



## Bifocal emotion regulation through acupoint tapping in fear of flying

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### ARTICLE INFO

#### Keywords:

Emotion regulation  
Acupoint tapping  
PEP  
Specific phobia  
Fear of flying  
Functional magnetic resonance imaging

### ABSTRACT

Very few studies have investigated the neural underpinnings of bifocal-multisensory interventions such as acupoint tapping (tapping) despite their well-documented efficacy. The present study aims to investigate the neural and behavioral responses to tapping during the perception of phobic and generally fear-inducing stimulation in a group of participants with fear of flying. We studied 29 flight-phobic participants who were exposed to phobia-related, fear-inducing and neutral stimulation while undergoing fMRI and a bifocal-multisensory intervention session consisting of tapping plus cognitive restructuring in a within-subject design. During tapping we found an up-regulation of neural activation in the amygdala, and a down-regulation in the hippocampus and temporal pole. These effects were different from automatic emotion regulatory processes which entailed down-regulation in the amygdala, hippocampus, and temporal pole. Mean scores ( $\pm$ SD) on the Fear of Flying scale dropped from  $2.51(\pm 0.65)$  before the intervention to  $1.27(\pm 0.68)$  after the intervention ( $p < .001$ ). The proportion of participants meeting the criteria for fear of flying also dropped from 89.7 percent before the intervention to 24.0 percent after the intervention ( $p < .001$ ). Taken together, our results lend support to the effectiveness of tapping as a means of emotion regulation across multiple contexts and add to previous findings of increased amygdala activation during tapping, as opposed to amygdala down-regulation found in other emotion regulation techniques. They expand on previous knowledge by suggesting that tapping might modulate the processing of complex visual scene representations and their binding with visceral emotional responses, reflected by the down-regulation of activation in the hippocampus and temporal pole. Bifocal emotion regulation was useful in ameliorating aversive reactions to phobic stimuli in people with fear of flying.

### 1. Introduction

Fear of flying (aviophobia) is a specific phobia of the situational type and is characterized by a marked, persistent, excessive fear induced by the immediate prospect or experience of air travel (American Psychiatric Association, 2013). It is a widespread phenomenon in Western civilization: only about 50% feel comfortable with flying, whereas 10–15% are affected by significant fear and another 22% feel discomfort while flying (Agras et al., 1969; Curtis et al., 1998; Institut für Demoskopie Allensbach, 2003). Stinson et al. (2007) report a prevalence of about 2.9% for aviophobia classified according to DSM-IV criteria. Fear of flying can restrict the person's personal and professional life and can provoke high levels of suffering, and the affected person usually identifies the activated fear response as unreasonable (Schindler et al., 2017). Correspondingly, a substantial body of work shows that the

ability to successfully modify emotions (i.e. emotion regulation), plays an essential role for subjective well-being (Diener and Ryan, 2009; Diener et al., 2009; Lewis et al., 2014) and that failure to self-regulate is associated with various social and mental health issues, as well as with imbalanced limbic-prefrontal processing (Heatherton and Wagner, 2011). Successful emotion regulation encompasses a host of strategies, ranging from more automatic to more controlled, all of which aim to influence emotions in their intensity, duration and nature (Ochsner et al., 2012). When performing uninstructed emotion regulation in daily life, people with anxiety use various strategies such as thought suppression, coercion, or direct avoidance at the behavioral level, as well as more subtle forms of avoidance such as distraction, mental rituals or security behavior. These strategies can lead to relief in the short term, however, they contribute to maintaining fear in the long term and are therefore counterproductive (Gross and Levenson, 1997, 1993; Parrish

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et al., 2008). As stated above, emotions and the impaired ability to regulate emotions play a part in various psychopathological conditions (Heatherington and Wagner, 2011). Emotions are multi-faceted and have a strong physiological component, which is why bifocal-multisensory intervention techniques use physiological stimulation as a means to achieve emotion regulation (Bohne, 2021; Dael et al., 2012; Shapiro, 2017). The term bifocal-multisensory intervention technique originates from Aalberse et al. (2012) and subsumes approaches with a two-part attentional focus in which attention is directed simultaneously towards negative emotional material and to a form of sensory stimulation. Acupoint tapping techniques such as Process- and Embodiment-focused Psychology (PEP) and Emotional Freedom Technique (EFT) or techniques such as Eye Movement Desensitization and Reprocessing (EMDR) share these characteristics (Bohne, 2021; Church, 2013; Shapiro, 2017). Depending on the approach, sensory stimulation can refer to different sensory modalities. While EMDR mainly uses eye movements, acupoint tapping techniques (tapping) use a sensory-tactile stimulation of different points on the skin. Bifocal-multisensory intervention techniques are clinically effective in regulating negative emotions, possibly by facilitating and enhancing both the healthy experience and the competent handling of unwanted feeling states. It is thought that the concomitant sensory stimulation functions as a kind of anchor and safety signal while participants are experiencing aversive feeling states, and that this anchor allows for the emotional reaction to 'run its course' instead of getting stuck in dysfunctional loops. When the initial strong emotional reaction has subsided, new and helpful thought patterns and beliefs are installed to ameliorate negative reactivity to the same kind of stimulation in the future (Bohne, 2021; Shapiro, 2001). Results of studies investigating tapping techniques show that especially patients with conditions characterized by high physiological arousal such as specific phobias and post-traumatic stress disorder (PTSD) benefit from this type of intervention (Clond, 2016; Feinstein, 2012). More specifically, tapping techniques including EFT and TFT (Thought Field Therapy) showed lasting (>12 months) and replicable reductions of anxiety and increases in the ability to approach phobic stimuli in participants with agoraphobia (Irgens et al., 2017), small animal phobia (Baker and Siegel, 2010; Salas et al., 2011; Wells et al., 2003a) and other specific phobias (Salas et al., 2011). These effects are unlikely to be due to nonspecific effects such as active factors of established psychotherapeutic interventions, regression to mean, fatigue, passing of time or practice effects: tapping techniques show greater effects than both diaphragmatic breathing (Wells et al., 2003a), supportive interviews or waiting (Baker and Siegel, 2010), and their efficacy is comparable with the effects of Cognitive Behavioral Therapy (CBT; (Irgens et al., 2017)).

Despite their clinical popularity and effectiveness, the emotion regulatory features of bifocal-multisensory techniques have to date received little attention in neuroscientific research. The neuroscientific study of emotion regulation traditionally centers cognitive emotion regulatory strategies such as reappraisal, distraction or detachment in healthy individuals (Dörfel et al., 2014; Ochsner et al., 2012; Schardt et al., 2010) and the neural and behavioral effects of cognitive-behavioral therapy and exposure therapy in individuals with various psychopathologies (Álvarez-Pérez et al., 2021; Paquette et al., 2003; Straube et al., 2006; Viña et al., 2020).

A recent study from our group provides first time evidence of neural and behavioral effects of visualized and actual acupoint tapping (tapping) in response to two types of aversive emotional stimuli in healthy participants (Wittfoth et al., 2020). In it, we find increased amygdala activation and decreased ventral anterior cingulate cortex activation during emotion regulation. We also find stimulus type-dependent regulatory effects in response to disgust-inducing scenes, but not fear-inducing scenes, both with respect to negativity ratings, and with respect to neural activation e.g. in the dorsolateral prefrontal cortex (dlPFC). Similarly, Herkt et al. (2014) investigated the effects of auditory EMDR on the neural and behavioral correlates of the perception of disgust-inducing scenes in healthy volunteers. Bilateral alternating

auditory stimulation entailed neural activation increases in the amygdala and activation decreases in the dorsolateral prefrontal cortex. Measurements of subjective affectedness remained unchanged both during bilateral simultaneous auditory stimulation and during bilateral alternating auditory stimulation. The pattern of neural activation and behavioral responses observed in these two studies of bifocal multisensory emotion regulation is particularly interesting as it is distinct from the pattern found in cognitive emotion regulation (Herkt et al., 2014; Wittfoth et al., 2020). A large body of literature shows that the application of cognitive strategies of emotion regulation is consistently characterized by reduced limbic (particularly amygdala) activation and increased prefrontal activation, while negativity ratings are commonly reduced (Braunstein et al., 2017; Ochsner et al., 2012). Furthermore, the increase in limbic activation and decrease in prefrontal activation following bifocal multisensory emotion regulation seems counterintuitive at first, particularly regarding clinical populations with dysfunctional emotional processing (Álvarez-Pérez et al., 2021; Paquette et al., 2003; Straube et al., 2006; Viña et al., 2020). Given the effectiveness of bifocal multisensory interventions in reducing negative affect and symptom severity in various clinical settings ranging from specific phobia (Baker and Siegel, 2010; Feinstein, 2012; Irgens et al., 2017; Salas et al., 2011; Wells et al., 2003b) to PTSD (Church, 2014; Church et al., 2018, 2016; Church and Feinstein, 2013; Gilomen and Lee, 2015; Karatzias et al., 2011), one would hypothesize to find a decrease in neural activation in regions underlying emotional processing, along with an increase in regions underlying cognitive control (Braunstein et al., 2017; Buhle et al., 2014; Denny et al., 2015; Morawetz et al., 2017; Ochsner et al., 2012). Theoretical models of bifocal emotion regulation however posit that a split of attentional focus between emotional stimulation and physiological stimulation can facilitate working through unwanted negative emotions in a way that is more conducive to one's wellbeing. Bifocal multisensory stimulation is thought to allow a person to remain with the negative stimulus long enough to let the emotion run its course, without defaulting to unwanted phobic or traumatic responses. The prolonged processing of the emotional stimulus in a state that allows for a new way of integrating it might in turn be represented by higher limbic activation and decreased prefrontal activation observed during the application of bifocal multisensory regulation (Herkt et al., 2014; Wittfoth et al., 2020).

### 1.1. Objectives

To date, empirically informed models about both the minimal and the critical components of bifocal-multisensory interventions, particularly those using tapping, remain elusive (Bohne, 2021; Church, 2013). The primary goal of the present work is to elucidate the immediate neural and behavioral effects of tapping as an emotion regulatory strategy during the perception of phobia-related and generally fear-inducing emotional picture stimuli in a group of participants with fear of flying. During tapping, we expect increased amygdala activation and reduced activation in the ventral anterior cingulate cortex compared to passive viewing of aversive stimuli. At the behavioral level, we assume that stimulus ratings are maintained during tapping (Herkt et al., 2014; Wittfoth et al., 2020). Comparing phobia-related pictures as well as generally fear-inducing pictures, we also address stimulus type-dependent effects of emotional perception and emotion regulation through tapping in the presence of fear of flying. Since valence and arousal interactively mediate approach and avoidance tendencies to various stimulus types (Ascheid et al., 2019; Citron et al., 2016, 2014; Feng et al., 2012), we measured these two rating dimensions separately to assess whether they are dependent on stimulus type, and whether they vary differently in response to tapping. We assume that tapping is effective in reducing arousal ratings, particularly for phobic stimulation (Clond, 2016), while negativity ratings are maintained across aversive stimulus types (Herkt et al., 2014; Wittfoth et al., 2020). Furthermore, we address the influence of a one-time bifocal-multisensory intervention

session on behavioral concomitants of fear of flying. The present study uses PEP, which is a combination of emotion-regulating interventions and transformations of core beliefs (Bohne, 2021). It aims to bring unconscious, symptom-producing dynamics into consciousness and to transform them into health-promoting strategies that foster a positive self-relationship. Emotion regulation is achieved by tapping sixteen body points in a fixed order (on non-dominant hand: 'karate chop', back of hand, little finger, middle finger, index finger, thumb; on the face: root of the nose, middle of eyebrow, beside eye, under eye, under nose, chin; on the upper body: below clavicle, side of ribcage, lower ribs (front, with both hands), sternum) while participants are experiencing stress, fear, anger, helplessness or other unpleasant feelings. Tapping continues until the intensity of the disturbing emotions is sufficiently attenuated. In a second step, participants speak affirmations of self-acceptance and self-empowerment while performing a circular motion with all fingers of their dominant hand on the area below the contralateral clavicle. Participants then go through a set of cognitive restructuring steps that are designed to bring them back into a state of competence and resolution (Bohne, 2021). Earlier research suggests that a single intervention session is sufficient to lead to a significant reduction in symptoms of various anxiety-related disorders including specific phobias, e.g. fear of flying and claustrophobia (Clond, 2016; Öst et al., 2001, 1997; Salas et al., 2011; Zlomke and Davis, 2008). Thus, we assume that a one-time PEP intervention session effectively reduces fear of flying, more specifically valence and arousal ratings in response to phobia-related emotional material and scores on a fear of flying questionnaire.

## 2. Materials and methods

### 2.1. Participants

A total of thirty-one participants matching the criteria for aviophobia were investigated in the present study. Participants were recruited from the population of staff and students of Hannover Medical School and Hannover University. Potential participants were screened using the Fear of Flying Screening Scale (FSB) from the Fear of Flying and Aviophobia Inventory (FAPI). Exclusion criteria were acute or past neurological, psychiatric or endocrine conditions, as well as use of psychotropic medication. Hannover Medical School's Ethics Committee granted ethical approval under Ethics Vote No. 6445, and we obtained written informed consent from each participant in accordance with the Declaration of Helsinki (World Medical Association, 2013). Data from two participants were excluded from the present analysis due to incomplete fMRI data (one developed vertigo during scanning, one did not comply with the experimental paradigm). The final analysis of functional imaging data, in-scan behavioral data, and personality questionnaires included a subset of twenty-nine participants between ages 19 to 59 (mean age = 37.24 years, SD = 11.91, 18 female; 25 right-handed, two left-handed, two ambidextrous). Out of this group, subjective units of discomfort (SUD) ratings for flying are available from twenty-five participants who attended a one-time bifocal-multisensory intervention session, which also served as compensation for participation.

### 2.2. Study design

Participants attended two separate appointments at Hannover Medical School. During the first two-hour session ('scanning session'), they underwent an fMRI measurement and filled in personality questionnaires assessing depressive symptoms (BDI-II), trait anxiety (STAI-T), general self-efficacy (SWE) and subjectively perceived emotion regulation skills (SEK-27). During the second appointment ('intervention session'), participants attended a 60–90 min bifocal-multisensory intervention session (PEP (Bohne, 2021)) regarding their fear of flying with one of four trained practitioners (DW, JB, MB, MW). The Fear of

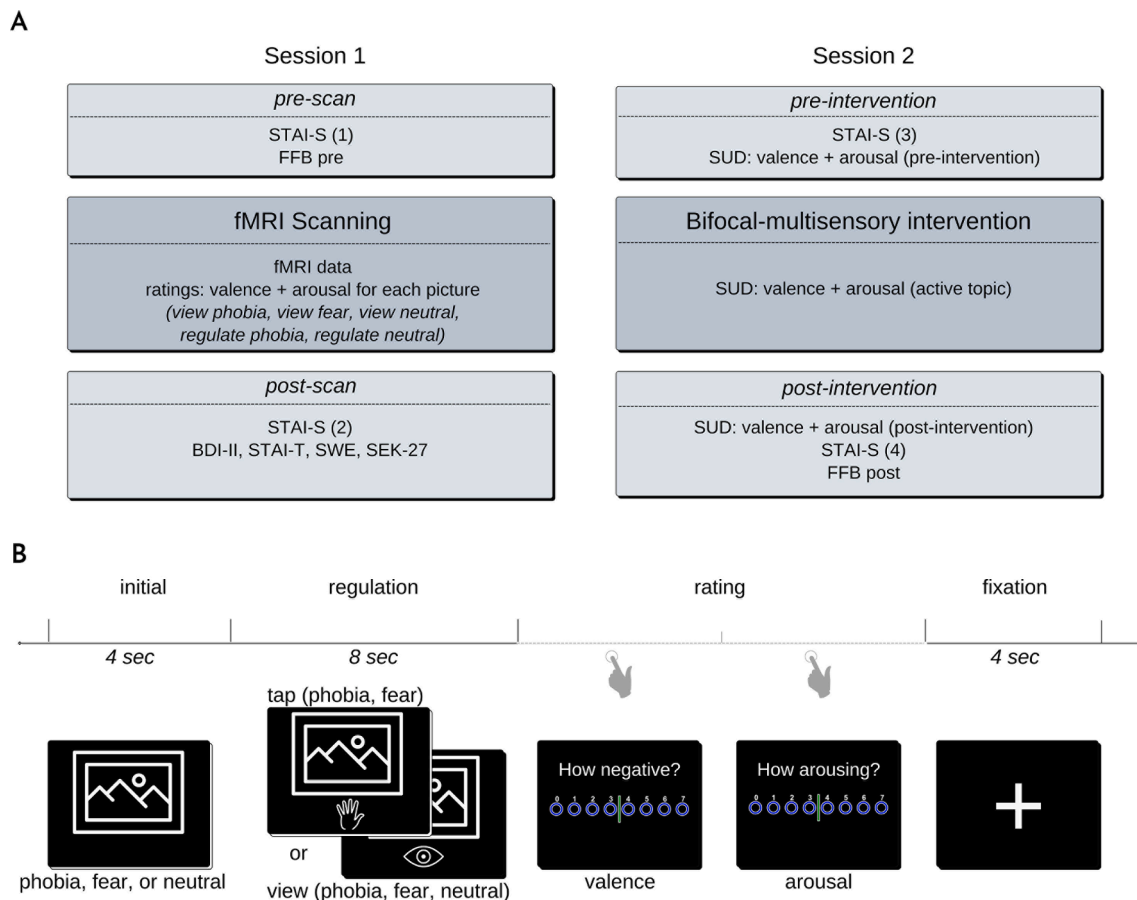
Flying and Aviophobia Scale (FFB) from the FAPI were filled in twice: i) before the scanning session, and ii) after the intervention session. We also recorded changes in state anxiety using the state version of the State-Trait Anxiety Inventory (STAI-S) before and after fMRI scanning as well as before and after the bifocal-multisensory intervention session. The study design is summarized in Fig. 1A.

#### 2.2.1. Experimental paradigm and behavioral data acquisition

While in the fMRI scanner subjects viewed phobia-related pictures collected from public resources (e.g. airport scenes, insides of airplanes, views from airplane windows), as well as generally fear-inducing pictures and neutral pictures from the International Affective Picture System (IAPS) and the Nencki Affective Picture System (NAPS) (Bradley et al., 2001; Lang et al., 1993; Marchewka et al., 2014). The stimulus set consisted of 90 slides: 30 fear-inducing pictures, 30 phobia-related pictures, 30 neutral pictures. The picture categories were matched with respect to picture content and valence ratings when available. The 30 neutral stimuli and half of the aversive stimuli (15 fear-inducing stimuli and 15 phobia-related stimuli) were presented in the viewing condition; the other half of the aversive stimuli (15 fear-inducing stimuli and 15 phobia-related stimuli) were presented in the regulation condition. Thus, the resulting five stimulus categories were viewing fear-inducing stimuli (vF), viewing phobia-related stimuli (vP), viewing emotionally neutral stimuli (vN), regulating fear-inducing stimuli (rF) and regulating phobia-related stimuli (rP). The experimental paradigm was presented on an MR-compatible 40-inch LCD screen (Nordic NeuroLab, Bergen, Norway) using Presentation® Version 17.1 (Neurobehavioral Systems, Inc., Berkeley, CA, USA). The stimuli were presented in a slow event-related within-subject design in pseudo-randomized order (i.e. a maximum of two images of the same condition were presented consecutively). Each stimulus was visible for 12 s. In the first four seconds participants were instructed to simply look at the picture attentively (initial phase). During the following eight seconds, one of two symbols (eye, hand) instructed participants to continue looking at the picture and to let emotions unfold naturally (viewing condition indicated by the 'eye' symbol) or to rhythmically tap on their sternum with all fingers of their right hand while looking at the picture (regulation condition indicated by the 'hand' symbol). The presentation of each stimulus was followed by a rating of valence ('How negative?') and arousal ('How arousing?'). Participants rated both dimensions on an 8-point Likert scale from 0-'weak' to 7-'strong' by pressing one of two buttons with their right hand index finger or thumb on an MR-compatible response grip (Nordic NeuroLab, Bergen, Norway). After completing both ratings participants saw a fixation cross for four seconds before the presentation of the next trial. Fig. 1B gives an overview of the experimental paradigm. Directly before fMRI scanning participants underwent a training session on a desktop computer to practice the viewing and tapping instructions, as well as the rating procedure. This approximately 5-minute training run presented on a desktop showed pictures that were similar to the pictures presented inside the fMRI scanner. Participants were instructed to tap when they saw the hand symbol, and to subsequently rate the pictures with their dominant hand. Participants were naïve to the purpose of tapping as it was introduced as an exercise rather than an emotion regulation technique. During the intervention session (50–60 min), participants underwent a bifocal-multisensory intervention (Bohne, 2021) and provided ratings of subjective units of discomfort (SUD; (Wolpe, 1969)) regarding flying. Here, participants were asked to rate both valence ('How negative?') and arousal ('How arousing?') when thinking about flying on a scale from 0-'none' to 10-'very much'. We collected SUD ratings at the beginning of the session, after activation of the topic (i.e. bringing to mind the most aversive aspects of flying), and after completion of the intervention session (compare Fig. 1A).

#### 2.2.2. Functional imaging data acquisition

We recorded fMRI data using a 3 T whole-body MR scanner



**Fig. 1. Experimental Setup.** A: Participants completed fMRI scanning in session 1, and a one-time bifocal-multisensory intervention (PEP (Bohne, 2021)) in session 2. Before and after each session, they filled in various questionnaires. They gave valence ratings and arousal ratings following each picture in session 1 and for thoughts of flying pre-intervention, after immersion into the topic (active topic) and post-intervention in session 2. B: Each trial of the emotion regulation paradigm that participants completed during fMRI scanning began with an initial phase of four seconds where participants simply looked at a phobia-related, fear-inducing or neutral picture. During the subsequent 8 s long regulation phase participants either continued simply looking at the picture (view), or they looked at the picture while simultaneously performing tapping (tap). After each picture, they gave valence and arousal ratings on a scale from 0 (weak) to 7 (strong). Each trial ended with the presentation of a fixation cross for four seconds. STAI-S: State version of the State-Trait Anxiety Inventory; FFB: Fear-of-Flying Questionnaire; BDI-II: Beck's Depression Inventory; STAI-T: Trait version of the State-Trait Anxiety Inventory; SWE: Self-Efficacy Questionnaire; SEK-27: Subjectively Perceived Emotion Regulation Skills; SUD: Subjective Units of Discomfort.

(MAGNETOM Skyra, Siemens Healthineers, Erlangen, Germany) with a 64-channel head/neck coil. We used foam pads to stabilize the participant's head and to minimize head movement. The scan protocol consisted of: 1) Functional whole brain gradient-echo echo-planar images (TR = 1180 ms, TE = 32 ms, 2 mm isometric resolution, matrix size 104 × 90 × 78 (FE × PE × Slices), echo spacing 0.71 ms, bandwidth 1718 Hz/Px, flip angle 64°, PE encoding direction A->P, SMS = 6, Partial Fourier 7/8, Filter = prescan normalization, slice orientation AC-PC + 30°, no interslice gap, 3 automatic dummy volumes); 2) Reference scan: equivalent to 1) without multiband acceleration (TR = 6770 ms); 3) Reference scans for unwarping: Two spin-echo images matched to 1) in distortion, without multiband acceleration, one with the same, the other with inverted phase encoding direction; 4) T1-weighted structural scans (1 mm isometric).

### 3. Data analysis

#### 3.1. Ratings and questionnaires

To make them comparable, we calculated standardized mean scores ( $\pm$ SD) by dividing raw scores by the number of possible answers minus 1 for in-scan valence and arousal ratings from the five experimental conditions and for SUD valence and arousal ratings regarding flying

collected during the intervention session (pre-intervention, after activation of the topic, post-intervention). We also calculated mean scores ( $\pm$ SD) for all personality questionnaires, for pre-intervention and post-intervention aviophobia scores, and for pre-intervention and post-intervention state anxiety measures from the scanning session and from the intervention session. We investigated associations between initial aviophobia scores and scores from the personality questionnaires by means of Pearson correlations at a one-sided  $p < .01$ . We compared in-scan valence and arousal ratings across stimulus types in the viewing condition by means of a within-subjects repeated measures ANOVA with the factors 'dimension' (valence, arousal) and 'stimulus type' (fear-inducing, phobia-related, neutral). In a second ANOVA investigated the main effects and interactions of the factors 'dimension' (valence, arousal), 'regulation' (viewing, regulation) and 'emotion' (fear-inducing, phobia-related) for the two aversive picture types only. For the twenty-five subjects who participated in the intervention session, we compared SUD valence and arousal ratings in a within-subjects repeated measures ANOVA with the factors 'dimension' (valence, arousal) and 'regulation' (pre-intervention, after topic activation, post-intervention). For this subset of participants, we also compared the effects of regulation between the scanning session and the intervention session. We included in-scan valence and arousal ratings for phobia-related stimuli and SUD valence and arousal ratings from the intervention session in a within-

subjects repeated-measures ANOVA with the factors ‘session’ (scanning, intervention), ‘dimension’ (valence, arousal) and ‘regulation’ (unregulated, regulated). The effects of regulation on state anxiety were investigated by comparing pre- and post-session STAI-S scores across appointments in a within-subjects ANOVA with the factors ‘session’ (scanning, intervention) and ‘time’ (pre-session, post-session). We report all above-mentioned ANOVAs at a statistical threshold of  $p < .05$  along with Bonferroni-corrected ( $p < .05$ ) post-hoc tests. In a next step, we assessed the effects of the bifocal-multisensory intervention on the presence of aviophobia. To this end, we i) calculated a paired t-Test ( $p < .05$ ) comparing FFB scores pre-intervention and post-intervention and ii) compared the proportion of participants with above-cutoff scores from the initial FFB measurement to the proportion of participants meeting the criteria for aviophobia post-intervention by means of a Chi-Square Goodness of Fit Test ( $p < .05$ ).

### 3.1.1. Functional data

Data were minimally processed using FSL to avoid unnecessary resampling steps. The pipeline consisted of only two spatial and one temporal resampling step. Motion correction (MCFLIRT (Jenkinson et al., 2002)) and unwarping (topup (Andersson et al., 2003; Smith et al., 2004)) were applied at the same time. After brain extraction (BET (Smith et al., 2004)), grand mean scaling and high pass filtering (0.01 Hz) were applied. A study template was generated using Advanced Normalization Tools (ANTs (Avants et al., 2011)) and the unwarped reference images (Andersson et al., 2003). The program uses a SyN (symmetric image normalization) algorithm and N4Bias field correction. The advantages of a study template are manifold. First of all, as an EPI-template, it does not suffer from transformation problems between EPI- and T1-images. Secondly, the template is created using the study population. Hence, transformations are less aggressive. All functional data were normalized to this template and smoothed with a 5 mm Gaussian kernel prior to statistical analysis. In order to register the results to MNI with high precision, we first generated a T1 study template. We then calculated the transformations between the EPI and the T1 template (6 degrees of freedom), and between the T1 and the MNI template (non-linear). Both transformations were applied to the results at the same time to minimize resampling.

We computed first level and group level statistics in SPM12. For each participant, we computed contrast images for the initial phase of stimulus presentation for fear-inducing [iF], phobia-related [iP] and neutral stimuli [iN], as well as the subsequent phases of viewing or regulating fear-inducing (view fear [vF], regulate fear [rF]), phobia-related pictures (view phobia [vP], regulate phobia [rP]) and neutral pictures (view neutral [vN]). We also included regressors for the valence and arousal rating phases. The fixed effects models for each participant were corrected for serial autocorrelations (AR1) and low frequency signals (high-pass filter of 128 s). The boxcar regressors were convolved with the canonical hemodynamic response function implemented in SPM 12. We calculated two random effects group level analyses. The first model aimed at elucidating general effects of picture viewing on the different stimulus types. The second model investigated the neural correlates of tapping as an emotion regulation strategy while viewing fear-inducing and phobia-related stimuli. To this end, we calculated two full-factorial within-subject GLMs at an FWE-corrected whole brain intensity threshold of  $p < .05$ . The first GLM encompassed the initial phases and the viewing phases of the three picture types and included the two factors ‘phase’ (initial, viewing) and ‘stimulus type’ (fear-inducing, phobia-related, neutral). Firstly, we computed T-contrasts comparing phobia-related stimuli with fear-inducing stimuli across phases ( $[iP + vP] > [iF + vF]$  and  $[iF + vF] > [iP + vP]$ ). We also compared phobia-related stimuli with neutral stimuli ( $[iP + vP] > [iN + vN]$ ) and fear-inducing stimuli with neutral stimuli ( $[iF + vF] > [iN + vN]$ ). Secondly, we contrasted the initial phase and the viewing phase across stimulus types ( $[iP + iF + iN] > [vP + vF + vN]$  and  $[vP + vF + vN] > [iP + iF + iN]$ ). To assess stimulus-type dependent effects across

phases, we also computed T-contrasts for the interaction between the factor ‘phase’ and the factor ‘stimulus type’ ( $[iP > vP] > [iF > vF]$  and  $[iF > vF] > [iP > vP]$ ). The second GLM encompassed the viewing condition and the regulation condition of the two aversive stimulus types. This GLM included the factors ‘condition’ (viewing, tapping) and ‘emotion’ (fear-inducing, phobia-related). Here, we computed T-contrasts comparing the viewing condition with the tapping condition across emotions ( $[rP + rF] > [vP + vF]$  and  $[vP + vF] > [rP + rF]$ ), and the interaction of the factor ‘regulation’ with the factor ‘emotion’ ( $[rP > vP] > [rF > vF]$  and  $[rF > vF] > [rP > vP]$ ). We also computed a post-hoc region of interest (ROI) analysis ( $p < .05$  FWE-corrected) for the amygdala using probabilistic maps extracted from the Juelich Histological Atlas (Amunts et al., 2005) which were transformed to the EPI study template and thresholded at 50% probability.

## 4. Results

### 4.1. Behavioral measures

#### 4.1.1. Measures of fear of flying and habitual emotion regulation

Initial scores from the Fear of Flying Scale (FFB-pre) showed that participants experienced a number of symptoms of fear of flying (mean = 2.53, SD = 0.61) and 26 out of the 29 participants met the criteria for aviophobia. All participants in our sample scored below the cut-off for depression (BDI-II < 14) and reported low levels of depressive symptoms (BDI-II mean = 5.34, SD = 0.69) and medium levels of trait anxiety (STAI-T mean = 35.59, SD = 9.19). Mean ( $\pm$ SD) scores of general self-efficacy and self-reported emotion regulation skills were 31.03 (SD = 4.89; SWE) and 78.45 (SD = 11.53; SEK-27). Participants with greater initial aviophobia scores (FFB-pre) showed more depressive symptoms (BDI-II,  $r(29) = .432$ ,  $p = .010$ ), and reported greater trait anxiety (STAI-T,  $r(29) = 0.458$ ,  $p = .006$ ). Participants with greater initial aviophobia scores also reported lower levels of general self-efficacy (SWE,  $r(29) = -0.420$ ,  $p = .012$ ). We found no association between initial aviophobia scores and self-reported emotion regulation skills (SEK-27,  $p = .017$ ).

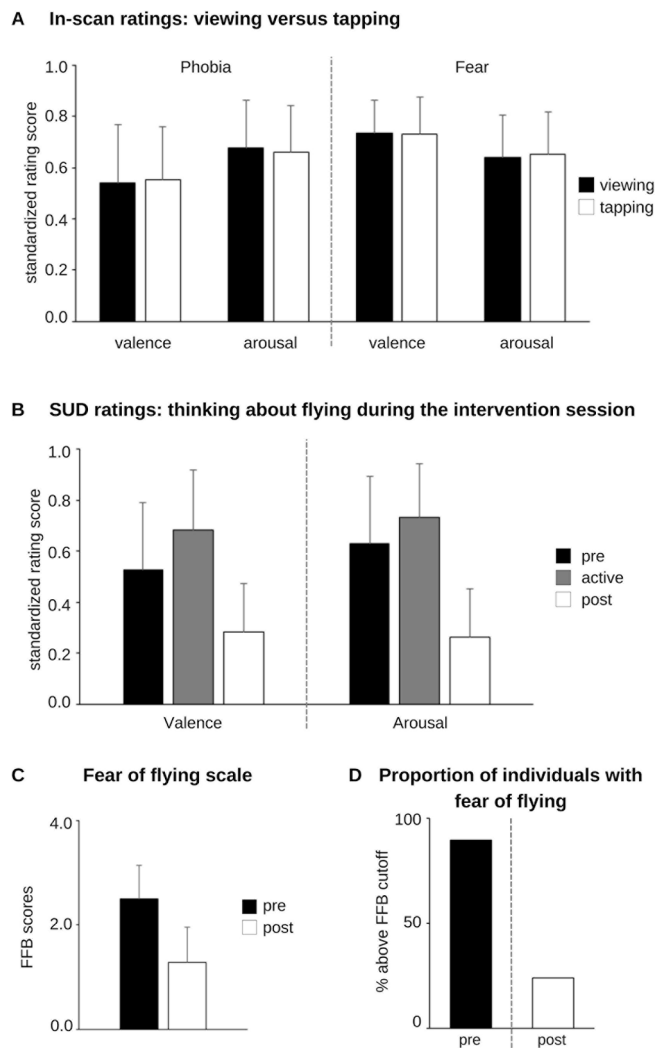
#### 4.1.2. Immediate effects of tapping on valence and arousal ratings

In the viewing condition, valence and arousal varied differently with respect to stimulus type (interaction ‘dimension  $\times$  stimulus type’:  $F(2,56) = 30.17$ ,  $p < .001$ ,  $\eta^2 = 0.519$ ). Post-hoc tests (Bonferroni-adjusted) revealed that participants rated fear-inducing stimuli as more negative both compared with neutral stimuli ( $t(28) = 27.97$ ,  $p < .001$ ) and compared with phobia-related stimuli ( $t(28) = 4.78$ ,  $p < .001$ ). Phobia-related stimuli were rated as more negative than neutral stimuli ( $t(28) = 10.72$ ,  $p < .001$ ). Both fear-inducing stimuli ( $t(28) = 18.79$ ,  $p < .001$ ) and phobia-related stimuli ( $t(28) = 15.74$ ,  $p < .001$ ) were rated as more arousing compared with neutral stimuli. Arousal ratings did not differ between fear-inducing stimuli and phobia-related stimuli ( $p = .406$ ).

Emotion regulation had differential effects on valence and arousal in the two aversive picture conditions (three-way interaction of the factors ‘dimension  $\times$  regulation  $\times$  emotion’,  $F(1,28) = 5.82$ ,  $p = .02$ ,  $\eta^2 = 0.172$ ). In Bonferroni-adjusted post-hoc tests, we found that fear-inducing stimuli were rated as more negative than phobia-related stimuli both in the viewing condition ( $t(28) = 4.78$ ,  $p < .001$ ) and in the regulation condition ( $t(28) = 5.24$ ,  $p < .001$ ). We observed no difference in arousal ratings between fear-inducing pictures and phobia-related pictures in the viewing condition ( $p = .406$ ) and in the regulation condition ( $p = .827$ ). We found no regulation-related differences for fear-inducing stimuli (valence:  $p = .905$ , arousal:  $p = .593$ ) and for phobia-related stimuli (valence: 0.419, arousal: 0.295). In-scan valence and arousal ratings are depicted in Fig. 2A.

#### 4.1.3. Effects of a one-time bifocal-multisensory intervention on fear of flying and measures of discomfort

Valence and arousal SUD ratings are depicted in Fig. 2B. Ratings



**Fig. 2. Behavioral effects of tapping.** A: Standardized mean ( $\pm$ SD) valence and arousal ratings for phobia-related pictures and fear-inducing pictures in the viewing condition (white bars) and in the tapping condition (black bars). Both valence and arousal ratings did not differ between the viewing condition and the tapping condition. Participants rated phobia-related pictures as less negative, but equally arousing compared with fear-inducing pictures. They also rated phobia-related pictures as more arousing than negative and fear-related pictures as more negative than arousing. B: Standardized mean ( $\pm$ SD) SUD valence and arousal ratings when thinking about flying given before the intervention (black bars), after topic activation (grey bars) and after the intervention (white bars). Both valence and arousal ratings increased when participants were actively immersing themselves in thoughts about flying (active). After the intervention, participants gave lower valence and arousal ratings both compared with pre-intervention and compared with topic activation. C: Mean ( $\pm$ SD) FFB scores collected before (black bar) and after the intervention (white bar). Participants scored significantly lower on the fear-of-flying scale after the one-time bifocal-multisensory intervention session. D: Proportions of individuals with above-cutoff FFB scores before (black bar) and after (white bar) the intervention. Fewer participants met the criteria for aviophobia after the intervention compared with before the intervention. SD: Standard Deviation; SUD: Subjective Units of Discomfort; FFB: Fear-of-Flying Questionnaire.

decreased during the intervention session (main effect 'regulation',  $F(2,48) = 64.52$ ,  $p < .001$ ,  $\eta^2 = 0.729$ ). Bonferroni-adjusted post-hoc analyses revealed that both pre-intervention ratings ( $p < .001$ ;  $0.304$ ,  $95\% \text{-CI}[0.201, 0.407]$ ) and ratings after topic activation ( $p < .001$ ;  $0.434$ ,  $95\% \text{-CI}[0.351, 0.517]$ ) were higher compared with post-intervention ratings. Pre-intervention ratings and ratings after topic

activation did not differ ( $p = .022$ ). The effect of regulation on valence SUD ratings and arousal SUD ratings was comparable (interaction 'dimension  $\times$  regulation'  $p = .62$ ). Participants scored lower on the fear of flying questionnaire (FFB) after the intervention session compared with before the intervention session ( $t[24] = 7.55$ ,  $p < .001$ ; Fig. 2C). The proportions of participants meeting the criteria for aviophobia as measured by the FFB was lower after the intervention session compared with before the intervention session ( $\chi^2(1, N = 54) = 23.97$ ,  $p < .001$ ; Fig. 2D).

Comparing valence and arousal ratings for phobia-related pictures in the scanning session with valence and arousal ratings for thoughts of flying in the intervention session, we found that regulatory effects on valence and arousal ratings differed between sessions (three-way interaction 'session  $\times$  dimension  $\times$  regulation',  $F(1,24) = 5.73$ ,  $p = .025$ ,  $\eta^2 = 0.193$ ). Bonferroni-adjusted post-hoc tests showed that valence ratings for unregulated phobia-related material were comparable in the scanning session and in the intervention session ( $p = .656$ ). The same was true for arousal ratings for unregulated phobia-related material ( $p = .349$ ). Regulated phobia-related material, however, was rated as both less negative ( $t(24) = -5.35$ ,  $p < .001$ ) and less arousing ( $t(24) = -8.31$ ,  $p < .001$ ) in the intervention session compared with the scanning session. In the scanning session, we found that regulation left both negativity ratings ( $p = .419$ ) and arousal ratings ( $p = .295$ ) unchanged. In the intervention session, however, regulation attenuated both negativity ratings ( $t(24) = 6.09$ ,  $p < .001$ ) and arousal ratings ( $t(24) = -7.65$ ,  $p < .001$ ). In the scanning session, participants rated phobia-related material as more negative than arousing both in the unregulated condition ( $t(24) = 4.45$ ,  $p < .001$ ) and in the regulated condition ( $t(24) = 3.36$ ,  $p = .002$ ). In the intervention session, we found no difference between negativity ratings and arousal ratings both in the unregulated condition ( $p = .066$ ) and in the regulated condition ( $p = .546$ ). Comparing state anxiety measures for  $N = 19$  participants with complete data sets for the STAI-S, we found a main effect of the factor 'time' ( $F[1,18] = 21.63$ ,  $p < .001$ ,  $\eta^2 = 0.546$ ). Bonferroni-adjusted post-hoc analysis revealed that post-session state anxiety scores were lower compared with pre-session state anxiety scores ( $p < .001$ ,  $-7.42$ ,  $95\% \text{-CI}[-4.07, -10.78]$ ). There were no differences in state anxiety between the scanning session and the intervention session (main effect 'session':  $p = .939$ ) and no interactions of the two factors 'session' and 'time' ( $p = .523$ ).

#### 4.2. Neural responses

In the following we list regions showing significant ( $p < .05$  FWE-corrected) activation in the whole-brain analyses for the respective contrasts. We also report results from anatomically constrained ROI analyses in the amygdala at an FWE-corrected  $p < .05$ . We summarize anatomical labels and MNI coordinates of cluster maxima, cluster sizes and t-scores for the activated regions in Tables 1-3.

##### 4.2.1. Responses to phobia-related pictures and fear-inducing pictures over time

In a first step, we compared neural responses to phobia-related pictures and fear-inducing pictures with neural responses to neutral pictures. Phobia-related stimuli elicited neural activation in the precuneus, the insula and in the basal ganglia including putamen and caudate. We also found activation to phobia-related stimuli in anterior cingulate dorsolateral prefrontal regions. Fear-inducing stimuli yielded activation maxima in the bilateral amygdala and other basal ganglia structures, as well as prefrontal and occipital regions.

In a second step, we compared the two aversive conditions with each other. Specific neural responses to phobia-related stimuli were again found in the right precuneus. Other regions that were specifically responsive to phobia-related stimuli included the thalamus as well as frontal, temporal, parietal and occipital cortical regions. Conversely, the bilateral amygdalae (superficial group), the left ventromedial prefrontal cortex and occipito-temporal areas showed increased neural reactivity

**Table 1**

Cluster size (k) of activated clusters, t-values and coordinates of peak voxels according to the Montreal Neurological Institute (MNI) stereotactic system from the whole-brain analysis in response to phobia-related pictures and fear-inducing pictures at a family-wise error (FWE) corrected  $p < .05$ .

	cluster size	t	MNI-coordinates				cluster size	t	MNI-coordinates		
			x	y	z				x	y	z
	<b>Phobia &gt; Neutral</b>						<b>Fear &gt; Neutral</b>				
Precuneus Cortex	251,769	14.70	18	-57	19	Superior Frontal Gyrus	46,969	8.19	-36	23	-2
Brainstem	9758	9.08	-7	-51	-51	Lateral Occipital Cortex	42,017	12.50	-50	-76	9
Frontal Pole	4675	7.82	-26	64	13	Middle Temporal Gyrus	17,435	11.00	51	-68	4
Superior Frontal Gyrus	4618	6.42	3	11	65	Precuneus Cortex	6129	7.25	-3	-47	29
Middle Frontal Gyrus	3298	7.55	30	27	57	Brainstem	5170	7.91	-6	-29	-5
Cerebellum	2856	7.16	38	-67	-51	Cerebellum	3820	6.37	16	-78	-25
Paracingulate Gyrus	2635	6.21	0	53	-4	Caudate	3410	6.41	-12	6	12
Cerebellum	2271	7.40	-35	-65	-54	Postcentral Gyrus	2769	6.08	-32	-28	65
Insula	1935	5.70	-30	21	-10	Cerebellum	1872	6.27	0	-48	-19
Cerebellum	1785	6.59	8	-82	-38	Precentral Gyrus	1745	6.91	-29	-5	64
Occipital Pole	1227	6.13	19	-89	-7	Frontal Medial Cortex	1581	6.46	-3	45	-18
Paracingulate Gyrus	1128	5.86	-6	34	38	Cingulate Gyrus	1414	6.33	-5	-21	48
Middle Temporal Gyrus	913	5.56	64	-12	-10	Inferior Frontal Gyrus, triangular part	1313	6.47	53	24	7
Frontal Pole	858	7.42	21	67	15	Cerebellum	1079	5.94	10	5	4
Frontal Operculum Cortex	750	5.72	51	15	-5	Superior Parietal Lobule	920	6.29	36	-39	59
Cerebellum	627	6.80	-8	-83	-41	Brainstem	905	7.17	-2	-37	-40
Cerebellum	471	5.59	45	-63	-26	Cerebellum	865	6.17	8	-56	-46
Cerebellum	215	5.13	1	-15	12	Amygdala	520	7.51	20	-4	-14
Postcentral Gyrus	138	5.15	34	-34	57	Amygdala	498	7.90	-18	-6	-13
Middle Frontal Gyrus	127	5.62	50	29	37	Postcentral Gyrus	270	5.73	-51	-38	58
Cerebellum	113	5.38	-49	-61	-31	Frontal Orbital Cortex	159	6.37	29	19	-14
Anterior Cingulate Gyrus	68	5.13	1	22	-7	Postcentral Gyrus	110	5.42	-65	-20	30
Cerebellum	61	5.03	-16	-76	-25	Putamen	81	5.47	-31	-16	-8
Middle Temporal Gyrus	59	5.10	62	-34	-3	Thalamus	60	5.56	-16	-23	5
Putamen	42	5.22	-24	2	7	Thalamus	16	4.98	17	-35	1
Cerebellum	33	4.89	22	-67	-21	Thalamus	15	4.89	7	-11	12
Caudate	24	4.98	10	5	3	Brainstem	15	5.04	-1	-20	-21
Superior Temporal Gyrus	14	4.91	51	-20	-11	Lateral Occipital Cortex	11	4.94	-17	-67	62
Paracingulate Gyrus	7	4.86	-1	40	24	Supramarginal Gyrus	7	4.88	-49	-50	53
Cerebellum	7	4.84	27	-45	-24	Frontal Pole	6	5.43	-30	64	13
Frontal Pole	5	5.04	29	55	33	Frontal Pole	4	5.05	-22	66	12
Frontal Pole	4	5.05	33	52	31	Frontal Pole	3	5.09	-23	66	16
Middle Frontal Gyrus	2	4.92	50	32	33	Frontal Pole	3	5.15	-28	63	19
						Frontal Pole	2	4.95	-43	52	4
						Frontal Pole	2	4.90	-27	57	28
	<b>Phobia &gt; Fear</b>						<b>Fear &gt; Phobia</b>				
Precuneus Cortex	137,191	20.60	20	-57	19	Inferior Lateral Occipital Cortex	6557	8.85	43	-55	-14
Fusiform Gyrus		17.70	28	-42	-9			8.75	44	-78	-8
Lingual Gyrus		17.40	-27	-45	-7			8.67	45	-77	-6
Cuneus		16.90	-15	-61	21			7.97	44	-48	-16
Middle Occipital Cortex		14.00	42	-79	29			7.76	41	-83	-6
Precuneus Cortex		12.80	9	-52	9	Inferior Lateral Occipital Cortex	2681	8.80	-45	-81	1
Lingual Gyrus	4049	8.89	12	-86	1			7.34	-39	-86	-7
		7.89	12	-81	-7			7.14	-41	-84	-7
Brainstem	2783	7.92	-8	-50	-52			7.12	-42	-86	-2
Cerebellum		6.94	-15	-44	-50	Temporal Occipital Fusiform Cortex	2004	10.40	-42	-49	-18
		6.58	-10	-52	-45	Amygdala (superficial group)	901	9.43	20	-4	-16
Paracingulate Gyrus	2256	6.44	8	39	-8		724	9.71	-20	-7	-15
Medial Superior Frontal Gyrus		5.71	10	57	1	Frontal Medial Cortex	363	5.96	-1	44	-20
Frontal Pole	2207	8.11	22	63	9	Superior Frontal Gyrus	210	5.47	-5	55	25
		8.03	23	61	6	Frontal Orbital Cortex	44	5.23	-40	28	-13
Middle Frontal Gyrus	1703	6.64	32	28	52			4.95	-37	28	-15
		6.57	31	28	50	Frontal Medial Cortex	2	4.83	0	53	-17
		5.68	28	16	49						
Frontal Pole	1683	6.88	-24	58	4	<b>Region of interest</b>					
		6.60	-23	55	3	Amygdala	436	9.65	-20	-6	-15
		6.59	-24	55	1		404	9.24	21	-4	-16
Brainstem	656	5.51	15	-43	-48						
Cerebellum		5.50	17	-43	-50						
		5.45	17	-51	-46						
		4.98	23	-45	-52						
Occipital Pole	655	6.31	-10	-90	-6						
Lingual Gyrus		6.29	-14	-89	-8						
Calcarine Sulcus		6.26	-13	-90	-6						
Subcallosal Cortex	475	7.45	2	23	-6						
Thalamus	306	6.54	14	-30	12						
Angular Gyrus	139	5.09	50	-50	47						
Inferior Parietal Lobule		5.00	45	-49	43						
Cerebellum	82	5.20	-39	-67	-51						
Lingual Gyrus	32	4.96	-10	-82	-12						

(continued on next page)

Table 1 (continued)

	cluster size	t	MNI-coordinates			cluster size	t	MNI-coordinates		
			x	y	z			x	y	z
Anterior Middle Temporal Gyrus	20	4.97	60	-4	-15					
Frontal Pole	2	4.85	28	43	11					

to fear-inducing stimuli. The initial phase of stimulus presentation led to increased neural activation in the bilateral amygdalae (superficial group), left anterior insula, left thalamus (pulvinar) and left putamen. Frontal areas that were more active during the initial phase of picture presentation included the bilateral dorsal anterior cingulate cortices, bilateral ventrolateral prefrontal cortices and bilateral dorsolateral prefrontal cortices. The fusiform gyrus, as well as other occipital regions and the brainstem were also more responsive in the initial phase. Conversely, greater activation during the later (viewing) phase of picture presentation was observed primarily in temporal regions, e.g. in the bilateral plana polare, right superior temporal pole, and right anterior middle temporal gyrus. Next, we investigated stimulus-type dependent differences during uninstructed emotional regulation over time. We found several regions that showed greater signal reductions over time that were specific to the perception of phobia-related pictures. These regions included the precuneus, bilateral insula, left hippocampus (subiculum) and bilateral mid- and posterior thalamus. The same pattern was found in temporo-occipital as well as medial and lateral prefrontal areas. Results from the above mentioned contrasts are summarized in Table 1 and Table 2 and displayed in Fig. 3.

#### 4.2.2. Up-regulation and down-regulation during bifocal emotion regulation through tapping

During emotion regulation compared with picture viewing, we found increased regulation-related neural activation in the right mid-insula and left putamen. Regulation-related activation in the left amygdala was confirmed by an anatomical ROI analysis (FWE  $p < .05$ ). We also observed increased activation in the bilateral postcentral gyri, precentral gyri, parietal operculum cortex, and right cerebellum. The same contrast yielded cluster maxima in several lateral and medial occipital areas including the occipital pole, cuneus, calcarine sulcus, lingual gyrus, inferior and superior lateral occipital cortex, and the temporal occipital fusiform cortex. Conversely, we observed decreased activation in the regulation condition compared with the viewing condition in the bilateral temporal pole extending into the left fusiform gyrus, the right precentral and postcentral gyri, and the bilateral hippocampus (cornu ammonis). The influence of regulation was comparable in both aversive conditions (fear-inducing, phobia-related) as the interaction contrasts did not yield significant results. Results from the whole brain and Amygdala ROI analyses of tapping during aversive picture viewing are summarized in Table 3 and displayed in Fig. 4.

## 5. Discussion

### 5.1. Summary

The present study finds evidence that bifocal emotion regulation through tapping is associated with increased amygdala activation and decreased hippocampus activation in a group of participants with fear of flying (Fig. 4). Valence ratings and arousal ratings are maintained during regulation (Fig. 2A). We also find that the precuneus is specifically responsive to phobia-related pictures, while the amygdala is specifically responsive to generally fear-inducing pictures (Fig. 3). On the behavioral level, participants rate phobia-related pictures as less negative, but equally arousing compared with generally fear-inducing pictures. Regulation has similar effects on both valence and arousal ratings. We find no differences in regulatory effects of tapping between the two aversive stimulus types both on the neural level and on the behavioral

level (Fig. 2). Uninstructed emotion regulation over time, however, yields differential activation patterns for the two aversive stimulus types in the precuneus, the insula, and the hippocampus (Fig. 3). For phobia-related emotional material, we find that a combination of tapping and cognitive restructuring during a one-time intervention session leads to a reduction of both negativity ratings and arousal ratings (Fig. 2). Participants also report lower scores on the fear of flying scale after compared with before the intervention (Fig. 2). Additionally, a lower percentage of participants meet the criteria for fear of flying after the intervention (Fig. 2).

### 5.2. Neural processing of phobia-related stimuli versus generally fear-inducing stimuli

Both aversive stimulus categories lead to robust activations in regions underlying emotional processing compared with neutral stimuli (Chang et al., 2015; Palomero-Gallagher and Amunts, 2022; Pessoa, 2017). We additionally observe activation that is specific to phobia-related stimuli and fear-inducing stimuli, respectively. Phobia-related pictures compared with fear-inducing pictures yield signal increases e.g. in the precuneus and the ventral and dorsal lateral prefrontal cortices. The amygdala as well as occipital regions are specifically responsive to fear-inducing pictures. Activation in differential ventromedial prefrontal regions, as well as medial orbitofrontal regions, is present both in response to phobia-related pictures and to fear-inducing pictures. We also find phobia-specific effects of greater signal attenuation over time in the precuneus, insula, hippocampus, as well as ventromedial and dorsolateral prefrontal cortices. Our findings are in line with previous reports of inconsistent amygdala involvement in specific phobia: some studies report increased responses (Dilger et al., 2003; Goossens et al., 2007; Schienle et al., 2005; Straube et al., 2006) while others fail to find phobia-specific amygdala activation (Álvarez-Pérez et al., 2021; Hermann et al., 2007; Larson et al., 2006; Straube et al., 2006). They are also in line with the large body of literature that links activation in the amygdala and visual cortices to the perception of aversive, and particularly fear-inducing stimuli (Adolphs, 2002; Adolphs et al., 2003; Davidson and Irwin, 1999; Schardt et al., 2010; Wittfoth et al., 2017).

The precuneus is part of the default mode network, and is commonly associated with episodic (autobiographical) memory, as well as tactile and self-centered mental imagery (Addis et al., 2004; Cavanna and Trimble, 2006; Schmidt et al., 2014). Moreover, higher baseline activation in the precuneus is associated with lower conscious perception of repeating stimuli, possibly due to increased introspection and self-orientation (Boly et al., 2007).

Ventral (vlPFC) and dorsal lateral prefrontal cortex (dlPFC) activation is associated with executive functions, i.e. top-down control and the integration of cognitive and motivational information (Clarke and Johnstone, 2013; Sakagami and Pan, 2007). Activation in ventral medial prefrontal brain regions underlying e.g. emotion regulation and reinforcement of behavior (Rolls, 2019; Rolls and Grabenhorst, 2008) are present for both aversive stimulus types.

Taken together, the differences in neural responses to phobia-related pictures compared with fear-inducing pictures suggest that aviophobia-related pictures are specifically processed in regions underlying higher order cognitive control and self-referential thinking (Clarke and Johnstone, 2013; Olson et al., 2007; Sakagami and Pan, 2007), while fear-related stimuli induce automatic, bottom-up processing in regions underlying visual and emotional processing (Adolphs, 2002; Adolphs et al.,



**Table 2**

Cluster size (k) of activated clusters, t-values and coordinates of peak voxels according to the Montreal Neurological Institute (MNI) stereotactic system from the whole-brain analysis comparing the initial phase and in the viewing phase across stimulus types at a family-wise error (FWE) corrected  $p < .05$ . Additionally, results from the amygdala ROI analysis using an anatomical mask are reported at an FWE corrected  $p < .05$ .

	cluster size	t	MNI-coordinates				cluster size	t	MNI-coordinates		
			x	y	z				x	y	z
			<b>Initial &gt; Viewing</b>						<b>Viewing &gt; Initial</b>		
Superior Lateral Occipital Cortex	199,949	15.00	-41	-49	-18	Lateral Ventral	36,779	13.20	33	-49	3
Fusiform Gyrus		14.90	-29	-49	-11			12.50	-32	-53	4
		14.90	-34	-61	-17			12.50	-33	-55	4
		14.80	-44	-55	-14			12.20	25	-40	14
		14.80	-28	-61	-13			11.90	-32	-48	3
		14.70	26	-47	-11			10.50	-13	-20	26
Precentral Gyrus	13,278	10.70	-43	7	27	Planum Polare	1589	8.16	45	-2	-10
Inferior Frontal Gyrus, triangular part		9.39	-41	17	27	Superior Temporal Pole		6.78	45	5	-16
		9.36	-40	15	27	Planum Polare	317	6.36	-44	-1	-14
		8.05	-46	28	19	Callosal body	277	5.35	26	41	10
Precentral Gyrus	12,550	12.30	43	9	28	Corticospinal tract	89	5.28	27	-21	46
Inferior Frontal Gyrus, triangular part		7.83	48	30	18	Callosal body	77	5.05	24	-50	31
		7.65	49	21	27			5.02	25	-51	29
Middle Frontal Gyrus		6.73	52	38	21	Anterior Middle Temporal Gyrus	60	5.08	57	0	-28
Precentral Gyrus		6.02	41	0	51			5.05	55	0	-29
		5.51	48	6	52						
Paracingulate Gyrus	6355	8.73	-5	11	51						
Supplementary Motor Area		7.13	6	16	50						
		6.30	-4	22	49						
Insular Cortex	4423	8.91	-33	22	-2						
Precentral Gyrus	2126	6.02	-28	-7	61						
		6.02	-27	-10	57						
		5.47	-37	-3	60						
		4.95	-21	-10	67						
Frontal Orbital Cortex	1439	6.92	33	25	-1						
Putamen	442	5.92	-26	2	5						
		5.84	-24	3	6						
Thalamus	201	5.32	9	-12	7						
Amygdala (superficial group)	190	6.03	18	-6	-13						
Thalamus	86	5.12	-8	-14	8						
Anterior Cingulate Gyrus	82	5.71	5	2	29						
Brainstem	65	5.19	-1	-36	-42						
Inferior parietal lobule	62	5.00	-57	-20	35						
Supramarginal Gyrus		4.99	-56	-22	36						
Anterior Cingulate Gyrus	24	5.30	-3	4	28						
Frontal Orbital Cortex	19	5.02	-38	33	-12						
		4.97	-39	32	-14						
Amygdala (superficial group)	7	5.01	-18	-7	-13						
<b>Region of interest</b>											
Amygdala	13	5.43	19	-6	-13						
			<b>Phobia (initial &gt; viewing) &gt; Fear (initial &gt; viewing)</b>						<b>Fear (initial &gt; viewing) &gt; Phobia (initial &gt; viewing)</b>		
Precuneus Cortex	147,587	13.10	20	-57	19			<i>no suprathreshold voxels</i>			
Lingual Gyrus		10.30	26	-45	-8						
Calcarine Sulcus		9.81	-13	-61	15						
		9.66	-11	-61	20						
Fusiform Gyrus		9.55	-27	-47	-8						
Cuneus		9.43	-19	-61	19						
Central Opercular Cortex	14,735	6.84	-48	2	1						
Insula		6.62	-43	3	4						
Superior Temporal Gyrus		6.61	-61	-9	2						
		6.61	-42	-38	15						
		6.61	-60	-6	3						
		6.59	-43	-38	17						
Parietal Operculum Cortex	14,614	6.84	58	5	3						
Superior Temporal Gyrus		6.49	38	-31	15						
		6.37	63	-27	14						
Rolandic Operculum		6.31	43	-32	23						
		6.25	63	0	11						
		6.23	61	1	10						
Superior Lateral Occipital Cortex	6058	8.08	44	-76	28						
Angular Gyrus		6.83	49	-69	35						
Middle Temporal Gyrus		5.86	52	-66	22						
Paracingulate Gyrus	1792	5.85	8	42	-5						
Medial Orbital Frontal Gyrus		5.37	0	53	-5						
		5.26	-1	46	-6						
		5.00	-11	42	-6						

(continued on next page)

Table 2 (continued)

	cluster size	t	MNI-coordinates			cluster size	t	MNI-coordinates		
			x	y	z			x	y	z
		4.99	-11	45	-6					
		4.97	-11	47	-5					
Middle Frontal Gyrus	1275	5.96	31	28	52					
		5.35	30	19	57					
Superior Frontal Gyrus		5.35	28	17	59					
Middle Frontal Gyrus		5.27	27	17	49					
Precentral Gyrus	1018	5.81	-33	-18	39					
		5.80	-33	-18	41					
Postcentral Gyrus		5.64	-46	-15	56					
Brainstem	790	6.48	-15	-50	-55					
Cerebellum		6.36	-11	-55	-56					
		4.91	-6	-63	-51					
Cerebellum	620	5.91	12	-66	-49					
		5.61	22	-57	-55					
		5.26	17	-61	-53					
Subcallosal Cortex/subgenual ACC	612	6.54	8	17	-9					
		6.03	3	21	-9					
Cerebellum	598	6.16	4	-73	-34					
Frontal Pole	462	5.29	-23	39	33					
		5.14	-24	35	38					
Hippocampus (subiculum)	246	5.18	-23	-22	-14					
		4.94	-25	-17	-19					
Thalamus	239	5.36	20	-23	13					
Posterior Middle Temporal Gyrus	95	5.15	-57	-16	-22					
Posterior Middle Temporal Gyrus	76	5.20	-66	-40	0					
		5.09	-64	-42	-2					
		5.05	-64	-45	-2					
		4.88	-66	-35	-4					
Cerebellum	64	5.16	16	-47	-53					
Precentral Gyrus	44	4.98	-24	-12	72					
		4.88	-21	-13	70					
Thalamus	41	5.05	4	-16	17					
Inferior Temporal Gyrus, temporooccipital part	30	5.08	-56	-59	-9					
Posterior Middle Temporal Gyrus	27	5.04	64	-33	-10					
		4.99	64	-35	-9					
Anterior Middle Temporal Gyrus	23	4.89	-53	-10	-21					
Precentral Gyrus	23	4.93	38	-12	42					
Central Opercular Cortex	22	4.92	39	4	10					
Insula		4.90	39	4	8					
Anterior Middle Temporal Gyrus	21	4.98	-56	-4	-25					
Middle Frontal Gyrus	21	4.96	-33	33	46					
Posterior Middle Temporal Gyrus	18	4.96	-62	-32	-11					
Brainstem	18	4.93	11	-53	-58					
Posterior Supramarginal Gyrus	14	4.89	-55	-50	47					
Inferior Parietal Lobule		4.86	-54	-53	46					
		4.86	-53	-55	46					
Postcentral Gyrus	6	4.90	-47	-31	57					
Middle Temporal Gyrus, temporooccipital part	6	4.94	-62	-45	-6					
Cerebellum	5	4.97	-9	-69	-49					
Thalamus	4	4.86	-17	-18	8					
Posterior Middle Temporal Gyrus	3	4.97	-65	-33	-6					
Occipital Fusiform Gyrus	3	4.88	-28	-71	-1					
Brainstem	2	4.84	-13	-46	-25					
Frontal Medial Cortex	2	4.86	11	32	-16					
Precentral Gyrus	2	4.85	-5	-32	71					

2003; Davidson and Irwin, 1999; Ochsner et al., 2012). Signal decreases in the above-mentioned regions during prolonged viewing of phobia-related stimuli suggest that these processes are subject to habituation (Frijda, 1988).

Given the differences in the neural networks involved e.g. in small animal phobia or dental phobia compared with our findings (most notably the absence of amygdala activation and the involvement of the precuneus) we want to point out that the above mentioned results and their interpretations are possibly specific for aviophobia (Caseras et al., 2010; Etkin and Wager, 2007; Hilbert et al., 2014; Sabatinelli et al., 2005; Shin and Liberzon, 2010). Future studies should aim to address the question of stimulus-specificity also in groups of participants with other types of phobias. Another avenue of research is the systematic

comparison of different fear provocation modalities as previous work suggests that the successful provocation of phobic reactions depends in part on the channel of presentation of phobia-related stimuli (e.g. combinations of visual and auditory stimulation in dental phobics (Hilbert et al., 2014).

### 5.3. Effects of tapping on the neural and behavioral correlates of the perception of phobia-related and fear-inducing stimuli

#### 5.3.1. Bifocal emotion regulation in regions underlying emotional perception

Bifocal emotion regulation through tapping leads to activation increases in the amygdala, insula, basal ganglia, somatosensory and motor

**Table 3**

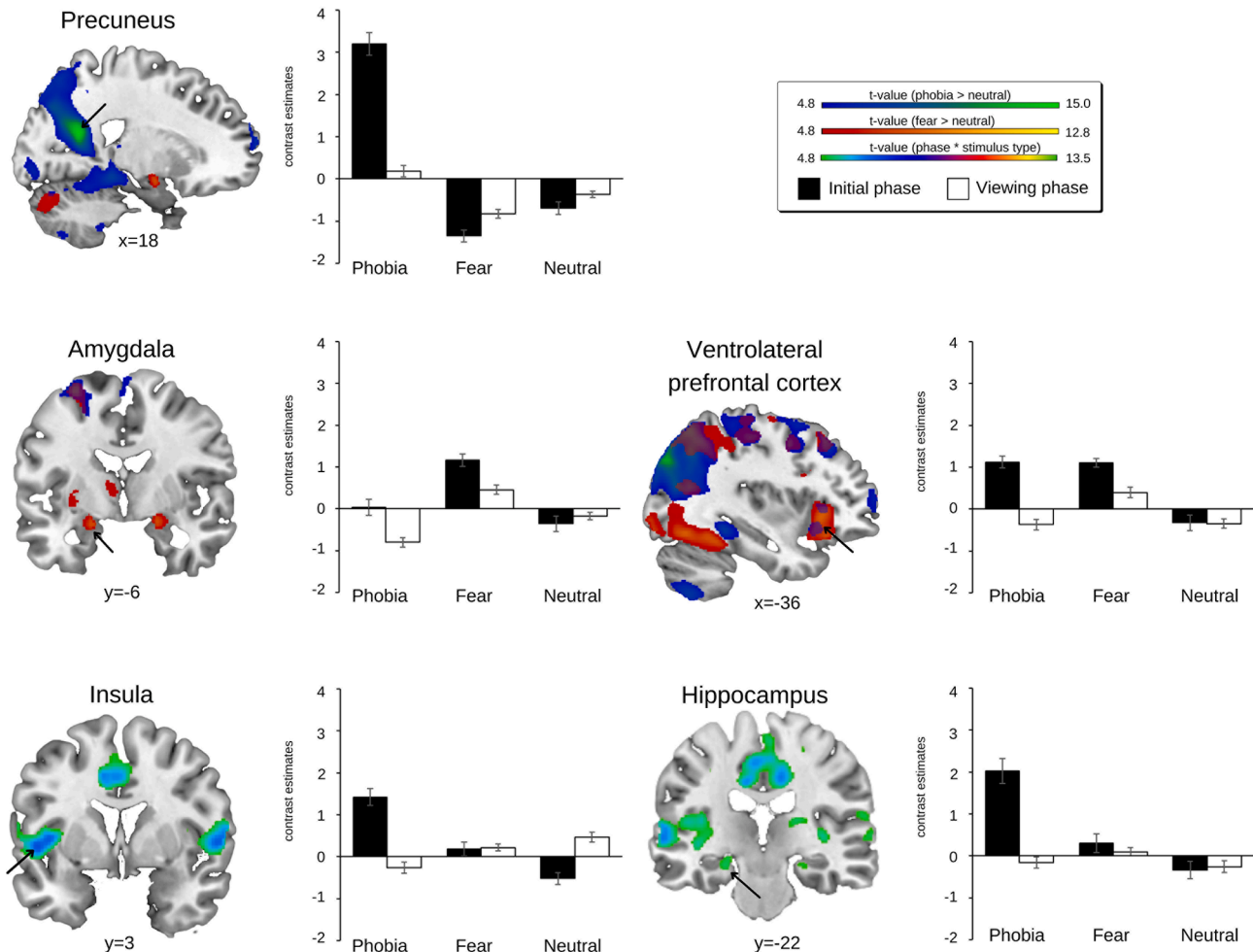
Cluster size (k) of activated clusters, t-values and coordinates of peak voxels according to the Montreal Neurological Institute (MNI) stereotactic system from the whole-brain analysis comparing regulation and viewing conditions across phobia-related and fear-inducing pictures at a family-wise error (FWE) corrected  $p < .05$ . Additionally, results from the amygdala ROI analysis using an anatomical mask are reported at an FWE corrected  $p < .05$ .

	cluster size	t	MNI-coordinates			cluster size	t	MNI-coordinates			
			x	y	z			x	y	z	
<b>Tapping &gt; Viewing</b>						<b>Viewing &gt; Tapping</b>					
Postcentral Gyrus	167,947	33.6	18	-52	-20	Temporal Pole	3930	9.32	46	12	-32
		26.8	-39	-23	55	Temporal Pole	2129	8.62	-48	10	-25
		26.8	-41	-20	61	Fusiform Gyrus		5.33	-32	-4	-31
Cerebellum		26.1	5	-62	-22	Precentral Gyrus	407	6.82	7	-23	69
		23	6	-67	-32	Postcentral Gyrus	126	5.59	40	-21	52
Precentral Gyrus		22.9	-33	-26	57	Right Lateral Ventricle	25	5.15	3	7	15
Parietal Operculum Cortex	19,778	12.4	50	-31	26	Hippocampus (cornu ammonis)	13	5.02	33	-12	-23
		10.8	63	-19	18	Hippocampus (cornu ammonis)	12	5.05	-32	-12	-20
Superior Temporal Gyrus		10.8	62	-22	18						
Rolandic Operculum		8.28	50	4	2						
Superior Temporal Pole		8.24	58	8	1						
Insula		7.84	46	2	7						
Postcentral Gyrus	8969	9.44	23	-43	71						
		9.06	32	-38	68						
		9.03	29	-40	70						
		8.82	32	-36	58						
Precentral Gyrus		8.39	26	-30	71						
Postcentral Gyrus		8.05	29	-31	65						
Occipital Pole	7818	8.4	-12	-88	34						
Cuneus		6.93	1	-92	15						
Calcarine Sulcus		6.84	2	-93	12						
		6.67	6	-93	14						
Cuneus		6.61	6	-92	16						
		6.05	-10	-78	33						
Inferior Lateral Occipital Cortex	5146	8.97	-53	-69	9						
Brainstem	2080	7.96	5	-46	-58						
Inferior Lateral Occipital Cortex	2020	8.38	52	-62	3						
Precentral Gyrus	222	5.41	16	-34	47						
Precentral Gyrus	202	6.34	43	-6	58						
Precentral Gyrus	129	6.08	-58	6	33						
Brainstem	92	5.68	8	-37	-44						
Temporal Occipital Fusiform Cortex	62	5.76	48	-62	-25						
Cerebellum		5.52	47	-59	-26						
Cuneal Cortex	46	5.05	7	-82	43						
		5.03	5	-80	43						
Temporal Occipital Fusiform Cortex	4	5.02	-47	-60	-27						
Lingual Gyrus	2	5.03	1	-82	-22						
Putamen	2	5.01	-26	4	0						
Superior Lateral Occipital Cortex	2	4.91	17	-83	21						
<b>Region of Interest</b>											
Amygdala	288	8.9	-23	-4	-10						
<b>Phobia (Tapping &gt; Viewing) &gt; Fear (Tapping &gt; Viewing)</b>						<b>Fear (Tapping &gt; Viewing) &gt; Phobia (Tapping &gt; Viewing)</b>					
<i>no suprathreshold voxels</i>						<i>no suprathreshold voxels</i>					

cortices; and to activation decreases in the hippocampus and the temporal pole, irrespective of stimulus type. We also find that valence ratings and arousal ratings are maintained for both phobia-related pictures and fear-inducing pictures. These effects differ from the automatic regulatory processes we observed when participants were simply viewing phobia-related pictures and fear-inducing pictures. Here, the amygdala, insula, visual and frontal areas and for phobia-related pictures also the hippocampus show decreased activation over time while anterior temporal regions show increased activation over time. Our findings are also opposed to the decreases in amygdala activation, insula activation, and negativity ratings that are commonly observed during cognitive emotion regulation in general (Braunstein et al., 2017; Ochsner et al., 2012). They are, however, congruent with previous reports of amygdala up-regulation and unchanged negativity ratings during bifocal emotion regulation using visualized tapping (Wittfoth et al., 2020) and auditory EMDR (Herkt et al., 2014). They are also congruent with reports of amygdala and insula down-regulation during automatic (i.e. implicit) emotion regulation (Gyurak et al., 2011; Koole and Rothermund, 2011; Mauss et al., 2007; Phillips et al., 2008; Silvers et al., 2015).

The activation decrease in the anterior hippocampus present during tapping might be related to regulatory influences on episodic memory functions (Bird and Burgess, 2008; Zhu et al., 2019), or on the visual exploration of the stimuli (Lee et al., 2012; Voss et al., 2017; Zeidman and Maguire, 2016). The hippocampus and the amygdala are known to mutually influence each other in response to emotional stimuli and the encoding and storage of emotional memories, and both regions are involved in novelty processing, particularly of natural scenes (Bradley et al., 2015; Phelps et al., 2004; Zeidman and Maguire, 2016). A main function of the hippocampus seems to be the representation of complex integrated conjunctions of spatial and non-spatial (e.g. emotional value) features of scenes based on incoming sensory information or prior experience, e.g. during novelty processing or the elaboration of autobiographical memories or future events (Bradley et al., 2015; Lee et al., 2012; Zeidman and Maguire, 2016). The down-regulation in both the anterior hippocampus and the temporal pole in the present work suggests that tapping might influence the representation of complex perceptual inputs and their subsequent binding with visceral emotional responses (Lee et al., 2012; Olson et al., 2007; Zeidman and Maguire,

## Aversive pictures during the initial phase and the viewing phase



**Fig. 3. Aversive pictures during the initial phase and the viewing phase** Results from the whole-brain analysis at FWE-corrected  $p < .05$  comparing phobia-related, fear-inducing and neutral pictures across the initial phase and the viewing phase. Bar charts depict mean ( $\pm$ SE) contrast estimates for the viewing phase (black bar) and the initial phase (white bar) from the right precuneus, left amygdala, left ventrolateral prefrontal cortex, right anterior insula, and left hippocampus. The precuneus, insula and hippocampus are specifically responsive to phobia-related pictures, and show a decrease in activation in the viewing phase. The amygdala is specifically responsive to fear-inducing pictures, and shows signal attenuation in the viewing phase. Aversive pictures lead to ventrolateral prefrontal (vLPFC) activation compared with neutral pictures. FWE: Family-Wise Error; SE: Standard Error.

2016). Of note in the current context is the dissociation between amygdala and hippocampus activation during tapping, as these regions tend to show similar responses to the perception of complex emotional and/or novel scenes in other studies (Bradley et al., 2015; Phelps, 2004), as well as during automatic emotion regulation in the present work.

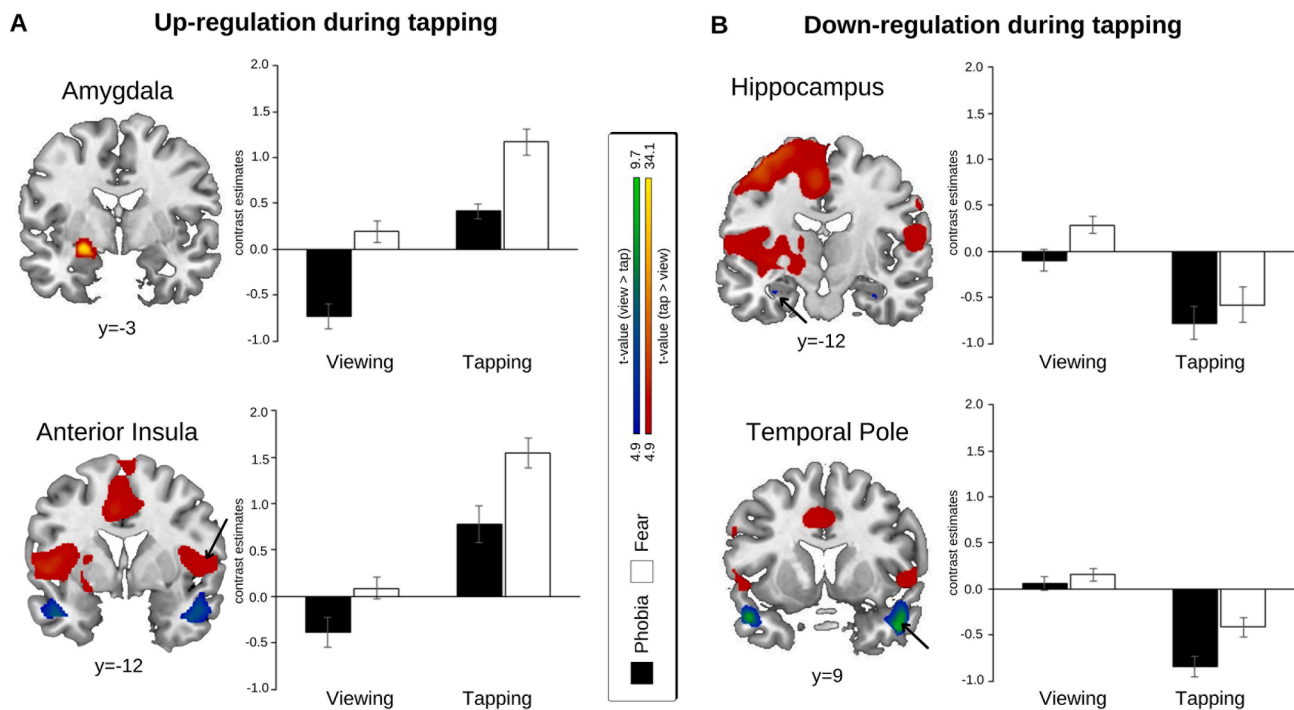
The present study finds no differential effects between the two aversive stimulus types during tapping. Previously, however, differential effects have been observed comparing fear-inducing and disgust-inducing stimuli in a healthy sample (Wittfoth et al., 2020). Bifocal emotion regulatory strategies are also known to be effective across different contexts (Bach et al., 2019; Church, 2013; Feinstein, 2018; Stapleton, 2019). This suggests that bifocal regulatory strategies are suitable for regulating various aversive emotions, and that the neural underpinnings of these effects might differ with respect to stimulus type and the presence or absence of psychopathology. Further investigations are needed to answer the question of stimulus specificity, both in healthy control groups and in patient groups, such as anxiety disorders (König et al., 2019) or PTSD (Church, 2013; Church et al., 2012).

In summary, tapping increases activation in regions underlying the processing of aversive emotional stimuli, somatosensory and motor functions as well as the perception of internal feeling states (Critchley

et al., 2004; Herkt et al., 2014; Wittfoth et al., 2020). Tapping down-regulates activation in regions underlying the representation of complex visual scenes and the binding of complex perceptual inputs with visceral responses of associated feeling states (Olson et al., 2007; Phelps, 2004; Voss et al., 2017).

Theoretical assumptions about the underlying mechanisms of tapping and other bifocal emotion regulation strategies posit that these techniques allow for a re-integration of aversive emotional material in a way that subsequently attenuates perceived distress (Bohne, 2021; Foa et al., 2006; Shapiro, 2001). The concept of so-called “fear structures” assumes that anxiety-related emotions, cognitions, and behaviors are coherently stored in memory (Foa et al., 2006; Foa and Kozak, 1986; Rachman, 1980). According to this concept, exposure can reduce the expectation of danger and the general fear response when it leads to the activation of a fear structure (high emotional arousal and anxiety) while simultaneously implementing corrective information regarding the harmlessness of the stimulus. In this way, exposure can lead to the formation of new “safety structures”, which inhibit the previous anxiety reaction (Foa et al., 2006).

Applying the concept of fear structures to the present work, we argue that fear inducing stimuli are present at the same time as the perception



**Fig. 4. Up- and Down-regulation during tapping** Results from the whole-brain (amygdala: ROI) analysis at FWE-corrected  $p < .05$  comparing the viewing condition and the tapping condition. Bar charts show mean ( $\pm$ SE) contrast estimates from the displayed regions in response to phobia-related pictures (black bars) and fear-inducing pictures (white bars). A: The left amygdala and the bilateral anterior insula showed an up-regulation of neural activation in the tapping condition compared with the viewing condition. B: The bilateral hippocampus and bilateral temporal pole showed the opposite pattern of down-regulation in the tapping condition compared with the viewing condition. Bar charts depict contrast estimates from the left amygdala, right anterior insula, right hippocampus and right temporal pole. FWE: Family-Wise Error; SE: Standard Error.

of (self-)touch which is known to have emotion regulatory properties from infancy (Bai et al., 2016; Duhn, 2010; Feldman et al., 2010) into adulthood (Cascio et al., 2019; Grunwald et al., 2014; Mueller et al., 2019; Pawling et al., 2017; Spille et al., 2022). Furthermore, C-afferent touch is known to relay to the posterior insula (Gordon et al., 2013; Morrison et al., 2011; Olsson et al., 2008; Pawling et al., 2017), a pattern we also see during tapping in the present study. Our participants also show increased neural activation in the amygdala, which is consistently associated with fear processing, and they report high emotional arousal ratings to negative stimuli. Both findings are in line with the idea of the activation of a fear structure mentioned above (Foa et al., 2006; Foa and Kozak, 1986; Rachman, 1980).

During the first seconds of tapping, we observe reduced activation in the hippocampus and in the temporal pole while valence and arousal ratings remain unchanged. Subsequently, the full PEP intervention session including both tapping and cognitive restructuring effectively reduces fear of flying. This suggests that PEP effectively implements corrective information in support of the harmlessness of the fear-inducing stimulus, possibly through tapping-related modulations of visual novelty processing and higher-order representations of complex scenes mirrored by activation changes in the hippocampus and the temporal pole (Bradley et al., 2015; Lee et al., 2012; Olson et al., 2007; Voss et al., 2017; Zeidman and Maguire, 2016). However, we can only draw conclusions about neural reactivity in the first few seconds of tapping based on the present results. More research is needed to elucidate neural responses to longer tapping sequences, and to combined tapping and cognitive restructuring as it is used during actual interventions (Bohne, 2021; Church, 2013).

### 5.3.2. Prefrontal cortex involvement in bifocal emotion regulation

In the present study, changes in neural activation in dorsal and ventral lateral and medial prefrontal areas are associated with unstructured (i.e. automatic) emotion regulation over time and with the

processing of phobia-related pictures, but not with bifocal emotion regulation through tapping. A large body of work shows that the ventral anterior cingulate cortex and the ventromedial prefrontal cortex are consistently associated with automatic emotion regulatory functions (Braunstein et al., 2017; Gyurak et al., 2011; Mcrae et al., 2008; Phillips et al., 2008). Previous work on bifocal emotion regulation however yields inconsistent results with regard to the role of the prefrontal cortex. While Herkt and colleagues (2014) do not report ventromedial prefrontal involvement in bifocal emotion regulation through binaural alternating EMDR, we did find signal attenuations in the vACC for bifocal emotion regulation via visualized tapping in a previous study (Wittfoth et al., 2020). Involvement of the dlPFC is commonly found during explicit, cognitive emotion regulation, e.g. reappraisal (Braunstein et al., 2017) or detachment (Dörfel et al., 2014; Schardt et al., 2010). In bifocal emotion regulation, dlPFC involvement seems to be at least in part dependent on stimulus type and has been reported for disgust-inducing stimuli (Herkt et al., 2014; Wittfoth et al., 2020), but not for fear-inducing stimuli (Wittfoth et al., 2020). Since we observed no involvement of either lateral or medial prefrontal areas in bifocal emotion regulation in the present study, we argue that activation in these areas might be connected with, but not crucial for bifocal emotion regulation. Differences in stimulus type, active (tapping) vs. passive (EMDR) administration of regulatory stimulation, and sensory channels involved (e.g. visual perception, auditory perception, haptic/tactile perception) might account for differential involvement of the prefrontal cortex. Furthermore, dorsal and ventral medial prefrontal areas, as well as orbitofrontal areas show divergent functional and anatomical patterns in various conditions including PTSD, social anxiety disorder, bipolar disorder and specific phobia (Etkin and Wager, 2007; Huber et al., 2019). A lack of neural effects in the prefrontal cortex may thus also relate to the presence of aviophobia in our sample. Further research is needed to elucidate these questions, e.g. by directly comparing different regulatory strategies and stimulus modalities, ideally between patient

groups and healthy controls.

#### 5.4. Correlates of fear of flying and their relation with personality measures and emotion regulatory skills

One of the goals of therapeutic interventions is the alleviation of avoidant behavior that is characteristic for specific phobia (Craske et al., 2008; Foa and Kozak, 1986). In the present work, valence and arousal ratings are maintained during short-term tapping on a single acupoint within the MRI scanner, while the combination of the full 16-point tapping routine with cognitive strategies during the intervention session leads to a significant reduction in both valence ratings and arousal ratings for phobia-related material, i.e. when thinking about flying. As stated above, the combination of physiological stimulation and cognitive interventions is thought to accomplish emotional down-regulation by implementing new, more supportive thought patterns while participants are in a state of altered processing and (re-)integrating of emotional material (Bohne, 2021; Foa et al., 2006; Shapiro, 2001). In line with this interpretation, participants in the present study report lower fear of flying scores, and fewer participants meet the criteria for aviophobia after the intervention compared with before.

Recent work by Ascheid et al. (2019) suggests that the avoidance of predictable situations characterized by high arousal and low negativity is associated with increased activation of brain regions relevant for conflict monitoring and the processing of self-relevant information. In line with this interpretation, participants in the present study rate phobia-related pictures as equally arousing but less negative compared with fear-inducing pictures. Furthermore, we find increased neural responses in the dlPFC, which underlies cognitive control (Yuan and Raz, 2014), and in the precuneus, which is associated with autobiographical memory (Cavanna and Trimble, 2006; Olson et al., 2007) in response to phobia-related pictures. We also find that participants with greater initial fear of flying report more depressive symptoms, greater trait anxiety and lower self-efficacy. Self-report scores of emotion regulation skills, however, are not associated with initial fear of flying symptom scores. Still, participants rate phobia-related pictures as arousing but not intensely negative, suggesting a possible disconnect between the perceived emotion regulation skills and the actual ability to implement emotion regulation for phobia-related material (Craske et al., 2008). Taken together, this pattern suggests that particular combinations of valence and arousal might entail differential neural processing depending on the action tendency that is currently present, and that approach-avoidance conflict might arise e.g. during the avoidance of predictable situations, as is the case in avoiding flying in aviophobia (Ascheid et al., 2019).

#### 5.5. Limitations

The present work is part of a series of studies which are the first to investigate the effects of visualized and actual tapping as an emotion regulation strategy during the processing of aversive emotional material (Wittfoth et al., 2020). These studies aim to elucidate the active ingredients of therapeutic interventions based on techniques combining tapping and cognitive restructuring, such as EFT (Church, 2013) and PEP (Bohne and Schmidt, 2019). Tapping as used in PEP (Bohne, 2021) is performed without concomitant affirmations (other than e.g. EFT (Church, 2013)), and even visualized tapping leads to emotion regulatory effects both on the neural level and on the behavioral level (Wittfoth et al., 2020). However, the neural and behavioral effects found here during scanning are only partially transferrable to those found in clinical settings which involve much longer, multipoint tapping sequences (Bohne, 2021). To ensure comparability to previous work on emotion regulation (Braunstein et al., 2017; Dörfel et al., 2014; Gyurak et al., 2011; Kanske et al., 2011; Morawetz et al., 2010; Ochsner et al., 2012; Phillips et al., 2008; Schardt et al., 2010; Wittfoth et al., 2020), we used picture stimuli for eliciting emotional responses in the scanner.

However, valence and arousal ratings for picture stimuli during scanning differ from those given when immersed in multisensory imagination of flying during the intervention session. Particularly, imagination of flying leads to high negativity and high arousal, while picture stimuli are rated as arousing but only moderately negative, suggesting that personally relevant phobic material entails more in-depth processing compared with generally phobia-related material (Hilbert et al., 2014). Recent work by Sambuco and colleagues shows that emotional imagery entails activation in various nodes of the Default Mode Network including the posterior cingulate cortex, anterior hippocampus and prefrontal cortex (Sambuco et al., 2021), but that the neural networks activated during emotional scene perception are largely distinct from those activated during emotional imagery (Sambuco et al., 2020). Thus, the neural effects of prolonged tapping during the perception or imagery of autobiographically relevant phobic material remain subject of further study. Furthermore, we investigate the combined effect of tapping and cognitive restructuring only on the behavioral level, with a limited sample size and without a control group. Thus, the interpretations given above regarding the effects of the full intervention remain somewhat tentative. Previous work posits that fear reduction, i.e. lower levels of fear ratings during exposure therapy in specific phobia, are not a reliable index of learning (Craske et al., 2008; Viña et al., 2020). Increased fear toleration, however, may lead to lasting reductions in fear, possibly by reshaping memory and forming new, secondary learning experiences based on brain regions that contribute to it (Craske et al., 2008). We did not include a follow-up measurement to investigate lasting effects of tapping and the intervention and thus cannot form conclusions regarding long-term effects. However, ways of developing competing, non-threat associations both at the explicit and at the automatic level, are important parts of fear extinction e.g. through exposure therapy (Craske et al., 2008; Viña et al., 2020). We argue that based on our findings, a combined approach of tapping and cognitive restructuring provides a promising avenue for a lasting reduction of negative feeling states. Tapping seems to induce a brain state that is conducive to the reshaping of memory and the experience of new, secondary learning experiences. These are introduced during cognitive restructuring in the intervention session, which we find subsequently leads to reduced ratings of subjective discomfort in response to phobic material. Our observations are supported by studies reporting an amelioration of symptoms of e.g. anxiety (Clond, 2016; König et al., 2019) or PTSD (Church et al., 2018; Church and Feinstein, 2013; Karatzias et al., 2011; Sebastian and Nelms, 2017), suggesting that tapping in combination with cognitive restructuring can be used successfully to induce immediate and long-lasting emotion regulatory effects in response to distressing emotional situations.

## 6. Conclusion

Taken together, our results suggest that bifocal emotion regulation alters the processing and re-integration of emotions and ameliorates fear of flying in participants with aviophobia. These effects are mirrored by increased activation in emotion-processing regions and reduced activation in regions subserving the perception and representation of visual emotional material (Aalberse et al., 2012; Lee et al., 2012; Voss et al., 2017; Zeidman and Maguire, 2016). Further support stems from the observed reduction in valence and arousal ratings and in fear of flying scores after an intervention session combining tapping and cognitive restructuring (Bohne, 2021; Church, 2013). The present results are also indicative of the particularities of bifocal emotion regulatory strategies as compared to other explicit and automatic emotion regulation strategies (Braunstein et al., 2017; Phillips et al., 2008). Most notably, the present work corroborates findings of an up-regulation of amygdala activation and an absence or reduction of lateral prefrontal activation during bifocal emotion regulation (Herkt et al., 2014; Wittfoth et al., 2020).

## Data availability

The datasets used and/or analyzed in the current study are available via the Mendeley Data repository, <https://doi.org/10.17632/bw2ddm2kfy.1>.

## CRedit authorship contribution statement

**Dina Wittfoth:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Jelena Beise:** Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Jorge Manuel:** Data curation, Formal analysis, Software, Writing – review & editing. **Michael Bohne:** Conceptualization, Funding acquisition, Investigation, Methodology, Writing – review & editing. **Matthias Wittfoth:** Conceptualization, Funding acquisition, Investigation, Methodology, Supervision, Writing – review & editing.

## Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Co-author MB is the founder and head of the Fortbildungsinstitut für PEP and provides recognized PEP trainings in Germany, Austria and Switzerland. This does not alter the authors' adherence to NeuroImage: Clinical's policies on sharing data and materials.

## Acknowledgements and Funding

This work was supported by the MHH+ Foundation. We thank all crowd funders who donated to MHH+ Foundation for their support in funding this study, and our participants for their outstanding compliance and commitment.

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