3. Absolute change in emotional ratings for the 150 pictures (averaged over all participants).

[3] The current test took, for each of the 150 pictures, the average change in rating given by the participants in the training group, and compared this with the average change in rating given to the same picture by the participants in the control group. Since this way of testing takes the pictures (instead of the participants) as a basis, the results cannot be generalised for the population as a whole. However, an additional (unpaired two sample) t-test has been performed in which for each participant the average change in rating over all 150 pictures was calculated, and these averages were used to compare the training group with the control group. Due to the low number of participants, these results were not statistically significant on the p<0.05 level, but a clear trend was found in the results (with t(8) = 2.05, p=0.07).

In addition, Figure 4 presents the results in a similar manner as shown for the Helm at el. experiment [5] in Figure 2. Hence, this figure shows both for the training group and for the control group, the relative change in emotional ratings between the first and the second test. As can be seen, the results for the control group are very similar to those of the wake group in [5], whereas the results for the training group are similar to those of the sleep group in [5]. The results for the training group are even more extreme (note the different scale on the y-axis): this group gave almost 15% more 1-ratings in the second test, and about 7% fewer 5-ratings.

We also found the overall drop in emotional ratings of the training group to be significant with $t(4) = 1.19$, $p<0.05$. On the other hand, the change in emotional ratings for the control group was not significant ($t(4) = 2.89$, *ns*). This provides strong evidence for the hypothesis that reappraisal-based virtual training can be used to reduce subjects' emotional responses to negative stimuli at later times.

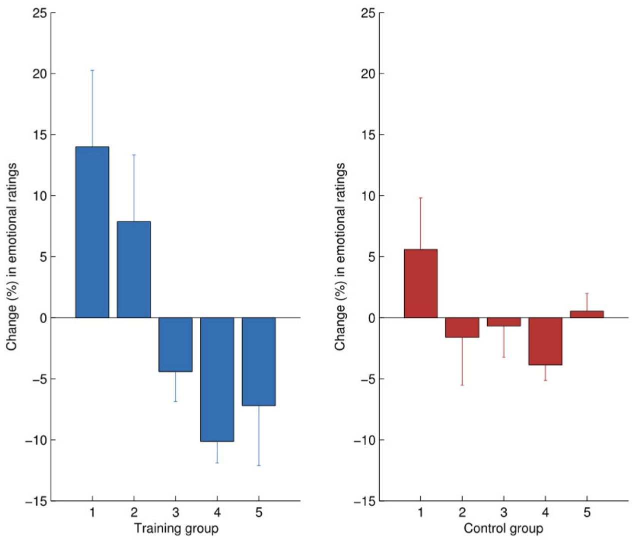

Fig. 4. Relative change in emotional ratings.

5 Discussion

In this paper work has been reported that has been performed to explore the use of Virtual Reality based training for handling stress levels. An experiment was described and conducted to investigate the impact of virtual training on the subjects' experienced stress responses. In the offered virtual training subjects were asked to actively apply reappraisal strategies as a form of emotion regulation when emotion eliciting pictures were shown. The idea is that, by exercising, such types of emotion regulation will provide (as a learned effect) a strengthened emotion regulation mechanism. The results indicate that indeed such a learned effect occurs: after a few hours the subjects participating in the virtual training gave significantly lower ratings for the emotional intensity of pictures shown than subjects in a control group who did not participate in the virtual training.

The experiment was set up similar to the experiment described in [5]. The main difference was that in the latter experiment not the role of virtual training was investigated but the role of sleeping, following hypotheses on the effect of dreaming on fear extinction learning as, for example, discussed in [9]. In comparison it was shown that the effect of the virtual training discussed here was similar but much stronger (up to a factor 2 for the most extreme pictures) than the effect of sleeping in the experiments of [5].

The effectiveness of the virtual training was measured a few hours after the training. It is not known yet to what extent the learned effect as found will still exist after a number of months or even years. In how far the learned effects will show some form of extinction, and how fast or slow this extinction process takes place is subject of further research. To this end, follow-up tests will be done with the subjects taking part in the experiment. If extinction turns out to take place at a certain pace, this may indicate that from time to time the training has to be repeated to maintain the effects.

Another research question that has not been addressed yet is to what extent transfer takes place from virtual training to real or different virtual situations: how context-sensitive are these effects? This is a research question to be addressed in the future.

Further work planned will also take into account larger numbers of subjects, and the use of physiological measures for stress levels. Moreover, it will be explored how the effectiveness of a virtual training may vary depending on certain aspects of the setup of the training and the instructions given. One of the questions addressed is in how far more intense stress levels elicited during the training also lead to a stronger learned effect. As some preliminary work shows this is not a straightforward issue, as too strong elicited stress levels may well lead to a counterproductive effect in the sense that after the training the pictures are experienced as more stressful than before the training. Finally a real virtual training environment will be developed for professionals in the domain of public transportation.

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