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ORIGINAL ARTICLE

# Reactivation and Evaluation of Mastery Experiences Promotes Exposure Benefit in Height Phobia

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## Abstract

The retrieval of personal mastery experiences has been linked to adaptive functions, such as increased perceived self-efficacy and coping capability. Successful exposure leads to an increased mastery experience with respect to anxiety provoking situations, possibly due to a violation of expected negative outcomes. We investigated whether the reactivation and evaluation of mastery experiences after a brief virtual reality exposure (VRE) training can enhance self-efficacy and promote exposure therapy benefit in patients with acrophobia. Acrophobic participants ($N = 56$) were randomly assigned to a memory reactivation and evaluation (= VRE–MRE) intervention, a control (= memory reactivation; VRE–MR), or no intervention (= VRE) after VRE. The VRE–MRE condition involved the evaluation of mastery experiences associated with exposure and related events from the past. The effects of the VRE–MRE intervention were assessed on the level of behavioral avoidance and subjective fear at post-treatment and one-month follow-up. Relative to both the VRE–MR and VRE conditions, the VRE–MRE group showed an increase in self-efficacy and exhibited more pronounced reductions in behavioral avoidance, subjective fear at the initial approach distance, as well as scores on the acrophobia questionnaire (AQ) from pre- to post-treatment. The superior effects of the VRE–MRE intervention remained evident on the level of behavioral avoidance and associated subjective fear at the initial approach distance, but not on the AQ, from pre-treatment to follow-up. These findings indicate that the reactivation and evaluation of mastery experiences could be used as a strategy to increase exposure-based therapy in anxiety disorders.

**Keywords** Acrophobia · Extinction · Exposure · Self-efficacy · Virtual reality

There is substantial evidence that exposure is amongst the most efficacious interventions to counteract pathological fear related to specific objects and/or situations (Butler et al. 2006; Norton and Price 2007; Ruhmland and Margraf 2001). The inhibitory learning model provides a useful framework to understand how exposure contributes to the long-term attenuation of fear and anxiety (Craske et al. 2018; Vervliet et al. 2013). According to this model, the extent to which expectations about negative consequences are violated by exposure determines exposure treatment success. Thus, establishing mastery experiences where patients deal with their particular objects of fear constitutes an important ingredient of treatment efficacy.

However, the extent to which patients profit from exposure is prone to inter-individual variability, and relapse following exposure poses a significant concern (Craske and Mystkowski 2006; Durham et al. 2012). Consequently, interventions aimed at promoting the acquisition and consolidation of corrective experiences (i.e., mastery experiences which ideally violate the expected negative consequences) in the context of exposure can be useful to increase exposure-based treatment outcome. Due to its high translational validity, fear extinction has been utilized as a laboratory model to identify such interventions, which then can be translated to exposure (Craske et al. 2018; Hofmann 2007; Vervliet et al. 2013).

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Apart from a general reduction in avoidance of fear-provoking situations and objects, exposure has been shown to contribute to an enhanced perceived self-efficacy and increased coping capabilities (Gallagher et al. 2013; Goldin et al. 2012). Moreover, an increment in mastery-related self-efficacy during exposure is directly linked to subsequent decrease in fear and avoidance (Williams and Watson 1985). Consequently, enhancing the subject's belief to cope with a demanding and threatening situation proved effective in decreasing phobic behavior (but see Williams et al. 1985), increasing general stress coping capability and promoting cognitive performance (Schönfeld et al. 2017).

The selective activation of autobiographical memories containing mastery experiences constitutes a powerful strategy to increase the subject's perceived self-efficacy and coping capability (e.g., Brown et al. 2016). Recently, the activation of a positive autobiographical memory content has been used in the clinical context as a strategy to increase self-efficacy and reduce trauma-associated distress (Morina et al. 2017) and to enhance positive future thinking and social problem solving skills in PTSD (Brown et al. 2016).

In a similar vein, we have shown that an experimental induction of increased self-efficacy via positive social feedback promotes the acquisition and retrieval of extinction memories, which are analogue to exposure-related corrective learning (Zlomuzica et al. 2015). The present study goes beyond previous work by examining whether the activation of autobiographical memories containing mastery experiences can be translated into a useful clinical application to further promote reduction in avoidance and fear after exposure. In this instance, we developed an intervention that incorporates the reactivation of the exposure experience and similar personal experiences in combination with an evaluation of expectancy violation during the respective episode. The latter is in accordance with the basic assumptions of the inhibitory learning theory (see Craske et al. 2014, 2018). We expected that the reactivation and evaluation of personal emotional experiences (such as the exposure session itself), in which a demanding situation has been mastered despite the expectancy that a negative consequence will occur (expectancy violation), should increase perceived self-efficacy and coping capabilities. We further assumed that this intervention should facilitate the consolidation of corrective experiences, similar to the effects shown for extinction memories (Zlomuzica et al. 2015). In the present study, we therefore tested whether such an intervention of reactivating mastery experiences in addition to exposure is superior to exposure as a stand-alone treatment and/or a control condition.

To this end, we first developed and validated a brief virtual reality exposure (VRE) training that proved to be effective in reducing avoidance and fear of heights in acrophobic participants. In general, VRE has been shown to be a similarly effective alternative to in vivo exposure (Emmelkamp et al. 2002), allowing to conduct exposure under highly standardized and controlled conditions. VRE can be utilized to examine the added benefit of additional interventions on exposure efficacy (e.g., de Quervain et al. 2011). We investigated whether a brief VRE in combination with the activation of autobiographic mastery experiences can induce more pronounced reductions in fear and avoidance in real-life situations and self-report measures. These were measured with subsequent in vivo Behavioral Approach Tests (BATs) which were performed 24 h after the VRE (post-treatment) and 4 weeks later (follow-up). Furthermore, treatment-related changes in self-report measures, that is, the AQ, were assessed. The effects of the additional intervention on these different outcome measures were compared to VRE alone and VRE in combination with a control intervention.

## Method

### Participants

Participants were recruited via bulletin board notices at the campus of the Ruhr University Bochum as well as announcements in social media networks.

Height-fearful participants aged 18–40 with corrected or normal vision and no neurological or mental and no current psychotherapeutic treatment were eligible for participation. Three participants terminated exposure due to cyber sickness, $n = 5$ participants dropped out after session 1, $n = 5$ participants had any other comorbid diagnosis considered more severe than height phobia (as assessed with the Mini-DIPS, see "Assessments" section), and $n = 2$ participants differed more than 2 SD from all other participants in their scores on the Anxiety Subscale of the AQ. Hence, our analytic sample comprised 56 participants who were randomly assigned to either one session of VRE without an additional intervention (VRE group, $n = 20$) or VRE in combination with one of the following retrieval interventions: (i) retrieval of exposure and similar events while focusing on mastery experiences, that is, memory reactivation and evaluation (MRE; VRE–MRE group: $n = 18$); (ii) retrieval of exposure and similar events, that is, memory reactivation (MR; VRE–MRE group; $n = 18$). The "Group Assignment" section describes these interventions.

All experimental procedures were approved by the local Ethics Committee of the Ruhr University Bochum and carried out in accordance with the Declaration of Helsinki. All participants provided written informed consent and received 50 Euro or 5 course credits for their participation.

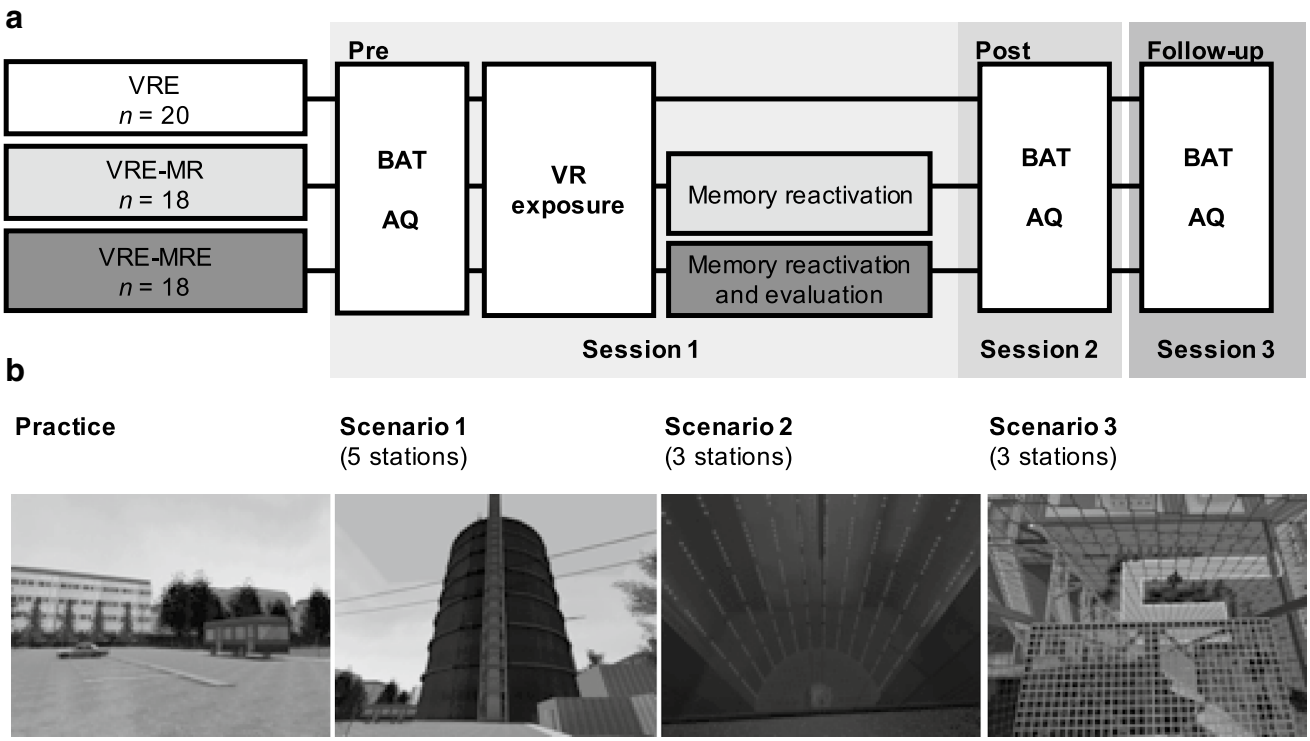


**Fig. 1** Illustration of the experimental design (**a**) and the different scenarios displayed during exposure (**b**)

## Virtual Reality Exposure

### Apparatus

We created a brief VRE for individuals suffering from height phobia. The design and procedure was adapted from similar existing interventions which have been used to alleviate fear and avoidance in height-fearful participants (Coelho et al. 2009). The training was conducted in and around a high building in VR environment that resembled a corresponding building from real environment (The "Gasometer" in Oberhausen, Germany). The VRE was created using the Source Engine SDK (Valve Corporation, Bellevue, Washington, USA). Participants were equipped with a stereoscopic head-mounted display (eMagin, Z800, USA) that displayed the virtual reality environment. Participants controlled their forward movements with the W key of a computer keyboard, which was highlighted by marker-points, while movement direction was controlled either by participants' head movements or by using a computer mouse. Participants stood in an upright position in the dark (i.e., lights switched off) experimental room, which was electronically connected to a control room, where the experimenter kept track of participants' performance in the VR (i.e. participant's vision was mirrored on a computer screen in the control room). Experimenter and participant could communicate via microphones and loudspeakers.

### VRE

In pilot studies, we showed that the brief VRE in acrophobic participants was effective in reducing avoidance and fear of heights when compared to a wait-list control group (unpublished data). Prior to the VRE, each participant was familiarized with the apparatus by allowing them to navigate through a neutral environment (i.e., exploring the area adjacent to the building, see Fig. 1b). The VRE consisted of three different scenarios (Fig. 1b) that were subdivided into different exercises of increasing difficulty. The scenarios involved going up (i) an outdoor-staircase (5 stations) and going up with an (ii) indoor elevator with (3 stations) and (iii) outdoor elevator (3 stations).

At the beginning of each station, participants rated their fear (SUD) and were instructed to move their heads to look around and look down in particular (i.e., use of keyboard was not allowed). Participants attempted the next exercise of the respective scenario when fear had declined to an SUD of 30 or below. VRE was terminated when either 60 min had elapsed or all scenarios had been successfully completed, whichever occurred first.

## Group Assignment

The retrieval interventions took part subsequently after the VRE training. We developed a set of questions (see

Supplementary Material) or instructions focusing on the participant's retrieval of exposure and highly related events from the subject's past. Our approach is similar to existing interventions used to selectively enhance perceived self-efficacy via activation of positive autobiographic experiences (see Brown et al. 2016; Morina et al. 2017). However, our intention was to further increase the subject's sense of mastery during the respective episodes by evaluating the degree to which the expectation of a negative outcome had been violated. The latter is in strong accordance with the propositions of the inhibitory learning theory (Craske et al. 2014, 2018). In the VRE–MR intervention, participants were asked to specifically retrieve the exposure session as well as to remember events from the own past which were similar to the exposure. In the VRE–MRE intervention, however, participants were further asked to elaborate on the basis of these experiences *whether* and *how* they mastered and/or coped within the respective situation. Our general aim was to induce differential levels of perceived self-efficacy in the VRE–MRE group relative to the VRE–MR intervention group. To compare the effects of the VRE–MRE, VRE–MR and the VRE conditions on positive and negative mood, distraction, excitement and perceived self-efficacy, manipulation checks were administered (see "Assessments" section).

## Assessments

### Control Variables

Prior to the experimental procedure, participants completed German versions of the Beck's Depression Inventory-II (BDI-II; Hautzinger et al. 2006) and the State-Trait Anxiety Inventory (STAI; Laux et al. 1981) to control for any pre-existing differences in depressive and anxiety symptoms among participants. Fear of heights and other comorbid diagnoses were ascertained with the short diagnostic interview for mental disorders (Mini-DIPS, Margraf 1994). Furthermore, treatment credibility was measured with the treatment credibility/expectancy questionnaire (TC/E; Borkovec and Nau 1972), with scores from 0 to 45, and general self-efficacy levels were assessed using the General Self-efficacy questionnaire (GSE; Jerusalem and Schwarzer 1999) prior to the VRE. After the VRE, the Igroup Presence Questionnaire (IPQ; Schubert et al. 2001) was administered to assess the degree of immersion into virtual reality.

### Treatment Outcome Measures

**Height Phobia-Related Questionnaire** The German version of the Anxiety Subscale of the Acrophobia Questionnaire (AQ; Cohen 1977) was used to assess anxiety provoked in different height-relevant situations at each of the sessions.

**BAT** At each of the three sessions, an in vivo BAT was conducted to assess change in fear and avoidance of heights. Participants were instructed to go up a church tower until fear becomes intolerable. The BAT was scored behaviorally, that is, in terms of pre-determined stations of different heights, varying from 0 (=top of church-tower, i.e., no avoidance) to 12 (=refused to go up). In addition, subjective fear using the Subjective Units of Distress Scale (SUD; Wolpe 1973) with scores from 0 (=no fear) to 100 (excessive fear) was collected at the highest station a participant was able to attain. At the post-treatment BAT, participants provided two fear ratings: at the pre-treatment BAT station, to which they returned first, and at the highest station tolerable, yielding subjective fear at the *initial* and *final* approach distance, respectively.

### Manipulation Check

Visual analogue scale (VAS), ranging from 0 (=minimal) to 100 (=maximum), were employed prior to exposure as well as after the intervention to assess current levels of positive and negative mood, distraction, excitement and perceived self-efficacy (self-confidence), according to the general approach by Brown et al. (2012, 2016).

## Experimental Design and Procedure

An outline of the experimental design is depicted in Fig. 1. Three sessions were undertaken, with 2–3 days imposed between Session 1 (pre) and 2 (post) and 4 weeks between Session 1 and 3 (follow-up). Importantly, after VRE, the additional interventions (i.e., MRE and MR) were undertaken. Exposure-induced changes in fear and avoidance of heights were again measured at each assessment with the AQ and the in vivo BAT (church-tower). At the end of Session 3, all participants were fully debriefed.

## Statistical Analyses

Statistical analyses were carried out using SPSS, Version 24 (IBM SPSS, Armonk, NY, USA). Group differences in pre-exposure participant characteristics were assessed with ANOVAs or Chi square tests as appropriate. Manipulation checks were analyzed with Mixed ANOVAs, for which time (prior to exposure, post intervention) was entered as within-subjects factor and group (VRE–MRE, VRE–MR, VRE) as between-subjects factor. Exposure-induced changes from pre-treatment to post-treatment and from pre-treatment to follow-up were analyzed separately due to participants' drop-out at follow-up. To examine whether groups differed with respect to the change in treatment outcome variables, Mixed ANOVAs were conducted. Power analysis revealed that our sample size ($N=56$ at pre- and post-treatment and

**Table 1** Demographic and clinical characteristics of the three study groups

| Variable | VRE ($n=20$) *M* (*SD*) | VRE–MR ($n=18$) *M* (*SD*) | VRE–MRE ($n=18$) *M* (*SD*) |
|---|---|---|---|
| Age | 25.25 (4.41) | 25.56 (4.16) | 25.94 (3.56) |
| Gender (*n* female) | 14 | 12 | 12 |
| BDI-II | 2.65 (3.13) | 4.39 (4.95) | 4.17 (5.91) |
| STAI-S | 35.10 (6.02) | 38.50 (9.49) | 36.61 (8.75) |
| STAI-T | 33.15 (8.03) | 35.56 (9.53) | 35.83 (11.15) |
| General self-efficacy | 31.35 (3.2) | 30.89 (3.95) | 31.61 (4.27) |
| Treatment credibility | 30 (8.87) | 30.61 (6.14) | 28.17 (5.9) |
| Treatment duration | 24.6 (10.25) | 24.11 (8.99) | 24.17 (9.93) |
| IPQ—total (range 0–6) | 2.51 (1.06) | 2.44 (1.18) | 2.3 (1.38) |

*BDI-II* Beck's depression inventory-II, *STAI* state-trait anxiety inventory, *IPQ* igroup presence questionnaire

$N=37$ at follow-up) exceeds (i.e., pre-treatment to post-treatment) or is comparable to (i.e., pretreatment to follow-up) the required sample size of $N=42$ to detect a medium effect ($f=0.25$) with sufficient power (0.8) for the within-between interaction in a mixed ANOVA with two levels of the factor time (i.e., pre-treatment, post-treatment; pre-treatment, follow-up) and three levels of the between-subjects factor group (i.e., VRE–MRE, VRE–MR, VRE). Significant interactions were further explored by analyzing the simple effect of time within each group and Bonferroni–Holm corrected pairwise-comparisons on the change score of the respective outcome measure, which quantified the amount of exposure-induced improvement in fear and avoidance. These change scores were calculated by subtracting post-treatment or follow-up scores from pre-treatment scores. In each of the analyses, a result was considered significant at $p<0.05$.

## Results

### Participant Characteristics

Demographic characteristics are displayed in Table 1. Groups did not differ in age ($F_{(2,53)}=0.14$, $p=0.87$), gender distribution ($\chi^2(2)=0.07$, $p=0.97$), their scores on the BDI-II ($F_{(2,53)}=0.76$, $p=0.47$), STAI-T and STAI-S (both $F_{(2,53)}<0.83$, $p>0.44$). Furthermore, all three groups were comparable in their general self-efficacy levels ($F_{(2,53)}=0.17$, $p=0.85$), their ratings regarding treatment credibility ($F_{(2,53)}=0.57$, $p=0.57$), the amount of time needed to accomplish exposure ($F_{(2,53)}=0.02$, $p=0.99$), as well as in the degree of immersion into the virtual reality ($F_{(2,53)}=0.14$, $p=0.87$). Importantly, groups were comparable with regard to pre-treatment BAT score ($F_{(2,53)}=0.37$, $p=0.69$), subjective fear during the BAT ($F_{(2,53)}=0.78$, $p=0.46$), as well as in their scores on the AQ ($F_{(2,53)}=1.21$, $p=0.31$).

### Manipulation Check

Descriptive statistics on each of the five VAS scale prior to exposure and post-intervention are shown in Table 2. No significant main effects for group, time, as well as their interaction were evident for distraction (all $F<2.1$, $p>0.15$), positive mood (all $F<1.89$, $p>0.16$) and negative mood (all $F<1.89$, $p>0.16$). However, a significant decline in excitement over time was found ($F_{(1,53)}=21.66$), $p<0.001$).

Most importantly, in terms of perceived self-efficacy, a significant main effect for Time ($F_{(1,53)}=11.67$, $p<0.001$) emerged, which was subjected to group differences (i.e.,

**Table 2** Scores on the VAS

| Variable | VRE ($n=20$) *M* (*SD*) | VRE–MR ($n=18$) *M* (*SD*) | VRE–MRE ($n=18$) *M* (*SD*) |
|---|---|---|---|
| Pre-exposure | | | |
| Distraction | 13.80 (21.35) | 21.22 (20.97) | 22.28 (27.69) |
| Excitement | 36.35 (24.45) | 34.89 (27.12) | 37.89 (28.20) |
| Positive mood | 70.55 (18.33 | 61.22 (21.61) | 67.44 (20.22) |
| Negative mood | 3.65 (7.53) | 14.06 (24.15) | 8.44 (17.53) |
| Self-confidence | 62.35 (20.68) | 51.61 (20.20) | 54.17 (22.86) |
| Post-intervention | | | |
| Distraction | 10.95 (13.35) | 20.33 (18.23) | 13.33 (23.77) |
| Excitement | 17.50 (18.48) | 26.11 (19.98) | 14.78 (22.34) |
| Positive mood | 67.35 (21.47) | 61.89 (22.49) | 75.00 (17.79) |
| Negative mood | 5.50 (12.42) | 10.83 (14.65) | 4.11 (8.13) |
| Self-confidence | 63.10 (22.33) | 53.83 (17.76) | 72.22 (15.16) |

VAS manipulation checks included subjective ratings of distraction, excitement, positive mood, negative mood and self-confidence according to the procedure by Brown et al. (2012, 2016). The term self-confidence was used interchangeably with self-efficacy since self-confidence is less prone to misinterpretation and is used more colloquially. Detailed information on the exact meaning of the scale and specific instructions on how to rate the VAS items were provided to each participant

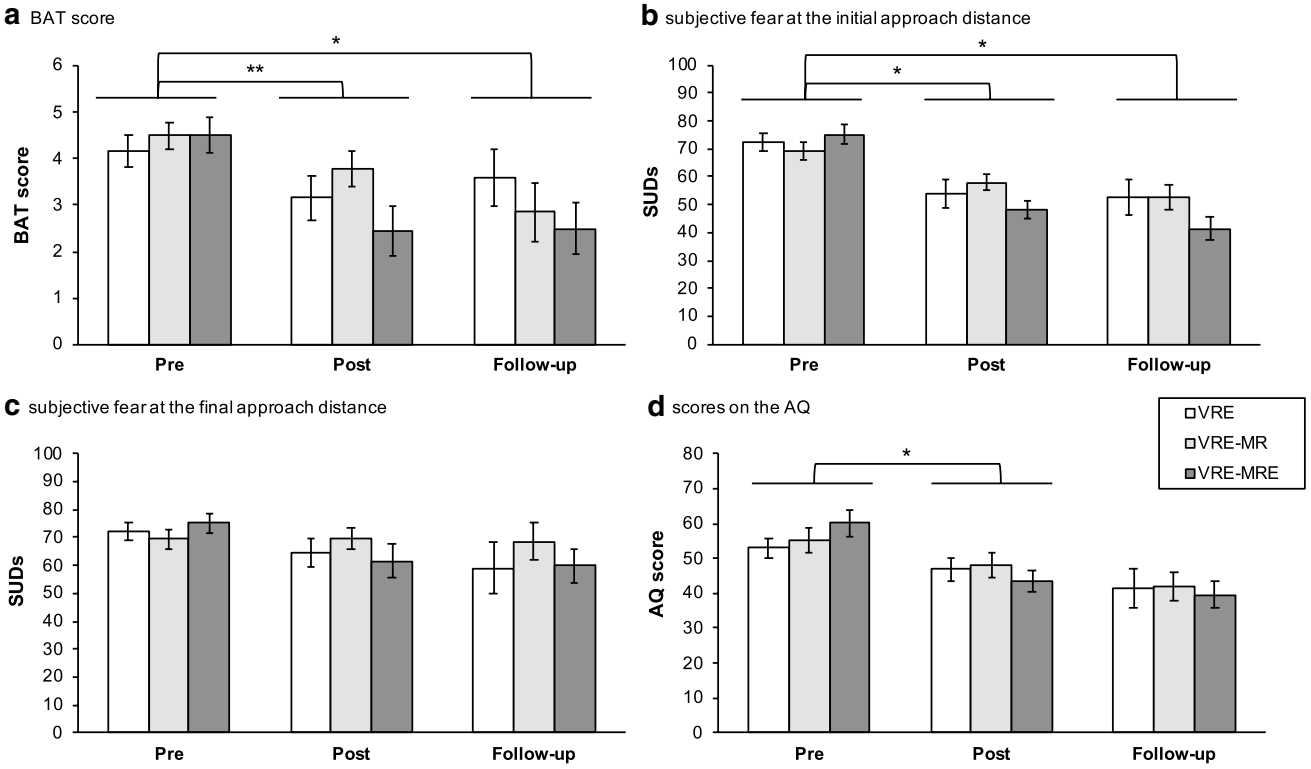


**Fig. 2** Treatment outcome measures at pre-treatment, post-treatment and follow-up in the tree study groups. **a** Behavioral avoidance (BAT score), **b** subjective fear at initial approach distance of the BAT, **c** subjective fear at the final approach distance of the BAT, and **d** scores on the AQ. Sample size was $N=56$ from pre-treatment to post-treatment and $N=37$ from pre-treatment to follow-up. Data represented as means ± 1 SEM. Asterisks denote significant time × group interaction (see text for further details), with $^{**}p<0.01$ and $^{*}p<0.05$

group × time interaction: $F_{(2,53)}=7.21$, $p=0.002$). Simple effects analyses on this interaction revealed that only the VRE–MRE group showed a significant increase in self-efficacy ($p<0.001$), whilst the other groups did not (VRE–MR: $p=0.54$; VRE: $p=0.83$). Bonferroni–Holm corrected analyses on the change score further revealed that the increase in self-efficacy in the VRE–MRE group differed significantly from those in the VRE–MR ($p=0.006$) and VRE ($p=0.003$) groups, with no differences between the latter ($p=0.769$).

## Treatment Outcome Measures

### Exposure-Induced Changes from Pre-treatment to Post-treatment

Results are displayed in Fig. 2. Regarding the BAT score, we found a significant main effect for Time ($F_{(1,53)}=61.33$, $p<0.001$, $\eta_p^2=0.54$) as well as a significant group × time interaction ($F_{(2,53)}=6.21$, $p=0.004$, $\eta_p^2=0.19$). Although all groups showed a decrease in behavioral avoidance from pre- to posttreatment (all $p\leq0.014$), the VRE–MRE group exhibited a stronger decline in scores than both the VRE–MR ($p=0.006$) and VRE group ($p=0.018$), with no differences between VRE–MR and VRE ($p=0.48$).

Similarly, participants showed a decline in reported fear at the initial approach distance[1] ($F_{(1,52)}=80.05$, $p<0.001$, $\eta_p^2=0.61$), which differed across groups (interaction: $F_{(2,52)}=4.94$, $p=0.011$, $\eta_p^2=0.16$). Although all groups showed a reduction in fear over time (all $p\leq0.003$), the strongest decline in terms of Bonferroni–Holm corrected pre-post change scores was observed for the VRE–MRE group, which was significantly different from the one observed within the VRE–MR group ($p=0.009$) and at trend from the VRE group ($p=0.10$), with no significant differences between the latter ($p=0.253$).

Likewise, participants showed a significant reduction in subjective fear at the final approach distance ($F_{(1,53)}=8.01$, $p=0.007$, $\eta_p^2=0.13$), yet the time × group interaction just missed statistical significance ($F_{(2,53)}=2.57$, $p=0.086$, $\eta_p^2=0.09$).

Scores on the AQ also declined over time ($F_{(1,53)}=38.33$, $p<0.001$, $\eta_p^2=0.42$), which was qualified by a significant time × group interaction ($F_{(2,53)}=4.4$, $p=0.017$, $\eta_p^2=0.14$).

[1] One participant in the VRE condition missed to provide a fear rating at the initial approach distance. Hence, this analysis is based on $N=55$ participants.

Although each group exhibited a decline over time (VRE–MRE: $p < 0.001$; MR: $p < 0.017$; VRE: $p = 0.026$), the VRE–MRE group had a significantly greater reduction (i.e., pre-post change score) relative to the VRE ($p = 0.027$) and VRE–MR group ($p = 0.038$), respectively (VRE–MR vs. VRE: $p = 0.829$).

### Exposure-Induced Changes from Pre-treatment to Follow-Up

Follow-up data was only available for 37 participants (VRE: $n = 10$, VRE–MR: $n = 13$, VRE–MRE: $n = 14$). Decision to engage in the follow-up assessment was not influenced by group assignment ($\chi^2(2) = 3.71$, $p = 0.16$). Furthermore, participants who were lost to follow-up did not differ from those who were willing to participate in any treatment outcome measure, that is, the change scores from pre- to post-treatment of the BAT ($p = 0.49$), subjective fear at the initial ($p = 0.78$) and final ($p = 0.88$) approach distance and the AQ ($p = 0.1$).

As shown in Fig. 2, the amount of improvement from pre-treatment to follow-up in terms of the BAT score differed across groups ($F_{(2,34)} = 3.78$, $p = 0.033$, $\eta_p^2 = 0.18$; main effect for time: $F_{(1,34)} = 42.34$, $p < 0.001$, $\eta_p^2 = 0.56$). Simple effects showed that only the VRE–MRE and VRE–MR, but not the VRE group ($p = 0.122$), showed a significant reduction in the BAT scores (both $p < 0.001$). Additional Bonferroni–Holm corrected analyses on the change scores revealed a greater decline in the VRE–MRE group relative to the VRE ($p = 0.03$), but not relative to the MR ($p = 0.324$) group, with no significant differences between VRE–MR and VRE ($p = 0.324$).

Similarly, the time × group interaction was significant at the initial approach distance ($F_{(2,34)} = 4.26$, $p = 0.022$, $\eta_p^2 = 0.20$; main effect for time: $F_{(1,34)} = 68.91$, $p < 0.001$, $\eta_p^2 = 0.67$). Although reported fear declined in each group (all $p \leq 0.003$), the VRE–MRE group showed a more pronounced decline than the VRE–MR group ($p = 0.021$), yet both intervention groups did not differ from VRE (VRE–MRE vs. VRE: $p = 0.148$; VRE–MR vs. VRE: $p = 0.43$).

Only the main effects for Time (both $F_{(1,34)} > 9.12$, $p \leq 0.005$, $\eta_p^2 > 0.21$) were significant in analyzing subjective fear at the final approach distance and the scores on the AQ.

Of note, an intention-to-treat analysis with the last observation carried forward method to impute missing values showed that the results were similar when all participants, instead of the reduced sample, were analyzed (main effects for time: all $p \geq 0.002$, $\eta_p^2 > 0.17$; interaction effects: BAT score: $p = 0.011$, $\eta_p^2 = 0.16$; fear at initial approach distance: $p = 0.005$, $\eta_p^2 = 0.18$; fear at the final approach distance: $p = 0.09$, $\eta_p^2 = 0.09$; AQ: $p = 0.056$, $\eta_p^2 = 0.10$). Yet, as for the BAT scores, Bonferroni–Holm corrected analyses showed that the VRE–MRE condition had a stronger decline in behavioral avoidance relative to *both* the VRE–MR ($p = 0.042$) and the VRE ($p = 0.015$) conditions. This was accompanied by a stronger decline in subjective fear at the initial approach distance in the VRE–MRE group as compared to *both* the VRE–MR ($p = 0.006$) and VRE ($p = 0.016$).

## Discussion

The main purpose of this study was to examine whether the reactivation of specific autobiographic memories containing mastery experiences can induce higher perceived self-efficacy and promote exposure treatment benefit in patients with height phobia. Our results indicate that such an intervention increased perceived self-efficacy in patients with height phobia. Most importantly, participants receiving such an intervention subsequently to VRE (VRE–MRE) showed a more pronounced reduction in acrophobic fear and avoidance compared to the mere reactivation of such experiences (VRE–MR) in combination with VRE and/or VRE alone. The beneficial effects of the VRE–MRE intervention (relative to both the VRE–MR and VRE conditions) on acrophobic behavior were evident on the behavioral level (i.e., behavioral avoidance as indexed by the BAT score) as well as on the subjective level (i.e., subjective fear at the initial approach distance of the BAT and scores on the AQ) from pre- to post-treatment.

Our findings are in line with recent studies using positive autobiographical memory activation to increase higher self-efficacy (e.g., Brown et al. 2016; Morina et al. 2017). The cognitive and neurobiological mechanisms of episodic/autobiographical memories are well explored (Pause et al. 2013). Alterations in the retrieval of (positive) episodic and autobiographical memories can have a detrimental effect on social and emotional functioning (Zlomuzica et al. 2014, 2018). There is increasing evidence that the capability to retrieve and reinstate personal events from the past and the potential future serves a number of adaptive functions (Breeden et al. 2016; Dere et al. 2018; Margraf and Zlomuzica 2015; Zlomuzica et al. 2014). For instance, recalling autobiographical memories can promote adaptive emotion regulation strategies (Carl et al. 2013), alter the hypothalamic–pituitary–adrenal axis stress response (Speer and Delgado 2017) and reduce temporal delay discounting (Lempert et al. 2017). Evidence from experimental and clinical work suggests that the retrieval of specific memories is less specific and fragmented during increased (negative) emotional activation (Kleim et al. 2014; Zlomuzica et al. 2014, 2016).

In the present study, we therefore applied a procedure that goes beyond the mere retrieval of autobiographical memories. Focusing on the inhibitory learning framework, we developed an intervention centered at the basic assumption of "expectancy violation" as a fundamental

ingredient of successful exposure therapy. Thus, our intervention combines the retrieval of specific experiences and its contextual details but also the reactivation of positive emotional changes which are presumed to be established whenever a demanding situation has been mastered (see Craske et al. 2014, 2018) despite the prior expectancy of negative consequences. In accordance with this hypothesis, our intervention led to positive changes in self-efficacy. While in previous studies similar interventions to augment self-efficacy have been shown to improve episodic future thinking and problem solving (Brown et al. 2016) and to reduce distress tolerance in PTSD (Brown et al. 2016), the results of the present study extend these findings. In particular, our intervention proved to successfully promote exposure-induced decrease in fear and avoidance. As such, our findings contribute important empirical evidence that a post-session discussion of mastery experiences derived from exposure is valuable after exposure. Most importantly, the differential effects of the VRE–MRE versus VRE–MR conditions highlight that this discussion should ideally focus on the mismatch between the expected and actual consequences, according to the central idea of the inhibitory learning framework (Craske et al. 2014, 2018).

Basic and translational work on fear extinction, which is analogous to exposure, may account for the herein observed effect. Exposure is considered a prototype of a therapy setting in which subjects acquire corrective experiences through mastery of fear-inducing scenarios. Reactivation and updating of experiences that have led to increased self-efficacy beliefs might contribute to an enhanced consolidation of corrective experiences. We have demonstrated a similar effect for extinction memories (Zlomuzica et al. 2015). In particular, a positive verbal feedback that leads to increased self-efficacy and positive mood promoted both the acquisition and consolidation of extinction memories (Zlomuzica et al. 2015). Thus, the present study provides an example of how such findings can be transferred to the therapy setting in order to promote corrective experiences and to increase exposure therapy efficacy for anxiety disorders. We further provide an example of how self-efficacy after exposure can be further enhanced. Notably, only the VRE–MRE (but not VRE and VRE–MR) group showed substantial increases in perceived self-efficacy, which might be due to the reactivation and evaluation of expectancy violation during exposure (and similar demanding experiences), which were the focus of our MRE intervention. Accordingly, such an intervention might have reactivated the associated feeling of having successfully mastered a challenging and demanding situation. In support, perceived self-efficacy is strongly implicated in the development and maintenance of phobic behavior (Williams and Watson 1985), and changes in perceived self-efficacy after exposure have been identified as significant predictors of a positive symptom improvement and reduction in avoidance behavior (Brown et al. 2014; Goldin et al. 2012).

Interestingly, it has been shown that increasing perceptions of self-efficacy in participants with PTSD is accompanied by changes in neural processing in regions implicated in the consolidation of extinction memories (Titcombe-Parekh et al. 2018). Accordingly, interventions which lead to enhanced self-efficacy following VRE might have contributed to an increased activation of neural pathways modulating the acquisition and consolidation of extinction memories, that is, medial prefrontal cortex and dorsal/ventral striatum (Phan et al. 2002; Rodriguez-Romaguera et al. 2012). This conclusion is speculative and needs further confirmation in future studies. Interestingly, Zbozinek et al. (2015) demonstrated a similar effect for extinction memories by using other interventions such as positive imagery training. Participants receiving positive imagery prior to extinction exhibited a decreased CS + negative valence during extinction and showed reduced reinstatement of fear in a differential fear conditioning paradigm. This is partially in line with our findings showing that increased self-efficacy also promotes the acquisition of extinction memories (Zlomuzica et al. 2015). Thus, it would be interesting to test whether increasing self-efficacy (similar to positive imagery training) prior to exposure could equally promote long-term exposure benefit. Finally, given that an increased relapse after successful treatment represents another major challenge of exposure-based therapy, one might test the efficacy of these interventions to increase treatment generalization (e.g., Preusser et al. 2017; Raeder et al. 2019) with the overall aim to reduce relapse phenomena.

A number of limitations must be mentioned. We utilized a brief VRE, that is, yielding suboptimal treatment effects, as a means for demonstrating the add-on benefit of the VRE–MRE intervention. This allowed to detect an additional treatment gain in participants receiving a combination of brief exposure and MRE (i.e., VRE–MRE). However, when applying a standard exposure used in routine care (e.g., (prolonged) in vivo exposure), the extent of the additional benefit of incorporating MRE needs to be examined. In addition, the generalization of the present findings to other anxiety disorders awaits further investigation.

Notably, the observed effects were not coherently evident during the follow-up assessment. Precisely, in the reduced sample that participated in the follow-up assessment, participants receiving the VRE–MRE intervention outperformed *either* the VRE or VRE–MR group with respect to the change in BAT score as well as subjective fear at the initial approach distance, respectively, from pretreatment to follow-up. This might relate to the high dropout rate, which, in turn, might reduce the statistical power. In accord, an additional intention-to-treat analysis showed

that the effects of the VRE–MRE condition relative to *both* VRE and VRE–MRE were indeed maintained on measures of behavioral avoidance and subjective fear (initial approach distance). However, in none of these analyses these effects could be maintained on self-report measures, that is, the AQ. This might be related to the desynchrony of fear reduction as manifested on different long-term outcome measures (Mystkowski et al. 2002; Rodriguez et al. 1999). Alternatively, the BAT and AQ might relate differently to actual coping in a specific height scenario (as assessed with the BAT) versus more general coping capabilities in diverse height-phobia related situations (as measured with the AQ).

Finally, the mechanisms governing the herein observed effects need further exploration. While the VRE–MRE group might have profited from the intervention due to a specific facilitation of extinction memory consolidation, a general increase in perceived self-efficacy and coping capabilities, that is, perceived belief to perform adequately in similar fear evoking scenarios, may account for the decreased fear and avoidance during the post-assessment. Future investigations which focus on changes in neuronal processing in selected neuronal circuits (see also Titcombe-Parekh et al. 2018) in relation to the specific interventions (i.e., MRE and MR) would provide significant insights on the mechanisms of the effects of selective reactivation of mastery experiences on fear and avoidance in patients with anxiety disorders.

In line with the former, it needs to be acknowledged that the current study design does not permit conclusions as to whether reactivating mastery experiences that specifically correspond to the exposure content is the core ingredient prompting the beneficial effects of the MRE relative to the MR intervention. Future research could examine the possible differences in the effects of reactivating mastery experiences that are either irrespective of exposure content or related to it.

Concluding, our results indicate that the reactivation of specific events containing mastery experiences in combination with VR exposure can be a promising add-on treatment to further decrease fear and avoidance in height phobia. It remains to be determined whether such interventions go along with changes in neural activation in the fear extinction network. Additional studies investigating whether such interventions are suitable to enhance (in vivo) exposure-based therapy outcome in different anxiety disorders are needed.

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## Compliance with Ethical Standards

**Conflict of Interest** Friederike Raeder, Marcella L. Woud, Silvia Schneider, Christina Totzeck, Dirk Adolph, Jürgen Margraf, and Armin Zlomuzica declare that they have no conflict of interest.

**Informed Consent** Informed consent was obtained from all individual participants included in the study.

**Research Involving Human Participants** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Animal Rights** No animal studies were carried out by the authors for this article.

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