Digital EMDR: Using Adaptive Algorithms in Digital Trauma Therapy to Improve Desensitization of Traumatic Memories in University Students

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Abstract

Background: Eye movement desensitization and reprocessing (EMDR) is commonly used in PTSD treatment to degrade traumatic memories by recalling the memory and simultaneously taxing one's working memory (WM). It is unclear how intensely WM should be taxed to maximize desensitization, but evidence points towards a linear dose-response relationship with a ceiling effect. As everyone possesses a unique WM capacity, this ceiling is individual. A digital EMDR application with an algorithm adapting to WM capacity may account for this.

Purpose: The aim of this study was to investigate to what extent digital EMDR using an algorithm adapting to individual WM capacity affects desensitization of traumatic memories. It was hypothesized that individuals receiving digital EMDR with an algorithm will show greater levels of desensitization than individuals who receive no EMDR. Further, individual WM capacity was expected to not correlate with desensitization.

Methods: University students were presented with a disturbing video and were randomly allocated to receive either digital EMDR with the algorithm or no EMDR. Emotionality and vividness (i.e., desensitization), were measured prior to, immediately after, and 24 hours after treatment.

Results: No significant differences in desensitization were found between the two groups. Further, no correlation between individual WM capacity and desensitization was found.

Conclusion: The notion that digital EMDR is effective is not supported by the results. Although the algorithm adapted WM load to individual capacity, the ceiling effect's existence may be questioned, in which case the algorithm may have inhibited desensitization. Digital EMDR without an algorithm may be preferable.

Keywords: EMDR, digital, PTSD, traumatic memories, desensitization, working memory, algorithm, randomized, mixed design

Digital EMDR: Using Adaptive Algorithms in Digital Trauma Therapy to Improve Desensitization of Traumatic Memories in University Students

Post-traumatic stress disorder (PTSD) is a serious psychological condition in which individuals experience flashbacks of a traumatic memory. This disorder can be treated with eye movement desensitization and reprocessing (EMDR), which involves making voluntary eye movements while recalling the aversive memory (Van den Hout & Engelhard, 2012). This treatment is based on the theory that an individual's limited working memory capacity is occupied by both actively recalling the memory and performing the visual task. As a consequence of both tasks competing for the limited capacity, the emotionality and vividness of said memory is weakened (Van den Hout & Engelhard, 2012). Further, there is evidence for a ceiling effect in the relationship between working memory load and effectiveness of EMDR depending on individual working memory capacity (Littel & Van Schie, 2019). The Dutch company Moovd has developed a digital application for taxing the working memory and thus proposes a digital method of administering EMDR. This application includes an algorithm that adapts working memory taxation induced by EMDR to one's individual working memory capacity, and thus to the possible ceiling effect. The aim of this study was to investigate the effect of digital EMDR using this algorithm on memory desensitization.

PTSD and EMDR

After having experienced a traumatic event, the psychological consequences differ from individual to individual. Some are not affected heavily in a psychological sense while others develop post-traumatic stress disorder. Events after which PTSD can develop include natural disasters, serious accidents, and war or combat, and patients commonly experience intrusive thoughts such as flashbacks or nightmares, which make them feel as if they re-live their traumatic experience (American Psychiatric Association [APA], 2013). Thus, patients develop avoidance behaviour to prevent encountering triggers that may lead to recalling the traumatic event (APA, 2013). This behaviour may include avoiding people, places, activities, objects and situations that may trigger stressful memories. Also alterations in cognition, mood and arousal, such as self-doubt, inability to experience happiness, and increased irritability or anger outbursts may occur (APA, 2013). Evidently, PTSD patients are severely impacted in their quality of life. Fortunately, therapeutic treatment offers several effective methods to help PTSD patients.

Several types of treatment exist for PTSD, some of which are used more often than others. Cognitive behavioural therapy and cognitive processing therapy are generally part of

the standard treatment for PTSD, as they focus directly on addressing and changing disruptive patterns of thoughts, feelings and behaviours (APA, 2013). Further, prolonged exposure is usually applied, where patients gradually approach their aversive memories, learning that cues related to their trauma are not dangerous (APA, 2013). In PTSD treatment, eye movement desensitization and reprocessing (EMDR) is an evidence-based method used to weaken traumatic memories. Evidence shows that EMDR can yield effective treatment results. However, this evidence is not as clear as for the standard treatments mentioned above (APA, 2013). Thus it is often, but not always used in addition to the standard procedure. The method was developed by Shapiro (2001) and involves patients recalling the traumatic memory and simultaneously engaging in bilateral stimulation (Van den Hout & Engelhard, 2012). Classically, this stimulation is administered two times a week for 6-12 sessions in total through horizontal eye movements (Shapiro, 2001). Before starting the procedure itself, the therapist prepares the patient by identifying targets for treatment such as past memories, current triggers or future goals (APA, 2013). Further, the patient is familiarized with the eye movements and precautions are taken to ensure a safe environment for the actual procedure. When all is set, the patient is asked to focus on their traumatic memory while engaging in the eye movement stimulation. However, tones or taps have also been explored as alternative methods of stimulation. This is then followed by further evaluations of the procedure and the memory itself. (APA, 2013). In contrast to the treatments mentioned above, EMDR focuses directly on the memory instead of altering related thoughts.

Working Memory Theory

The EMDR procedure is based on the idea that while patients recall the traumatic memory, it is temporarily moved from their long-term memory into their working memory (WM). The patient is then being engaged in an activity that further taxes their WM, for example eye movements, while simultaneously recalling the memory. According to the Working Memory Model by Baddeley and Hitch (1974), our WM consists of two subsystems: the visuospatial sketchpad which stores visuospatial information, and a phonological loop which stores verbal and auditory information. These subsystems, and thus the WM overall, have a limited capacity, which can hence be occupied by both visual and auditory stimuli. This dual-task approach of recalling a memory while experiencing stimulation (e.g., controlled eye movements) in turn has a weakening effect on the intensity of the traumatic memory, as both tasks compete for the limited WM capacity (Van den Hout & Engelhard, 2012). More specifically, the traumatic memory in the WM becomes unstable and is reconsolidated in the

long-term memory afterwards. As attention is not focused solely on the memory during EMDR, but also on the second task, the memory is degraded in the reconsolidation process (Van den Hout & Engelhard, 2012). This degradation of the traumatic memory allows patients to distance themselves from the experienced traumatic event more easily (Landin-Romero et al., 2018). Hence, patients' quality of life can be substantially improved. Although EMDR has proven to be effective and taxing the WM does indeed seem to help with desensitization and reprocessing of traumatic memories, there is still unclarity about which versions of EMDR, or rather which methods of taxing the WM, are most effective.

Taxing the Working Memory

As eye movements are not the only way of taxing the WM, other stimuli such as auditory beeps have been explored. Van den Hout and Engelhard (2012) state that merely listening to the beep would not tax the WM enough to affect traumatic memories. Their study also found that replacing eye movements completely with beeps is ineffective in taxing the WM and would be highly unlikely to have clinical effects. The crucial component here is turning the beeps into an active task, for example requiring a reaction to the stimulus. This is key for measuring WM taxation, as WM load is commonly assessed by measuring the reaction time (RT) to the respective stimulus (Van den Hout & Engelhard, 2012). It is difficult to assess WM load through eye movement alone, as eye movement in EMDR is a continuous stimulus, rather than a momentary one to which one could react. Thus a combination with beeps may be sensible. A study by Van Veen et al. (2019) compared RTs to auditory beeps combined with different eye movement conditions. They found that participants, on average, took longer to press the button after hearing a beep when they moved their eyes, than when having them fixed, unfocused or even closed. This suggests that eye movements indeed help tax the WM and that combining multiple stimuli increases this effect, even if only one of the stimuli is an RT task. Additionally, other tasks that require active participation, such as playing Tetris and mental arithmetic have proven to be effective in occupying the WM (Van den Hout & Engelhard, 2012). However, interval reaction time tasks like beeps and other visual stimuli, combined with eye movements, may offer increased practicality. Being able to slightly adjust, for instance, the time intervals of beeps and the speed of eye movements makes it possible to change the WM load by small, controlled margins. This may be valuable, as there is no consensus yet on how much the WM should be taxed to achieve the best possible clinical effects on traumatic memories.

Optimal Working Memory Load

Earlier research suggests a theory of an inverted U-curve, which suggests an optimal level of WM taxation for effects on traumatic memories. Easy subtraction tasks or simply no dual-task (resulting in fast RTs) showed no or little effect on emotionality, while complex tasks (resulting in slow RTs) did not either (Engelhard et al., 2011). Meanwhile, subtraction tasks of intermediate difficulty affected emotionality of the memory the most. These findings may imply that there seems to be a window of an optimal WM load to achieve the highest effect, hence the image of an inverted U. In this study, this was the case for emotionality, but not vividness, suggesting that taxing WM may not affect both variables equally in individuals (Engelhard et al., 2011). More recent studies found that this relationship between WM load and traumatic memories may be linear. A study by Littel and Van Schie (2019) which also utilized subtraction tasks found indications for a linear dose-response relationship between WM load and the degradation of memories, meaning that the more the WM is taxed, the more the memory is weakened, at least immediately after the experiment. In a follow-up measure one day later, the effect was not as strong (Littel & Van Schie, 2019). Littel and Van Schie (2019) note that this linear relationship may still be skewed to the left or may have a ceiling effect, meaning that for each individual, there is a point where WM taxation is too high, and the memory is not altered anymore. This failure to degrade the memory may be the consequence of the complex task occupying too much space in the WM, which in turn leaves too little room for the memory itself. Indeed, Van Veen et al. (2016) stress the importance of actively recalling the traumatic memory during the procedure, which may be more difficult as the complexity of the task increases. Next to variables such as severity of the traumatic memory or temporary circumstances, which may be difficult to control for, a key component in figuring out a suitable WM load is the fact that each individual has a different WM capacity.

Algorithm Adapting to Individual Working Memory Capacity

Being able to identify each person's unique WM capacity is crucial to finding out at which point that person's WM will get too overloaded to effectively benefit from EMDR. Moovd has developed an application for digital EMDR which introduces an implemented algorithm which is able to adapt to an individual's RT in real time. The average human reaction time lies at approximately 180-200ms for visual stimuli and 140-160ms for auditory stimuli (Jain et al., 2015). For instance, a relatively slow RT will cause the algorithm to slow down the eye movement speed and increase the allowed reaction time interval for the other stimuli slightly, while a fast RT will trigger the algorithm to speed up the eye movements and reduce

the possible reaction time. After some registered RTs, this algorithm would balance out the difficulty of the tasks tailored to the individual, which should make it possible to find a point where the task is neither too easy nor too difficult. Further, Moovd's application found a way to integrate a second visual task next to the eye movement, which requires a response by the individual. Van den Hout and Engelhard (2012) directly compared the WM taxation by eye movements combined with auditory stimuli but faced an issue in having a second visual stimulus, next to the eye movement, to measure RT and thus WM taxation. They argued that a second visual stimulus could not be used, as "people would lose track during the eye movement condition," meaning they would not be able to pay attention to a visual stimulus and react to it, while still following the eye movements. In the digital application developed by Moovd however, a second visual stimulus of a ball occasionally changing into a cylinder requires the participant to react to this change. Additionally, this ball moves, and is thus also the point of fixation for the eyes. Consequently, this makes it possible to have an additional visual stimulus with a reaction response next to the eye movements, instead of only the combination with the auditory beep. Applying these three stimuli with the adaptive algorithm should provide a high enough initial WM load to allow the algorithm to quickly adapt the difficulty of these tasks to the person's RTs to the two response stimuli, and thus their WM capacity.

Aims and Expectations

Investigating the effectiveness of such an algorithm could prove valuable for further evolving EMDR and maximizing treatment effects for PTSD patients. Especially during times of the current COVID-19 pandemic, a digital version of EMDR may find suitable appliance. This effect will be investigated in a sample of university students. Consequently, the following research question is proposed: "To what extent does digital EMDR using an algorithm which adapts reaction time tasks to individual WM capacity affect desensitization of traumatic memories in university students?" It is hypothesized that individuals who receive digital EMDR with an algorithm will show greater levels of desensitization than individuals who receive no EMDR. This is important for establishing that the application including the algorithm is effective in degrading stressful memories. Furthermore, the purpose of the algorithm is to adapt the difficulty of RT tasks (i.e. WM load) to individual WM capacity, and to find an optimal level where tasks are neither too easy nor too difficult. This will account for the possible ceiling effect and should ideally minimize the effect of individual working memory capacity on desensitization. Thus it may be further insightful to investigate whether individuals with lower WM capacity will show greater levels of desensitization due to the linear effect in combination

with the limited WM capacity. As the algorithm is supposed to account for individual differences in WM capacity, a correlation between WM capacity and desensitization should not be the case.

Methods

Design

This study aimed to investigate the effectiveness of the digital EMDR application with an adaptive algorithm by measuring desensitization before and after the intervention. Thus, a 2x3 mixed study design was employed, including a between-participants variable and three within-participants measures. Desensitization was measured prior to, immediately after, and 24 hours after treatment. The independent variable "EMDR" differentiates between the two experimental groups. The control group received no intervention, while the experimental group went through a digital EMDR procedure. This independent variable of receiving EMDR was expected to influence desensitization in the two post-measures.

Participants

Participants were recruited via convenience sampling and through University of Twente's test subject pool SONA. All participants were university students. Prior to data collection, ethical approval was obtained from the Ethics Committee and a power analysis was conducted to specify a suitable sample size. Using the programme G*Power (UCLA, 2021), a sample size of $N = 86$ was determined. This analysis was conducted with following settings: A repeated measures ANOVA, between factors for F-tests; $\eta^2 = .25$; $\alpha = .05$; power = .80; number of groups = 2; number of measurements = 3; correlation among repeated measures = .50. Exclusion criteria for taking part in this study were the following: being younger than 18 years old; having impaired vision or hearing; currently using benzodiazepines, antidepressants, antipsychotics, or mood stabilizers; being diagnosed with bipolar disorder, major depression, PTSD, psychosis, or autism spectrum disorder; having had EMDR treatment less than three years ago and/or more than ten sessions; and having consumed alcohol or other drugs 12 hours prior to the experiment.

Over four weeks, 56 participants were recruited. Thirteen participants had to be excluded, four of them due to technical difficulties. The other nine were not randomized into the two experimental groups, as they showed too low levels of disturbance after watching a stressful video, which will be described further below. Thus, 43 participants were randomly assigned to the two groups and were included in the final analyses, 21 in the control condition

and 22 in the experimental condition. Ages ranged from 18 to 39 ($M = 22$; $SD = 3.30$). Twenty-one participants were male and 22 were female. Furthermore, 30 participants were German, seven Dutch and six were of a different nationality. Regarding education, 32 participants had obtained a high school degree or equivalent, nine had a bachelor's degree and two a master's degree. For the continuous variable age, an independent *t*-test showed no significant differences between the experimental and control group. For the categorical variables gender, nationality and education, a chi-square test of independence revealed no significant differences either. Table 1 displays the participant characteristics and significance levels.

Table 1

Participant characteristics and p-values for differences between the two groups.

	Experiment	Control	
	N		p^a
Age	22	21	.09
Gender			
Male	10	11	.65
Female	12	10	
Nationality			
German	15	15	.94
Dutch	4	3	
Other	3	3	
Education			
High school / equivalent	14	18	.18
Bachelor's degree	6	3	
Master's degree	0	2	

[a] *P*-values of continuous outcomes based on independent *t*-test. *P*-values of categorical outcomes based on Pearson chi-square test.

Materials

Devices and Questionnaires

As the study was conducted online, participants were required to use their personal mobile phone and laptop or PC. The screening questionnaire asked participants to confirm that they do not meet any of the aforementioned exclusion criteria. Further, the questionnaire included demographics, namely age, gender, nationality, and education level. It also included

necessary materials and instructions (see Appendix A), which will be elaborated on below. In addition, a follow-up questionnaire containing post-measures and debriefing (see Appendix B) was sent to participants 24 hours after the experiment.

Trauma Film and Debriefing

To simulate the experience of a traumatic event, a disturbing film excerpt was used to induce distressing memories. This method is based on the trauma film paradigm (James et al., 2016). Several other studies have used the trauma film paradigm in EMDR research (Nixon et al., 2009; Van Schie et al., 2019). The selected two-minute film clip from the French film "Irréversible" (Noé, 2002) depicts a man brutally and repeatedly assaulting another man with a fire extinguisher. The scene is expected to evoke strong negative emotions and intrusive memories and has been used in other research (Cuperus et al., 2017). To let the stressful memory sink in, calm, classical music was used as a 5-minute filler task for participants to listen to shortly after having watched the film scene. In the debriefing of the follow-up questionnaire mentioned above, a short behind-the-scenes clip was provided, where it is explained how the brutal film scene was shot using special effects. Lastly, the debriefing included a guided meditation video (The Honest Guys – Meditations – Relaxation, 2015) to give participants the option to further relieve potential tension.

Emotionality and Vividness

To test the effects of digital EMDR treatment on desensitization, two scales were used. The subjective unit of disturbance (SUD) scale, first introduced by Wolpe (1969), is frequently used to measure perceived intensity of disturbance or distress, or emotionality, induced by recalling a negative emotional memory or image. Disturbance is indicated on an 11-point Likert scale from 0 (no distress at all) to 10 (maximum distress). The question is formulated as follows: "Thinking about the video clip, how unpleasant does it feel or how much distress do you feel, estimated on a scale from 0, no distress at all, to 10, maximum distress?" The SUD scale is often used in research about EMDR and is part of the standard EMDR treatment protocol (Shapiro, 2018). Similar to Matthijsen et al. (2021), participants who, after watching the stressful film clip, had a score of 5.5 or lower on the SUD scale immediately discontinued the experiment and were not randomized to the control or experimental group. As they did not seem to show prominent signs of disturbance in the first place, EMDR treatment would not have contributed much to desensitization. In this presented study, this was the case for nine participants. Further, an additional 11-point Likert scale was used to measure vividness of the

memory, which also ranged from 0 (not vivid at all) to 10 (very vivid). The question was worded as follows: “And how vividly can you picture the video clip, estimated on a scale from 0 "not vivid at all," to 10, "very vivid"?” A measure of vividness is frequently used in EMDR-related research (Matthijsen et al., 2021; Van den Hout & Engelhard, 2012). These two scales were used thrice, once after the 5-minute filler task after watching the stressful video, once after the digital EMDR intervention and one last time in the follow-up 24 hours after the experiment.

Digital EMDR Application

The digital EMDR application including the adaptive algorithm was developed by the Dutch company Moovd (n.d.). To use the application, the participant had to be connected to the researcher via a session code. Once the connection was established, the participant saw an empty apartment and two buttons on their screen, one on each side (see Appendix C). The researcher could now choose from a variation of stimuli presentable to the participant. In this study’s case, pre-programmed combinations were prepared, which only required one button press from the researcher to start the desired task. For example, the participant would see a grey ball moving around randomly in the apartment, while occasionally changing its shape into a cylinder (see Appendix C). This change into the cylinder was the visual stimulus that required a reaction from the participant. Meanwhile for the auditory stimulus, the participant would hear a drumming sound which gradually changed into a higher pitch. While following the ball with their eyes, the participant had to press the respective button as quickly as possible when presented with the visual or auditory stimulus. If the participant did not react to the stimulus within a certain time frame, the cylinder or the drumming sound would reset. This is where the adaptive algorithm came into play. Based on the participant’s RT, the allowed time interval for a button response changed, in addition to the movement speed of the ball. This means that if the participant reacted relatively quickly to a stimulus, the ball’s movement speed increased and the possible reaction interval for the cylinder and drumming sound decreased. The opposite applied when the participant reacts relatively slowly. The exact parameters of this algorithm are intellectual property of Moovd. For more information, it is possible to contact them via https://moovd.nl.

Procedure

Participants signed up for the study via SONA and an online meeting was scheduled. They received an email with a Zoom link and a link to the screening questionnaire and the further questionnaire in Qualtrics (see Appendix A). Before the session, each participant was

informed that they should connect to Zoom on their laptop or PC and should have their charged smartphone at hand for the study procedure. After the researcher and the participant had shortly introduced themselves, the researcher followed a verbal protocol (see Appendix D) to assure standardized treatment between participants. The researcher informed the participant about this and gave a brief summary of the study and content of the session. Subsequently, the researcher checked that the participant was connected to Zoom with their computer and had their smartphone ready to use, as this was necessary to access the digital EMDR environment. The participant was further asked whether their phone was charged sufficiently and whether they found themselves in a calm, non-distracting environment. The participant was then instructed to open the online questionnaire via the link in their sign-up email and to follow it until they had to enter a code. They went through the informed consent, were asked to agree and to confirm that they did not meet any of the listed exclusion criteria. Afterwards, they were verbally provided with the code needed to continue the questionnaire. This was done to prevent participants from going through the questionnaire prior to the scheduled online session. Subsequently, the participant was instructed to continue in the questionnaire where they were asked demographic questions.

As soon as the participant had reached the QR code in the questionnaire, they were asked to verbally notify the researcher. The participant scanned the QR code with their smartphone camera and were directed to the digital EMDR website in their browser (https://research.ut.digital-emdr.com). They were then asked to select the role of client, to scroll down in the agreement and to accept it. Afterwards, they were instructed to rotate their phone and to hold it horizontally. Then, it was explained to the participant that the left button would be used for the auditory stimulus, while the right button belonged to the visual stimulus. It was clarified that the participant should press the respective button as soon as possible when they would hear the pitch-changing drumming sound or would see the ball change its shape into the cylinder. It was also specified that as soon as they pressed the correct button, the sound would immediately stop, and the cylinder would immediately change back into the ball. Additionally, it was mentioned that the ball may also move around during the task.

The participant was then asked to start the session and to provide the researcher with their session ID, so the connection could be established. The participant was reminded to turn up their phone volume so they could hear the sound, and to press the respective buttons as quickly as possible after the stimulus. Subsequently, they went through a short practice phase to get acquainted with the tasks. This included a 30-second set for only the visual stimulus and a 30-second set for only the auditory stimulus. There was no practice phase for the combined

stimuli with eye movements. During each of these 30-second periods, the participant was presented with approximately 15 stimuli. To ensure that the app worked correctly on the participant's smartphone, they were asked whether they could indeed see the ball change and hear the sound.

The participant then continued in the online questionnaire, until they had reached the stressful video. Before letting the participant start the video, the researcher clarified that the participant should imagine that they are a bystander at the depicted scene and should keep their attention on it without looking away. The researcher instructed the participant to start watching in full screen and then turned off their camera to let the participant fully immerse themselves in the scene. While the video was playing, the researcher observed the participant and would discontinue the experiment, should the participant show too strong signs of disturbance such as crying. After the video, the participant was given a 5-minute filler task during which they had to listen to classical music to let the memory sink in. After this task, the participant was asked to recall their memory of the video clip and rate it from 0 to 10 on the disturbance/emotionality and vividness scales. In case the participant indicated a score of 5.5 or lower on the SUD scale, the study was discontinued at this point, as the video did not seem to have enough of a stressful effect on the participant. Otherwise, the participant continued in the questionnaire. At this point, participants were randomly assigned number 0 or 1 in the Qualtrics questionnaire, which separated them into control and experimental groups. The verbal procedure for both groups was similar. The only difference was that the control group did not receive a dual task.

The participant then reconnected to the digital EMDR application with a QR code and the session ID. They were asked to select the most distressing moment of the video in their memory and to pause it, so it would become an image. They then stated which image evoked the most distress for them and where in their body they felt it most strongly. In the control group, the participant was instructed to keep their eyes open and look at the phone screen. Meanwhile in the experimental group, the researcher mentioned that they were about to start the task in the application. The researcher then started the first of 12 30-second sets. In the control group, the participant looked at the empty apartment on the screen and only recalled the memory without performing a secondary task. In the experimental group, the participant was presented with the moving ball, the visual task of the changing ball and the auditory task of the drumming sound. During these sets, the adaptive algorithm adjusted the ball's speed and the allowed reaction time interval for the visual and auditory task to the participant's reaction times. In both groups after each 30-second set, the researcher asked the participant what was going through their mind. If the participant mentioned something related to the video, they were asked

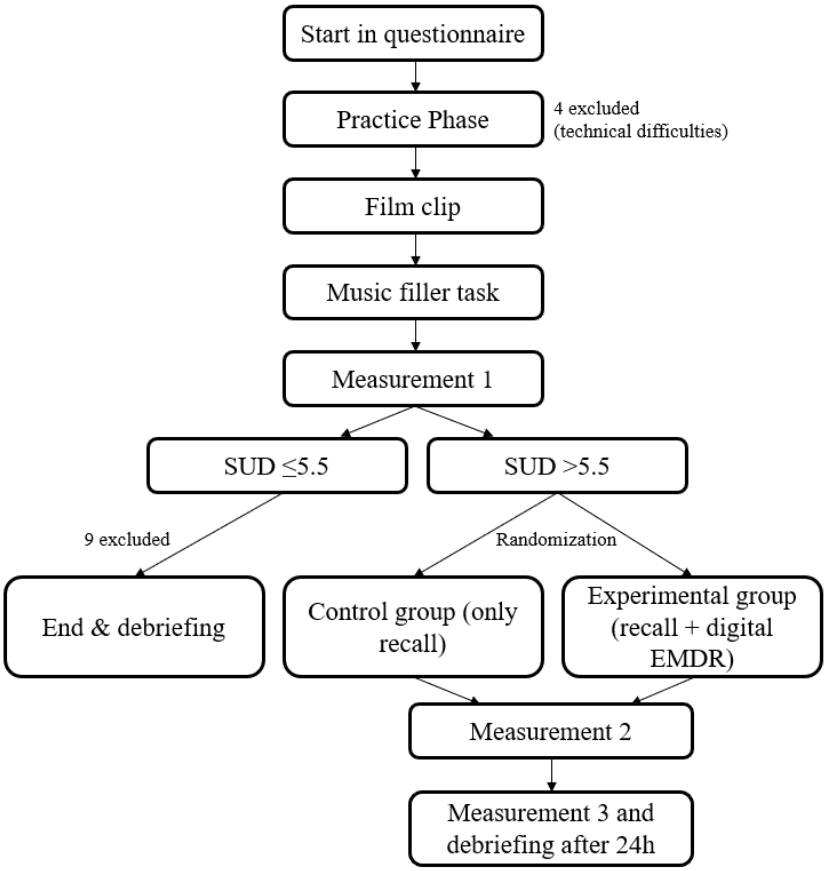
to focus further on that. If they mentioned something unrelated, they were reminded to think back to the most disturbing image. Afterwards, the researcher started the next set. This was repeated eleven times, amounting to 12 sets in total.

The participant then continued further in the questionnaire. They were asked to rate their disturbance/emotionality and vividness on the two 11-point Likert scales. Upon reaching the end of the questionnaire, the participant was informed that they would receive a follow-up questionnaire after 24 hours and that they may reach out to a psychological professional provided by the research team, if they felt the need. The video conference was then concluded.

As mentioned above, the participant received the follow-up questionnaire via email 24 hours after the online session, which they were required to fill out before the end of the day. As a second post-measurement, the participant once again rated their disturbance/emotionality and vividness of the stressful memories on the respective scales. Further, they responded to the four other follow-up questions about lasting experiences in relation to the memory. Subsequently, the participant was debriefed and was once again provided with a professional psychologist's contact details. In case participants in the control group wished to receive digital EMDR treatment as well, they were invited to contact the researchers. To further relieve potential tension, participants were given the option to watch the behind-the-scenes clip for the stressful video, as well as a short, guided meditation exercise. This concluded the end of the follow-up questionnaire and thus the study procedure. Figure 1 visualizes the main parts of the procedure and at which points participants were excluded.

Figure 1

Flowchart of study procedure



Data Analyses

All statistical measures were performed in SPSS. As mentioned above, 13 participants were excluded, leaving 43 for the analysis. For the hypothesis that individuals who receive digital EMDR with an algorithm will show greater levels of desensitization than individuals who receive no EMDR, a two-way ANOVA with repeated measures was applied. The assumptions of homoscedasticity and independence were met. The assumption of normality was only not met for the third vividness measure in the experimental group. As the two-way ANOVA is considered robust to violations of normality, it can be tolerated in this case. The ANOVA was performed separately for both emotionality and vividness measures, which together indicate desensitization of the memory. Moreover, effect sizes were calculated. Additionally, it was explored whether the algorithm achieved its purpose of adjusting for WM capacity. With the algorithm, individuals with lower WM capacity should not show greater levels of desensitization due to the linear effect in combination with limited WM capacity. As the algorithm adapts the allowed reaction time intervals to the individual's RTs, the number of

recorded reactions should be an indicator of an individual's WM capacity. To showcase whether this succeeded, descriptive statistics were computed for the number of recorded responses. Due to the algorithm slowing the tasks down when a slow response is recorded, individuals with less recorded RTs would thus have a lower WM capacity than individuals with more recorded RTs within the 12 30-second sets. As the algorithm's purpose is to account for individual differences in WM capacity and thus the possible ceiling effect, there should be no correlation between the number of recorded reactions and desensitization. Thus, an exploratory correlational analysis using bootstrapping was performed. 95% confidence intervals, bias-corrected and accelerated, were computed using 1,000 bootstrap samples. Lastly, it was explored whether a curvilinear relationship may exist between the number of recorded reactions and desensitization.

Results

Regarding the hypothesis that individuals who receive digital EMDR with an algorithm will show greater levels of desensitization than individuals who receive no EMDR, a two-way repeated measures ANOVA was applied. Table 2 shows mean scores of both emotionality and vividness across all three measurements between the two groups. Figures 2 and 3 illustrate the changes in memory emotionality and vividness over the three measurements. One can observe that emotionality and vividness mean scores of the EMDR group were slightly lower than those of the control group on the second measurement, but not on the third. Additionally, changes in measurements over time were substantial and comparable in both groups. When looking at emotionality, there was a significant main effect for the time factor, $F(2, 82) = 102.66$, $p < .01$, $\eta_p^2 = .71$, but there was no significant main effect for condition, $F(1, 41) = .022$, $p = .88$, $\eta_p^2 < .01$. The interaction effect between time and condition was also non-significant, $F(2, 82) = .70$, $p = .50$, $\eta_p^2 = .02$. Regarding vividness, there was also a significant main effect for time, $F(2, 82) = 120.31$, $p < .01$, $\eta_p^2 = .64$, but no significant effect for condition, $F(1, 41) = .10$, $p = .75$, $\eta_p^2 < .01$. The interaction effect between time and condition was non-significant for vividness as well, $F(2, 82) = .10$, $p = .90$, $\eta_p^2 < .01$. Overall, there was a significant decrease in both emotionality and vividness across the three measurements, as the time effect indicates. However, the crucial interaction effect between time and condition was non-significant for both emotionality and vividness, as displayed in Table 2. This indicates that there were no significant differences in desensitization between the group who received digital EMDR with an algorithm and the group who received no EMDR.

Table 2

Mean scores (SD) of emotionality and vividness across measurements between the two groups (recall + EMDR; recall only); and interaction effects between time and condition.

	Experiment	Control		
	M (SD)	*M (SD)*	*F (df)*	*p*
Emotionality			.70 (2, 82)	.50
Measurement 1	7.95 (0.84)	7.71 (1.31)		
Measurement 2	5.59 (1.82)	6.00 (1.76)		
Measurement 3	3.86 (1.70)	3.86 (1.91)		
Vividness			.10 (2, 82)	.90
Measurement 1	8.00 (1.48)	8.14 (1.32)		
Measurement 2	5.96 (2.19)	6.24 (2.02)		
Measurement 3	4.73 (2.07)	4.76 (2.02)		

Figure 2

Change of emotionality mean scores across three measurements between the two groups

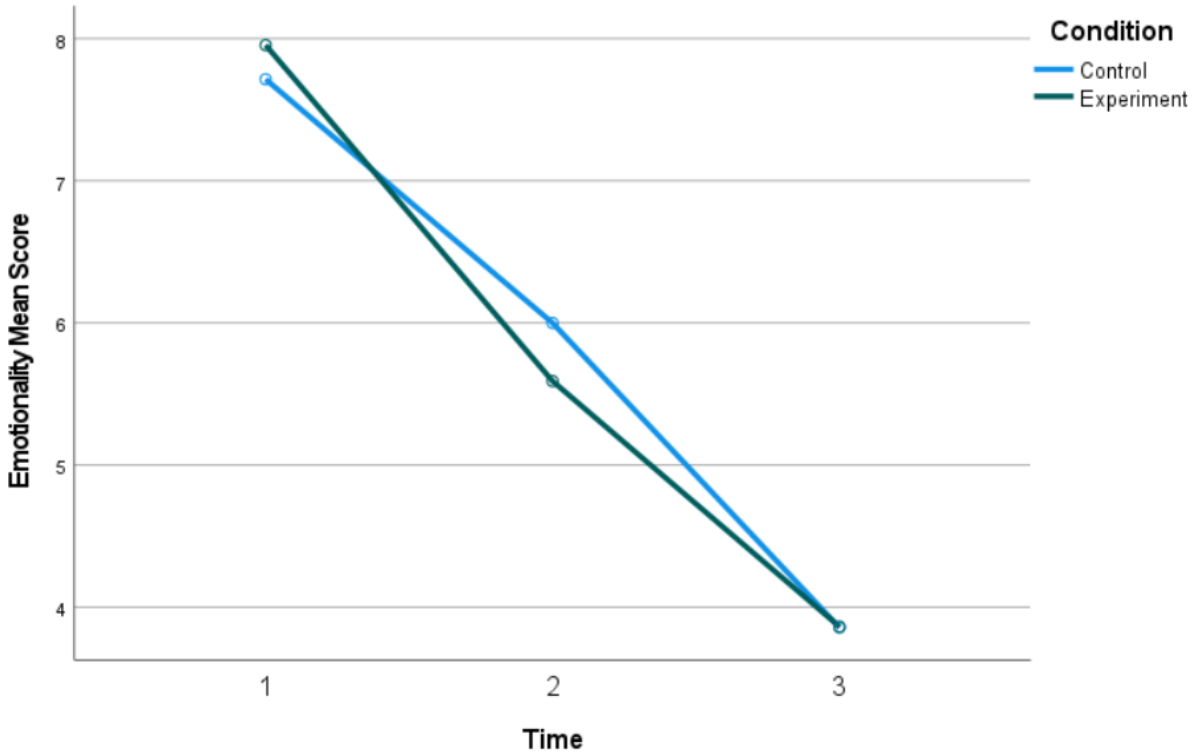
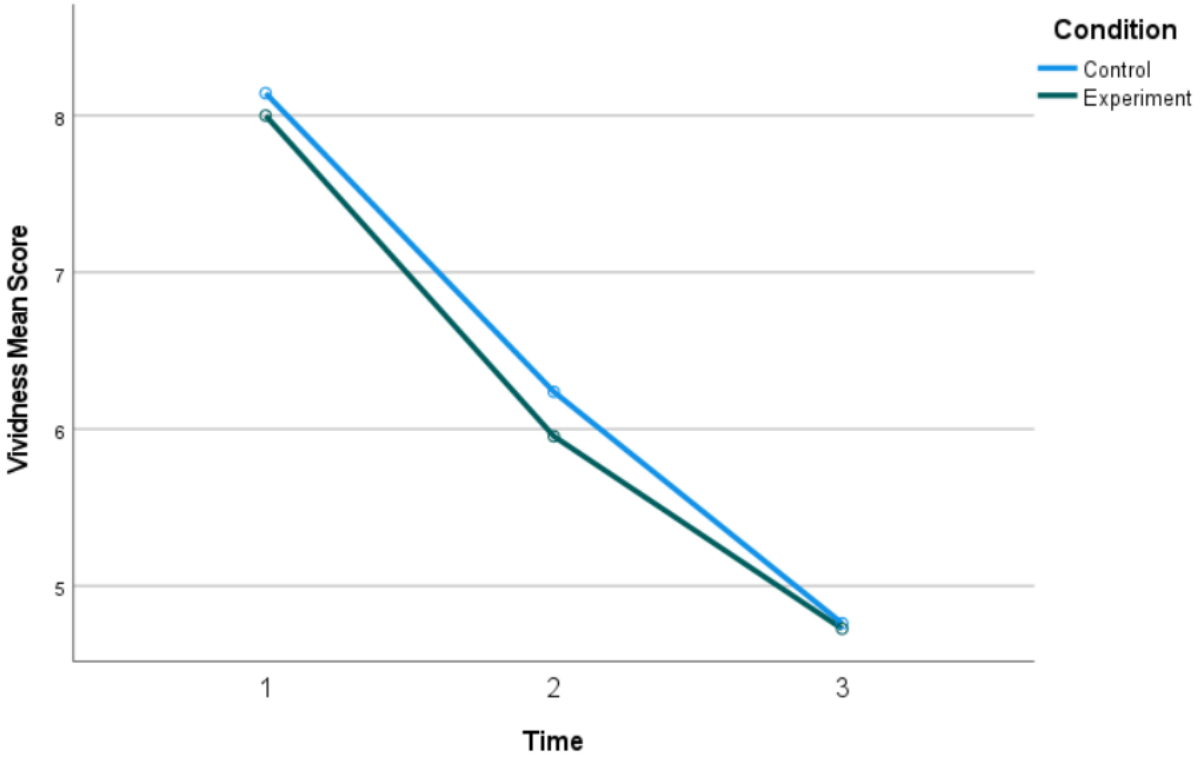


Figure 3

Change of vividness mean scores across three measurements between the two groups



The number of recorded reactions ranged from 125 to 344 (M = 268.60; SD = 50.02) among participants in the experimental group. Figure 4 displays the distribution of recorded responses. For the correlation between the number of recorded reactions and desensitization, bias-corrected and accelerated 95% confidence intervals were computed using 1,000 bootstrap samples. As presented in Table 3, correlations between the number of recorded reactions and post-measures of emotionality and vividness were low. Further, the bootstrapped confidence intervals were overall large and included zero. Most importantly, all computed correlations were non-significant. As there did not appear to be a linear relationship, a possible curvilinear relationship was inspected additionally. Figures 5, 6, 7 and 8 display both linear and quadratic curves in scatter plots. One can observe that there are curved lines for the third measure on emotionality and the second measure on vividness. However, these quadratic relations were also non-significant. This suggests no correlation between the number of recorded responses and desensitization, which is in line with the exploratory assumption.

Figure 4

Distribution of number of recorded responses among participants of the experimental group

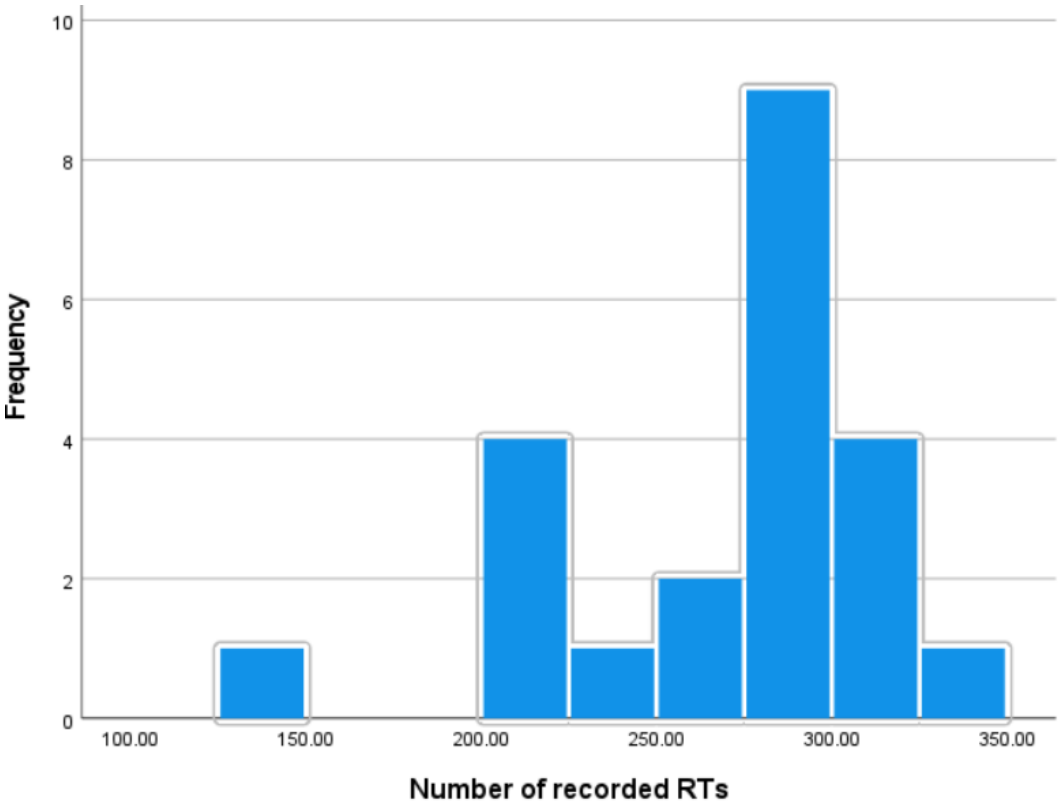


Table 3

Pearson correlation, significance, and confidence intervals for number of recorded responses and post-measures on emotionality and vividness.

	Number of recorded reactions			
	r	*p*	CI lower bound	CI upper bound
Emotionality 2	-.05	.83	-.41	.34
Emotionality 3	-.28	.21	-.69	.35
Vividness 2	.07	.76	-.27	.36
Vividness 3	-.04	.85	-.43	.42

Note. Sample only includes the experimental group of 22 participants. The 95% confidence intervals were bias-corrected and accelerated and computed using 1,000 bootstrap samples.

Figure 5

Curvilinear relation between number of recorded responses and second emotionality measure

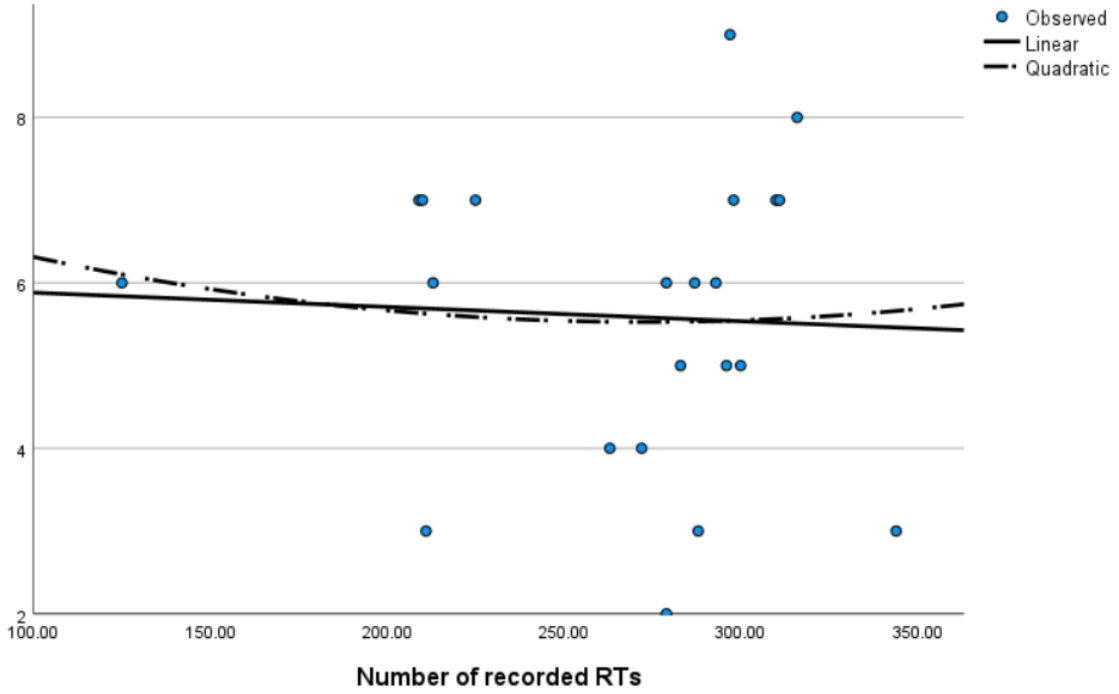


Figure 6

Curvilinear relation between number of recorded responses and third emotionality measure

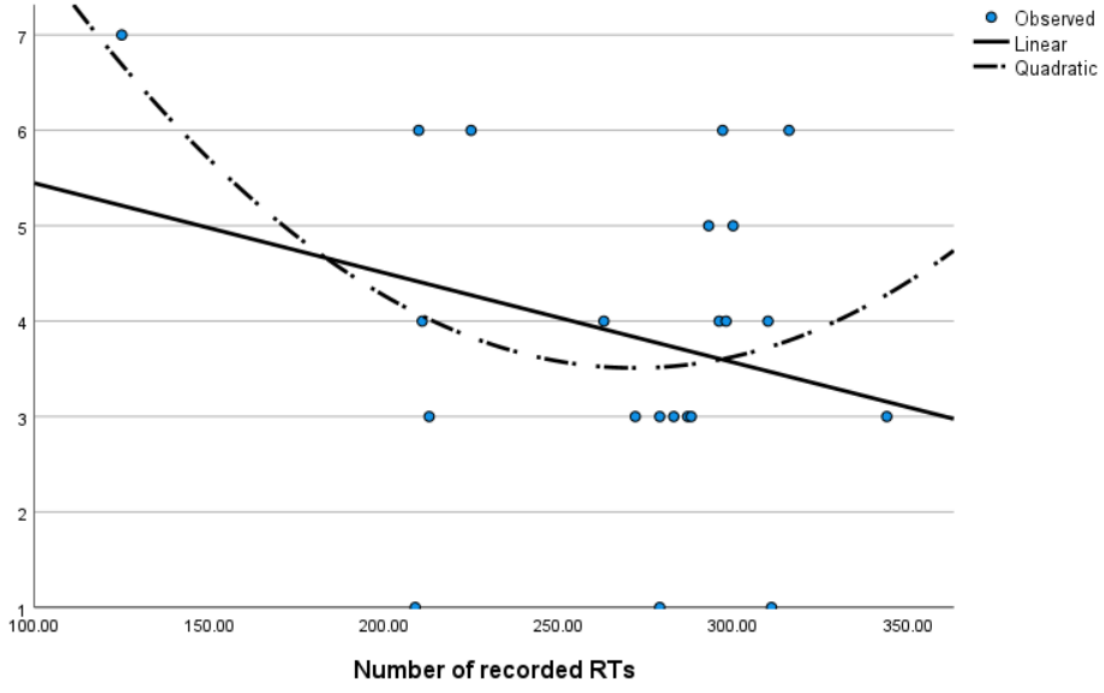


Figure 7

Curvilinear relation between number of recorded responses and second vividness measure

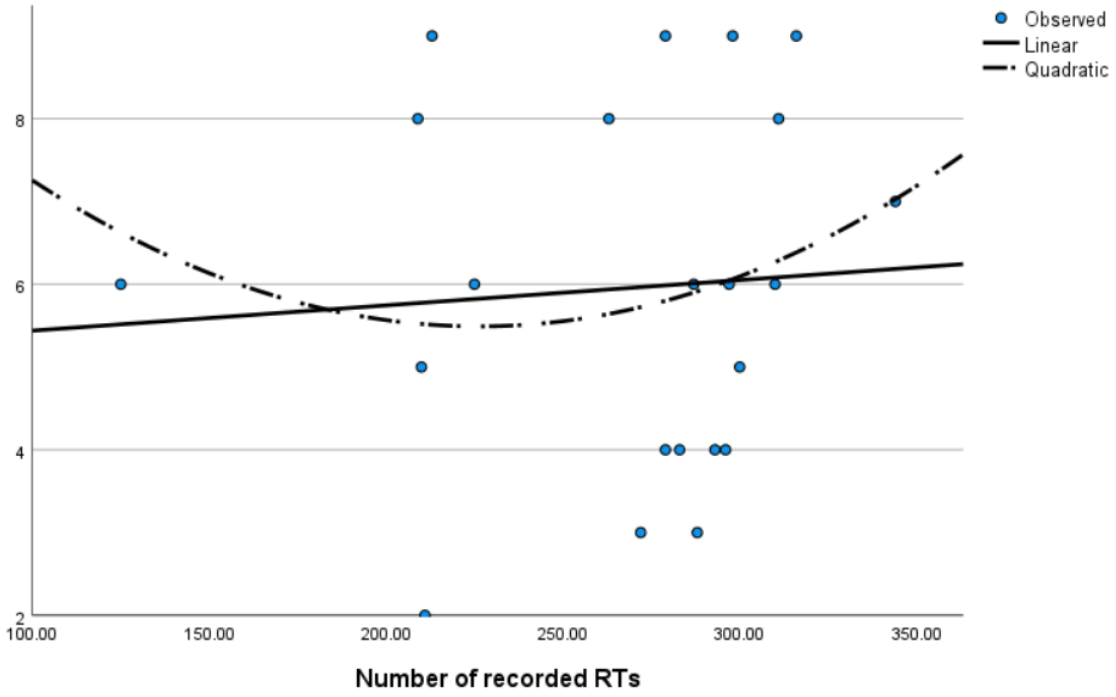
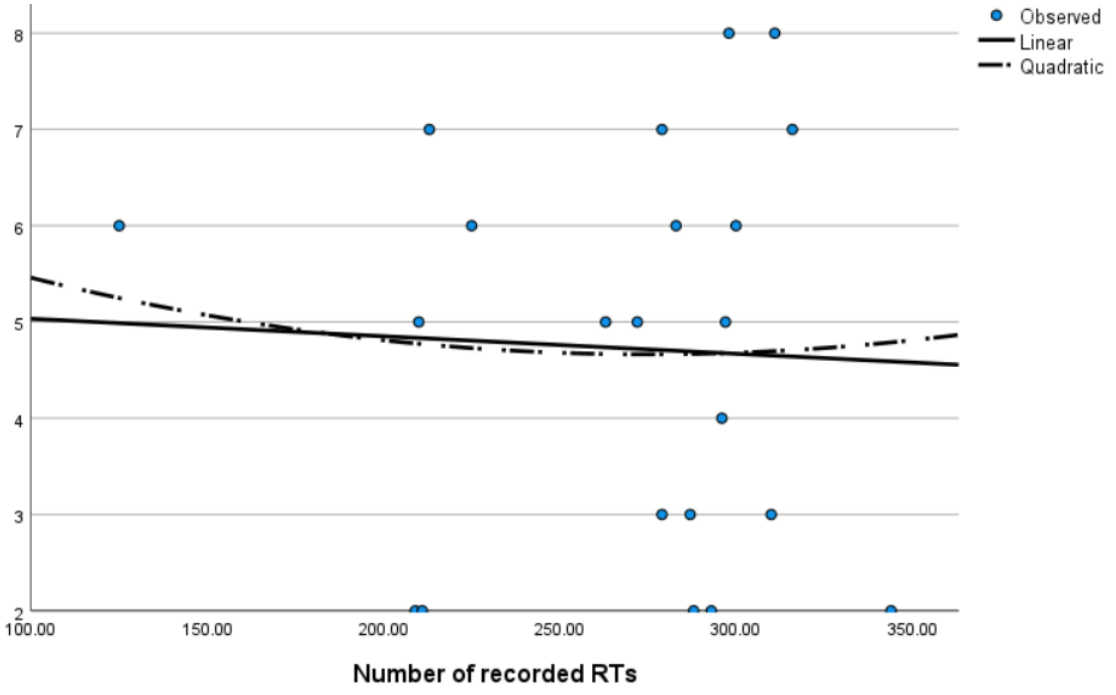


Figure 8

Curvilinear relation between number of recorded responses and third vividness measure



Discussion

Summary and Implications

The purpose of this research was to examine whether digital EMDR using an algorithm adapting to individual working memory capacity would increase desensitization of traumatic memories. Contrary to the hypothesis, no significant differences in both emotionality and vividness measures were found between the two groups. Thus it can be inferred that both the group receiving digital EMDR and the group only recalling the stressful memory had similar experiences concerning desensitization. However, in the present study, both emotionality and vividness considerably decreased from the pre-measurement over the post- and follow-up measurement. The memory of the trauma film faded relatively quickly over time in both groups, without the digital EMDR having an influence. Thus, this research provides neither additional validity for digital EMDR, nor for combining it with an adaptive algorithm in clinical appliance. This is contradictory to the findings of Van den Hout and Engelhard (2012) and the practice of EMDR in general. In the present study, EMDR did not make a difference in desensitization, despite there being strong signs of desensitization overall.

Nevertheless, it can be concluded that the adaptive algorithm did indeed work, as participants in the experimental group did have varying numbers of recorded reaction responses, ranging from 125 to 344 responses within the 12 30-second sets. This occurred while using auditory cues as suggested by Van Veen et al. (2019). As expected, no correlation between this number of recorded responses and desensitization, i.e. emotionality and vividness, was found. This represents that participants of the experimental group did not experience differing levels of desensitization in correlation with their individual working memory capacity. While the algorithm may have successfully adapted working memory load to individual capacity, it cannot be inferred that it diminished differences in desensitization between individuals, as the EMDR procedure did not have an effect. Based purely on the absence of a correlation between number of recorded responses and desensitization, the optimal working memory load as a possible ceiling effect suggested by Littel and Van Schie (2019) may have been achieved by applying the adaptive algorithm. These findings should however be viewed critically and as exploratory due to the small sample size of the experimental group in this analysis, even with bootstrapping performed.

On the one hand, the present findings may indicate that interval reaction time tasks, in form of an adaptive algorithm in this case, did seem useful in finetuning working memory taxation and adapting to the ceiling effect. It could be an improvement to conventional methods of taxing working memory in EMDR, as presented by Van den Hout and Engelhard (2012) and

Van den Hout and Smeets (2011). On the other hand, the relationship between working memory taxation and desensitization may be strictly linear, as first hypothesized by Littel and Van Schie (2019), and the suspected ceiling effect may not exist. This would mean that too much working memory taxation would not be an issue for the limited capacity and would always be desirable for increasing desensitization. It may be possible that in the present study, the algorithm dampened the taxation by the visual and auditory stimuli, which successfully desensitized in previous studies (Van Veen et al., 2019). If the ceiling effect is non-existent, the algorithm may have prevented taxation from being high enough to desensitize the memory.

Overall, the presented findings reflect that while an adaptive algorithm may diminish differences in desensitization between individuals due to working memory capacity, digital EMDR using this algorithm may not induce additional desensitization as compared to only recalling the stressful memory. The passing time was predominantly responsible for desensitization for both groups in this study. In several other studies, only either emotionality or vividness were significantly reduced by EMDR (Cuperus et al., 2016; Littel & Van Schie, 2019). It is unclear why this is the case. Perhaps, a similar factor prevented the desensitization of both emotionality and vividness in the present study. It may be the case that digital EMDR without an adaptive algorithm is more effective in desensitizing memories. After all, specifically digital, remote EMDR finds itself with a small body of research, which may have led this study to have some flaws.

Limitations

The present research had certain limitations which may undermine its validity. As mentioned above, significant desensitization over time also occurred in the group not receiving digital EMDR treatment. This poses the question to what extent the selected trauma film induces intrusive memories comparable to those of PTSD patients. Of course this simulation is not to be held to the same standard as treating clinical patients with EMDR, but the memories of the presented film clip seem to have faded quickly in participants, even without EMDR. The selected film clip has been used and has proven to be effective in inducing stressful memories in other studies however (Cuperus et al., 2017). This may point out several complications with this study's experiment environment. As this was an online study, participants watched the film clip in their own home, so several factors could not be controlled for. This is equally applicable for the digital EMDR treatment. Outside noises, notifications on participants' mobile phones and other distractions may have disrupted a flawless and standardized procedure. In such a remote study, it may be the case that there are factors other than working memory influencing

desensitization, which are different than in an in-person EMDR procedure. Working memory taxation is conventionally measured through reaction times (Van den Hout & Engelhard, 2012), which is not possible with an adaptive algorithm, as reaction times are consequentially not standardized. Therefore, it may be necessary to measure working memory load using physical symptoms such as heart rate (Cranford et al., 2014). Furthermore, the studied population of university students presumably consisted mostly of individuals with rather high working memory capacity. Thus, it could be questioned to what extent the adaptive algorithm aided in diminishing individual differences in desensitization. With a more heterogeneous sample with a larger age range for example, the capabilities of the algorithm could have been put to the test to a greater extent. Overall, a larger sample size may have been beneficial, especially for the exploratory correlational analysis, as it only included participants of the experimental group.

Future Research

This leads over to what future research may improve on and could explore additionally. Firstly, one could focus on comparing standard EMDR to digital EMDR and digital EMDR using the adaptive algorithm to investigate how desensitization differs between these three conditions. As standard EMDR is evidently effective in desensitizing traumatic memories, this approach may be worthwhile to explore whether the present study's findings of a non-significant effect are due to the innovative digital aspect. Measuring working memory taxation with heart rate would also make it possible to compare taxation through normal EMDR with EMDR using the algorithm. Additionally, such a study with more experimental groups could showcase more clearly what the adaptive algorithm adds to standard and digital EMDR. This would also help with exploring the prevailing unclarity about the ceiling effect in working memory capacity more explicitly. A study like this should preferably be conducted in a laboratory with controlled environment.

Conclusion

Despite its limitations, this study can be seen as an expansion of knowledge about the small body of research about digital EMDR. While it may not have been proven with this study, digital methods of EMDR, in theory, offer much more possibilities for precise adaptations to individual needs. Finetuning working memory load and being able to analyse the recorded data has the capability to significantly contribute to EMDR-related research progress. Be it with or without adaptive algorithms, digital EMDR possesses great potential for expanding knowledge and maximizing treatment benefits for PTSD patients. Overall, this study may serve as an

impulse to conduct further research about digital therapy methods and how digital, adaptive manipulation can be used to influence how patients react to such treatments. Especially in the digital age, available resources should be utilized to their full extent to develop more efficient methods of therapy and in turn increase patients' psychological benefits.

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Appendix

Appendix A

Questionnaire

Introduction:
Dear participant,
We would like to invite you to take part in our online study, which will take you around 30 minutes to complete. Please note that you need a laptop/PC and a mobile phone to participate.
Before you decide to participate, please read the following information carefully.
Eye movement desensitization and reprocessing (EMDR) is an evidence-based therapy often used to treat post-traumatic stress disorder (PTSD). Our research aims to investigate the effectivity and efficacy of a digital EMDR application (developed by Moovd; www.moovd.nl). We aim to find out how different combinations of sensory information (visual and auditory stimuli) differ in levels of working memory taxation, which will be assessed through reaction time tasks. Using this application, we want to research if taxing the working memory, using different combinations of sensory information, can reduce the emotionality and vividness of memories after watching a shocking film scene.
During the study, you are asked to fill out questionnaires and engage in an online experiment, where you will watch a short shocking film that is used to elicit stressful memories. Then, you will be either assigned to a control group or the experimental group engaging in a digital EMDR intervention to desensitise your stressful memory. After 24 hours, a follow-up measure is planned via email. You will need to fill in a short questionnaire about the experiment. Additionally, we will provide you with detailed information about the film and a mindfulness breathing exercise to relieve tension. Before and after finishing the experiment, you will receive contact details of a licensed clinical psychologist whom you can contact in case you would like to talk about this experience or have troubles of any kind.
During the study, you are exposed to a short excerpt of a shocking film depicting a man assaulting another man violently. You are asked to recall the most disturbing scene. Risks you may be exposed to include psychological stress and physical discomfort. In the short-term, you might be reminded of a similar experience (i.e., flashbacks) or experience general discomfort. In the long-term, anxiety, intrusive thoughts and feelings, flashbacks to the films, or difficulties sleeping (i.e., nightmares) might emerge. The research has been reviewed and approved by the BMS Ethics Committee. Your participation is voluntary, and you can withdraw from the study at any time without any reason.
You are NOT allowed to participate if you:
Are younger than 18 years old.
Have impaired vision or hearing.
Currently use benzodiazepines, antidepressants, antipsychotics or mood stabilizers.
Are diagnosed with bipolar disorder, major depression, PTSD, psychosis or autism spectrum disorder.
Had EMDR treatment less than three years ago and/or more than ten sessions.
Used alcohol or drugs 12 hours prior to participation.
For our research goal, we need to store your responses to the questionnaires and your (reaction time) responses during the experiment. The anonymized data will be treated confidentially and solely be used for our research report, which can be accessed by our research team as well as the UT teaching staff. If you are interested in the results of the study,

you can send an email to one of the researchers (m.c.gerdemann@student.utwente.nl). You will receive 2.25 SONA credits as a reimbursement for your participation.

Informed Consent:
I have read and understood the study information dated 29/03/2022. I have been able to ask questions about the study and my questions have been answered to my satisfaction.

- YES
- NO

I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.

- YES
- NO

I understand that taking part in the study involves answering several questionnaires, taking part in a reaction time experiment and a digital EMDR intervention.

- YES
- NO

I understand that taking part in the study involves the following risks: Exposure to a shocking film (depicting extreme violence); Physical or mental discomfort (i.e., flashbacks, anxiety)

- YES
- NO

I am eligible to participate in this study as I fulfil none of the exclusion criteria: Diagnosed with mental health disorder within the last 12 months; Taken psychoactive medication within the last 12 months; Received EMDR treatment less than three years ago and/or more than ten sessions; Visual or hearing impairment; Consumed alcohol or drugs within the last 12 hours

- YES
- NO

I understand that information I provide will be used for student reports and perhaps a journal publication.

- YES
- NO

I understand that personal information collected about me that can identify me, such as my name, will not be shared beyond the study team.

- YES
- NO

I give permission for the (anonymised) reaction time data that I provide to be archived in Moovd's data base so it can be used for future research and learning.

- YES
- NO

Password:
Enter the Code you received from the researcher

- _____

Demographics:
How old are you? Please indicate in numbers.

- ____

What gender do you identify with?

- Male

- Female
- Non-binary / third gender
- Prefer not to say

What is your nationality?

- Dutch
- German
- Other

What is the highest degree or level of school you have completed?

- High school degree or equivalent
- Bachelor's degree
- Master's degree
- Doctorate

Practice phase:
The visual stimulus will appear as a ball that changes to a cylinder. Every time you see that the ball changes to a cylinder, please press the button on the right (eye).
The auditory stimulus appears as a melody. Please press the left button as soon as you hear a melody (sound wave). In addition, some tasks include eye movements. You will perform a practice phase for both stimuli.
You will also receive oral instructions. Please scan this QR-code or enter the link below (smartphone):

(https://research.ut.digital-emdr.com/)

Trauma film:
You will now be asked to watch a shocking film excerpt. It has been used in other research about EMDR and has been ethically approved. Should you have any concerns or doubts, please let the researcher know. Remember that you are free to discontinue the study at any point, for any reason.
While watching the film, try to imagine that you are present as a bystander at the scene of the video. You are watching the situation unfold right before your eyes, really engaging with the situation and trying to blend in. Please keep your attention on the film and try not to look away or close your eyes. Open the film in fullscreen and preferably use headphones.
The clip is supposed to be disturbing, but should you become too uncomfortable at any point, please stop the video and notify the researcher.
Embedded film excerpt here

You will start the digital EMDR treatment after a 5-minute music break. Please continue to the next page to start the break.

Break:
Please listen to the music. After the 5 minutes are over, please continue.
Embedded classical music here

First measurement:
You have just seen a video clip. Please recall the memory you have of the clip.
Thinking about the film scene, how unpleasant does it feel or how much distress do you feel, estimated on a scale from 0 (not distressed at all) to 10 (maximum distress)?

- 0 1 2 3 4 5 6 7 8 9 10

How vividly can you picture the film scene, estimated on a scale from 0 (not vivid at all) to 10 (maximum vividness)?

- 0 1 2 3 4 5 6 7 8 9 10

Intervention:
Please notify the researcher that you have reached the QR-code. In your smartphone browser, close the tab with the application if you have not done so before and then scan this QR-code again or enter the link below (smartphone):

(https://research.ut.digital-emdr.com/)

Second Measurement:
Please recall the memory you have of the video clip.
Thinking about the film scene, how unpleasant does it feel or how much distress do you feel, estimated on a scale from 0 (not distressed at all) to 10 (maximum distress)?

- 0 1 2 3 4 5 6 7 8 9 10

How vividly can you picture the film scene, estimated on a scale from 0 (not vivid at all) to 10 (maximum vividness)?

- 0 1 2 3 4 5 6 7 8 9 10

Follow-up information:
This is the end of today's session. Thank you for your participation.
If you feel the need to talk to someone professional about this experience/the stressful memory, then you can contact this licensed clinical psychologist for free:
Derks, Youri (UT-BMS) (*email and telephone included*)
Moreover, this study is not yet fully completed. You will receive an email in 24 hours with a follow-up measure, which will take around 5 minutes to fill out. Please complete the follow-up survey as soon as possible after receiving the email. After we received your response, we will grant you 2.25 SONA credits. If you do not complete the follow-up tomorrow, you will not be granted any SONA credits.
Additionally, the email includes a documentary about the film excerpt that you watched. It explains how the scene was shot including special effects. You can watch it if you feel like it will help you in dealing with the scene. Further, we will include a YouTube video about guided meditation to relieve tension.
Please proceed to finish the questionnaire.
Please enter your SONA number to receive the credits.

- _____

Appendix B

Follow-up questionnaire

Dear participant,
Thank you for your participation in our study to investigate the effectiveness of digital EMDR therapy. You already helped us with your cooperation to obtain an insight into the effect of online EMDR on the emotionality and vividness of stressful memories. This is the final follow-up measurement.
Yesterday you watched a video clip. Please recall the memory you have of the clip and answer the following questions.

Thinking about the film scene, how unpleasant does it feel or how much distress do you feel, estimated on a scale from 0 (not distressed at all) to 10 (maximum distress)?

- 0 1 2 3 4 5 6 7 8 9 10

How vividly can you picture the film scene, estimated on a scale from 0 (not vivid at all) to 10 (maximum vividness)?

- 0 1 2 3 4 5 6 7 8 9 10

Debriefing:
EMDR is an evidence-based therapy to desensitize stressful memories in PTSD patients. During several sessions, the patient is asked to execute an active task such as moving the eyes horizontally while simultaneously recalling an aversive memory. Both, the recall and the execution of another task are competing for limited working memory capacity. When patients perform the active task, the working memory capacity is loaded. Simultaneously recalling the memory overloads working memory resulting in desensitization of the memory.
A Dutch company (Moovd) developed a digital application to expand the field and use of EMDR therapy. Our study investigates the effectiveness of that application and forms a foundation of statistical data. In the first part, you needed to perform several reaction time tasks. These were used to analyse the loading of the working memory (i.e., which task combinations load working memory most). In the second part of the study, you were asked to watch a film clip that was used to elicit stressful memories. During a pre-test, you indicated the emotionality and vividness of your memory. You were then allocated either to a control group (looking at the living room, recalling the memory but not performing any other task simultaneously) or to the experimental group (performing visual and auditory tasks and simultaneously recalling the memory). After twelve sessions you were instructed to scale the emotionality and vividness a second time. This helps us to analyse the difference between the pre- and post-test and thus examine whether the application (digital EMDR) significantly reduced the emotionality and vividness of your memory. The follow-up measure serves as another post-test to look at the long-term effects of the intervention.
Your data will be treated confidentially and anonymously. If you decided to withdraw your consent to participate or to withdraw your data from the study, please let us know immediately.
Moreover, if you would like to know the outcome of our study, please feel free to contact us (m.c.gerdemann@student.utwente.nl). If you were part of the control group and would like to receive EMDR treatment as well to further relieve your memories of the film, you may also contact us.
Furthermore, we will provide you with a documentary about the film excerpt that you can watch. It explains how the scene was shot including special effects. This may help you to cope with the situation. In addition, you can perform a guided meditation to relieve tension.

In case you feel distressed or experience any physical or mental symptoms based on our study, you can contact a licensed clinical psychologist for free:
Derks, Youri (UT-BMS) (*email and telephone included*)

If you want you can watch this short video explaining how the stressful film was made. This may relieve tension and help you deal with your memory. Special effects and latex dolls were used to create the scene.
Embedded behind-the-scenes clip here

In addition, if you would like to perform a guided meditation to relieve tension you can watch the following video.
Embedded guided meditation here

Please indicate your SONA number to receive the credits.

- _____

Thank you again for your participation. You will now be reimbursed with 2.25 SONA credits.

Appendix C

Empty apartment with reaction buttons

Researcher view

Moving ball changed into cylinder

Appendix D

Verbal Protocol

7.1 Introduction (10 min)

Hello, my name is [NAME]. Thank you for your participation.
Can you see and hear me well? (…)
My oral instructions will be read from a protocol to make sure that every participant receives the same instructions.
Welcome to our study in which we will investigate the effectiveness of an online trauma treatment. During the study, you will execute some sets of Reaction Time tasks. In the second part, you will be asked to watch a film clip that should evoke a strong negative emotional reaction. After watching the movie clip, you will complete an online task.
I can see you are connected on Zoom with your laptop or PC. If possible, have headphones ready to connect to your laptop/PC later. Do you also have your phone at hand? (…)

- **NO**: *You will need it to access the online application. Could you please get it, so you have it ready later on?*
- **YES**: *Good you will need it later to access the online application.*

Is your phone charged (at least 40%?) and are you in a calm and non-distracting environment? (…)

- **NO**: *Maybe you can get a charger and relocate to a calm and non-distracting environment*
- **YES**: *Great*

Before we begin, do you have any questions or comments for me at this time? (...)
Good, in SONA / chat you can find a link to Qualtrics, an online survey tool. Please open the link and follow the instructions in the questionnaire. Read the information carefully and make sure you don't fulfill any of the exclusion criteria. Let me know if there are any questions and when you are finished reading the information.
After reading this information, do you definitely want to participate in the study? (…)

- **NO***: Ok, I understand that you do not agree with the conditions of this survey. You have, of course, every right to do so. However, may I ask which part you do not agree with or why you do not agree?* Make a note of any important points and then finish the conversation.
- **YES:** *All right. I would like to emphasize that you may stop participating in the study at any time. If you are ready, we will start the study.*

Please continue in the survey and start by filing out the informed consent form in the survey. (…)
When you are asked to enter a code, let me know. (…)
*The code is "**EMDR**". Please continue the survey. When you get to a QR code in the survey, please let me know.*

7.2 Connecting EMDR Environment (5 min)

Please scan the QR code with your phone camera now. If it doesn't work, you can also manually enter the link below into your smartphone browser. Now please select "Client", scroll down and tap accept. Then please hold your phone horizontally. If the screen does not rotate, please disable the "lock screen rotation" function on your phone and try again.
On the left, you see a button for audio tasks, which you have to press as quickly as possible when you hear a drumming sound. The button on the right is for visual tasks. You will see a ball that occasionally changes its shape into a cylinder. When this happens, press the right button as quickly as possible. After you have tapped the button, the cylinder will immediately change back into the ball (or for the audio task the sound will stop). Please only tap when the ball changes into a cylinder, not the other way around. The ball will sometimes also move around. Do you understand the instructions? (…)

- NO: *Is there anything that is unclear?*
- YES: *Great, then please tap "start session."*

Now you see an empty apartment and a Session ID at the top of the screen. Could you please tell me this ID or type it into the chat, so I can connect with you? (…)

7.3 Reaction Time Experiment (20min)

Thank you, you will now go through a set of response tasks. Please turn your phone volume up, so you can hear the sound well. Please hold your phone around 30 cm from your face. First, we will have a little practice phase, first for the visual stimulus, then for the auditory so you get a feeling for the task. So again, as soon as you either see the ball changing into a cylinder or hear the drumming sound, tap the respective button as fast as you can. Are you ready? (...)

Okay, then let's start.

START Practice Visual

Do you see how this is working?

- **NO**: *What is the problem?*
- **YES**: *Great, Let's continue with the auditory practice phase*

START Practice Auditory

Do you see how this is working? Could you hear the sound and respond to it?

- **NO**: *What is the problem?*
- **YES**: *Thank you, now we're done with the first part of the study. You can put your phone away for now, but we will need it again shortly. Please continue with the questionnaire now. (...)*

Please continue in the questionnaire until you can see the video clip. Before you start it, let me know. Please read the information carefully. You will be shown a short video clip of about 2 minutes. Please sit quietly and watch the video clip carefully. I am going to ask you questions about this video clip later.

I do not want you to watch this film as you normally would. I want you to try to imagine that you are present as a bystander at the scene of the video. You are watching the situation unfold right before your eyes, really engaging with the situation and trying to blend in. Please keep your attention on the video and try not to look away or close your eyes. I will turn off my own camera so you can concentrate on the film, but your camera will stay on. Is that okay with you? (...)

- **NO**: *Ok, what is bothering you?*
- **YES**: *It is very important that you watch the video according to these instructions. Just to check that you understood the instructions correctly, would you summarize what I just explained (...)*

Please start watching the film which will have some French dialogue in full-screen and turn up the screen brightness.

STOP if the participant is very upset by the movie. It is okay to be a little shocked but crying or being upset is emphatically not the intention. IF IN DOUBT, ALWAYS STOP!

- **IF UPSET:** *I see that you are very upset by seeing the video clip. Do you want to stop the experiment? We did not intend for you to become so upset by the video clip. (...)*
  I am sorry for the fact that the film upset you so much. When participants in this study get very distressed, the protocol is that you receive the contact details of a clinical psychologist whom you can talk with.

To let the memory sink in, you will have a 5-minute break during which I ask you to listen to the music. After the countdown is over, please let me know and continue with the survey.

7.5 PRE SUD-Measurement

You have just seen a video clip. I would like to ask you to recall the memory you have of the video clip:

1. *Thinking about the video clip, how unpleasant does it feel or how much distressed do you feel, estimated on a scale from 0, no distress at all, to 10, maximum distress?*
1. *And how vividly can you picture the video clip, estimated on a scale from 0 "not vivid at all," to 10, "very vivid"?*

Please indicate your answers in the questionnaire.

EXCLUDE if SUD = 5.5 or lower

- **IF 5.5 OR LOWER***: Based on the scores you just mentioned, we have to exclude you from this study. The movie doesn't seem to do much with you and therefore you are*

unfortunately not suitable for this study. I would like to thank you for your participation, and I will make sure you will receive your compensation/participant points.

- **IF 5.6 OR HIGHER:** *Please continue*

7.6. Conditions

As soon as you see a QR code again, please let me know.
Please scan the QR code with your phone camera now. If it doesn't work, you can also manually enter the link below it into your smartphone browser. Now please select "Client", scroll down and tap accept. Then please hold your phone horizontally. Tap "start session.". Could you please tell me the session ID or type it into the chat, so I can connect with you?
LOOK at Condition (Excel): Control or Experimental

- 7.6.1 Control
- 7.6.2 Experimental

7.6.1 Control Condition: Recall Only

In a moment I will ask you some questions about your memory of the video clip that we are going to work on.
From your memory of the whole video clip, choose the image that you find most distressing to watch right NOW. In other words: what is at this moment, when you look at it from here and now, the most disturbing image of this memory, or which image evokes the most distress at this moment? Imagine looking at the video clip again and then pausing it- at the second - so that it becomes an image.

- *Which image is the most disturbing image of the event / Which part of the memory evokes the most distress? (...)*
- *Where in your body do you feel it ('that distress/tension') most strongly? (...)*

You are supposed to keep your eyes open and look at the screen. Is that okay? (…)
Take the most disturbing image in mind, do you have that? (...)
Be aware of the tension in your [location of tension]. Give the participant a moment to concentrate.
Focus on the memory and relax while looking at the screen.
We will now start with the sets.
FOR 12 SETS:
START Recall Only Condition
AFTER 30s have a small break and say:

- *What comes to mind? / What is going through your mind? / What do you notice?*
  - **If someone names something related, say:** *Focus on that, continue with that.*
  - **If someone says nothing comes up or names something unrelated, say:** *Okay, now focus again on the most disturbing image again.*
- *I'll put the task back on NOW.*

7.6.1 Experimental Condition: Recall + Dual Task

We will now continue with the task that you have practiced with before. Do you remember what to do in this task? (...)

- **If necessary,** explain the task again.

In a moment we are going to do this task several times. Please press the buttons as fast as possible again when you see the cylinder or hear the sound. But when you do the task this time, I'll also ask you to do something else as well.
I'm going to ask you some questions about your memory of the video clip that we're going to work on. From your memory of the whole video clip, choose the image that you find most distressing to watch NOW. In other words: what is at this moment, when you look at it from the here and now, the most disturbing image of this memory, or which image evokes the most tension at this moment? Imagine looking at the video clip again and then pausing it- at the second - so that it becomes an image.

- *Which image is the most disturbing image of the event / Which part of the memory evokes the most distress? (...)*
- *Where in your body do you feel it ('that distress/tension') most strongly? (...)*

We are about to start the task, so look at the screen and meanwhile take the most disturbing image in mind, do you have that? (…)

Be aware of the tension in your [location of tension]. Give the participant a moment to concentrate.
Pay attention, follow the ball, and react to the tasks. I am starting the task NOW.
FOR 12 SETS:
START Combi + Eye-movement + algorithm Condition
AFTER 30s have a small break and say:

- *What comes to mind? / What is going through your mind? / What do you notice?*
  - **If someone names something related, say:** *Focus on that, continue with that.*
  - **If someone says nothing comes up or names something unrelated, say:** *Okay, now focus again on the most disturbing image, follow the ball, and react to the task.*
- *I'll put the task back on NOW.*

7.7 POST SUD Measurement
Please continue in the questionnaire
I would like to ask you to recall the memory you have of the video clip.

1. *Thinking about the video clip, how unpleasant does it feel or how much distressed do you feel, estimated on a scale from 0, no distress at all, to 10, maximum distress?*
1. *And how vividly can you picture the video clip, estimated on a scale from 0 "not vivid at all," to 10, "very vivid"?*

7.8 Conclusion
Thank you, we are done with the phone application now. Please proceed with the questionnaire. When you reach the end of the questionnaire, please let me know.
We have now come to the end of this appointment. How are you doing now? (...)
IF THE PARTICIPANT IS STILL UPSET by the movie, again give the option to speak with the clinical psychologist.

- **If still upset:** *I am sorry for the fact that the film upset you so much. When participants in this study get very distressed, the protocol is that you receive the contact details of a clinical psychologist who you can talk with.*

As you just read, you will receive an email tomorrow with a follow-up questionnaire, which only takes around 5 minutes. I would like to ask you to complete it tomorrow as soon as possible. I will also remind you again that if you feel you need someone to talk to about the stressful memory, feel free to reach out to Youri, our psychological professional. After the follow-up survey tomorrow, there will also be some measures to relieve potential tension. Do you have any final questions or remarks? (...)

- **YES:** Briefly discuss how to help
- **NO**: *Great, that concludes today's session then. Thank you for participating.*

Would you like to participate in the voucher give-away?

- **YES:** *Then I will need your email address. Please use the chat function for this. Thank you.*
- **NO**: *Have a nice day.*