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Treating chronic worry: Psychological and physiological effects of a training programme based on mindfulness

Luis Carlos Delgado [a], Pedro Guerra [a], Pandelis Perakakis [a], María Nieves Vera [a], Gustavo Reyes del Paso [b], Jaime Vila [a,*]

[a] Department of Personality, Assessment and Psychological Treatment, University of Granada, Spain
[b] Department of Psychology, University of Jaén, Spain

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ABSTRACT

The present study examines psychological and physiological indices of emotional regulation in non-clinical high worriers after a mindfulness-based training programme aimed at reducing worry. Thirty-six female university students with high Penn State Worry Questionnaire scores were split into two equal intervention groups: (a) mindfulness, and (b) progressive muscle relaxation plus self-instruction to postpone worrying to a specific time of the day. Assessment included clinical questionnaires, daily self-report of number/duration of worry episodes and indices of emotional meta-cognition. A set of somatic and autonomic measures was recorded (a) during resting, mindfulness/relaxation and worrying periods, and (b) during cued and non-cued affective modulation of defence reactions (cardiac defence and eye-blink startle). Both groups showed equal post-treatment improvement in the clinical and daily self-report measures. However, mindfulness participants reported better emotional meta-cognition (emotional comprehension) and showed improved indices of somatic and autonomic regulation (reduced breathing pattern and increased vagal reactivity during evocation of cardiac defense). These findings suggest that mindfulness reduces chronic worry by promoting emotional and physiological regulatory mechanisms contrary to those maintaining chronic worry.

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Introduction

Worry has been defined as a chain of negatively affect-laden and relatively uncontrollable thoughts and images that promote mental attempts to avoid anticipation of potential threats (Borkovec, 2002). Worry may serve various adaptive functions. According to Tallis and Eysenck (1994), worry acts as an alarm warning of potential danger, prepares us to cope with anticipated threats and maintains awareness of unresolved problems. However, excessive worry is considered maladaptive and is the defining characteristic of Generalized Anxiety Disorder (GAD) (American Psychiatric Association, 1994). The warning of potential danger and the anticipation of threat imply activation of defence reactions, i.e., the fight-flight or freezing response (Borkovec, 2002). Continuous activation of this type of defence reaction represents a state of permanent stress and vigilance for negative emotional information, hence increasing the risk of physical and mental problems (Brosschot, Gerin, & Thayer, 2006; Knepp & Friedman, 2008). In addition, the mental avoidance of low-probability negative future events by engaging in worry is an inefficient coping strategy, since it does not reduce the likelihood of negative outcomes (Borkovec, Hazlett, & Diaz, 1999) or generate effective problem solving (Stöber, 1998).

The psychological and physiological correlates of chronic worry have been investigated by a number of studies in non-clinical high trait worriers and patients with GAD (Brosschot, Van Dijk, & Thayer, 2003; Borkovec, Robinson, Pruzinsky, & DePree, 1983; Borkovec & Roemer 1995; Conrad, Isaac, & Roth, 2008; Davis, Montgomery, & Wison, 2002; Dua & King, 1987; Hoehn-Saric, Hazlett, & McLeod, 1993; Hofmann et al., 2005; Jönsson, 2007; Karteroliotis & Gil, 1987; Lyonfields, Borkovec, & Thayer, 1995; Segerstrom, Glover, Craske, & Fahey, 1999; Thayer & Brosschot, 2008; Thayer, Friedman, & Borkovec, 1996; Thayer et al., 2000; Wilhelm et al., 2001). The two most consistent physiological findings were the absence of sympathetic hyper-activation (indexed mainly by skin conductance) and the presence of reduced parasympathetic control (indexed by respiratory sinus arrhythmia and heart rate variability measures). Skin conductance is a measure of eccrine sweat gland activity, which is innervated exclusively by sympathetic axonal terminations. The term respiratory sinus arrhythmia (RSA)

* Corresponding author at: Facultad de Psicología, University of Granada, 18071 Granada, Spain. Tel.: +34 958 243753; fax: +34 958 243749.
E-mail address: jvila@ugr.es (J. Vila).

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describes the phenomenon of cyclic heart rate changes in phase with respiration: heart rate increases during inhalation and decreases during exhalation. This cardio-respiratory synchrony is mediated by the parasympathetic (vagal) nervous system, which is known to exert an inhibitory effect on heart rate: increased vagal discharges during exhalation produce cardiac deceleration, while vagal inhibition during inhalation causes cardiac acceleration. Thus, quantitative measures of RSA during resting or stationary states are considered as indirect indices of tonic parasympathetic influences on the heart. Another common quantitative measure of parasympathetic cardiac control is the power of the high frequency spectral band of heart rate variability (HRV), which coincides with the respiratory rhythm. Since a state of autonomic hyper-activation can be achieved either by an increase in sympathetic action or by a decrease in parasympathetic action, or both working reciprocally, the above findings of unaltered sympathetic activation accompanied by decreased indices of parasympathetic tonic control in high worriers, suggest that chronic worry is characterized by poor autonomic regulation due exclusively to reduced vagal control.

A recent study (Delgado et al., 2009) examined high and low chronic worriers during resting and self-induced worry periods and during cued and non-cued defence reaction paradigms. It confirmed the presence in high worriers of reduced indices of sympathetic activation (skin conductance) to emotional pictures and reduced indices of vagal control (measured by RSA) during the resting period (vagal tonic measure), accompanied by increased respiration indices. It also reported a greater defence response in the non-cued defence paradigm (cardiac defence) but no difference in the cued defence paradigm (eye-blink startle probe), supporting the notion of chronic worry as a state of anticipatory anxiety or non-cued fear reaction (Lang, Davis, & Öhman, 2000). The differences in cardiac defense also allowed identifying a deficit in vagal control in high worriers. Cardiac defense is a pattern of phasic heart rate changes to an intense white noise with a short- and a long-latency acceleration/deceleration (see Vila et al., 2007, for a review). The short-latency acceleration/deceleration is vagally mediated whereas the long-latency acceleration/deceleration is controlled by sympathetic and parasympathetic influences working reciprocally (Reyes del Paso, Vila, & García, 1994; Reyes del Paso et al., 1993). Since the differences between high and low worriers were found in the first acceleration/deceleration, it was concluded that the reduced vagal control in high worriers assessed during the resting period (vagal tonic measure) was also associated with the increased cardiac reactivity to environmental threats observed during the cardiac defense response paradigm (vagal phasic measure).

In their above-cited study, Delgado et al. also found that high worriers had significantly higher scores for trait anxiety, depressive symptoms, negative affect and subjective health complaints in comparison to low worriers and significantly lower scores for positive affect. None of their high worriers were diagnosed with GAD according to ADIS-IV clinical interview (Brown, Di Nardo, & Barlow, 1994), but their elevated scores for worry and self-reported negative symptoms suggested that they would benefit from a programme aimed at reducing chronic worry.

Mindfulness has received much attention in recent years as a therapeutic tool for psychological disorders (Allen et al., 2006; Baer, 2003; Carmody, 2009; Grossman, Niemann, Schmidt, & Walach, 2004; Lazar, 2005; Toneatto & Nguyen, 2007). It has been used as an integral part of the following psychological training programmes: (1) *Mindfulness Based Stress Reduction (MBSR)* (Kabat-Zinn, 1982), originally developed for managing chronic pain and currently used to reduce psychological suffering in chronic disease and to treat emotional and behavioural disorders; (2) *Dialectic Behavioural Therapy (DBT)* (Linehan, 1993), aimed at reducing maladaptive behaviours in personality disorders; (3) *Mindfulness Based Cognitive Therapy (MBCT)* (Segal, Wiliams, & Teasdale, 2002), a combination of cognitive therapy and meditation specifically designed to treat depression (Teasdale et al., 2000); (4) *Acceptance and Commitment Therapy (ACT)* (Hayes, Strosahl, & Wilson, 1999) a mindfulness-based procedure claimed to be effective in numerous applications; and (5) *Mindfulness-based relapse prevention (MBRP)* (Witkiewitz, Marlatt, & Walker, 2005), a programme for the treatment of substance abuse that combines mindfulness techniques and relapse prevention principles.

Mindfulness, based on Buddhist meditation, has also been used in the treatment of chronic worry in GAD patients (Craigie, Rees, Marsh, & Nathan, 2008; Evans et al., 2008; Kim et al., 2009; Roemer & Orsillo, 2002, 2007). In current psychology, two fundamental components of mindfulness are distinguished (Bishop et al., 2004): (1) self-regulation of attention (awareness) towards the present experience, and (2) an attitude of curiosity, openness and acceptance of the present experience. Awareness and acceptance of internal and external aspects of the present experience are assumed to bring about emotional stability through a non-evaluative *re-cognition* of thoughts, sensations and emotions, without avoidance or over-involvement (Carmody, 2009; Chambers, Gullone, & Allen, 2009). These key characteristics of mindfulness are clearly opposite to those of chronic worry, i.e., anticipation of future events, cognitive avoidance of internal experience and non-acceptance of uncertainty (Arch & Craske, 2006; Borkovec, 1994; Borkovec, & Inz 1990; Freeston, Dugas, & Ladouceur, 1996; Freeston et al., 1994). Hence, mindfulness training can be postulated as a potential reciprocal inhibitory mechanism that can help to modify and cope with chronic worry.

The aim of the present study was to test this hypothesis by examining the psychological and physiological (somatic and autonomic) indices of emotional regulation in non-clinical high worriers after a mindfulness-based training programme aimed at reducing worry. Participants were the same individuals studied in the paper by Delgado et al. (2009). Previous studies on mindfulness-based clinical interventions have usually been limited to self-report measures, and they have rarely included physiological indices that might help to identify the mechanism underlying the expected clinical improvement (Lau & Yu, 2009). The only physiological measures reported in mindfulness research to date have been electrophysiological and metabolic indices of Central Nervous System functions (Cahn & Polich, 2006; Creswell, Way, Eisenberger, & Lieberman, 2007; Davidson et al., 2003; Farb et al., 2007; Goldin, Ramel, & Gross, 2009). The present study was designed to differentiate the specific effects of mindfulness by using a control group that received a parallel treatment based on progressive relaxation plus the instruction to postpone worrying to a later specific time. This type of self-instruction has been successfully used in high worriers (Brosschot & Doef, 2006; Wells, 2002). We predicted that both groups would show significant post-intervention improvements in daily measures of worry and in clinical questionnaires but that the mindfulness training group would have better indices of emotional meta-cognition (attention, comprehension, and regulation of feelings and emotions) and physiological regulation (parasympathetic cardiac control and respiration) during periods of resting, meditation/relaxation and self-induced worry and in the non-cued defence paradigm (cardiac defence). The groups were not expected to differ in the cued defence paradigm (startle probe).

Method

Participants

Participants were 36 female volunteer university students (18–24 years) with high scores in the Penn State Worry

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Questionnaire (PSWQ) (Meyer, Miller, Metzger, & Borkovec, 1990; Sandín, Chorot, Valiente, & Lostao, 2009). The selection was based on an initial pool of 438 students who completed the questionnaire. Participants had scores within the top fifth of the PSWQ distribution (M = 69.9, SD = 3.6, *range* 63–77). No participant was undergoing psychological or pharmacological treatment, or had auditory or cardiovascular problems. They were all screened using the ADIS-IV (Brown et al., 1994) to guarantee that none of them suffered from GAD.

Design

Participants were randomly split into two equal intervention groups: mindfulness and relaxation. They all underwent a psychological and psychophysiological assessment procedure before and after the intervention. The intervention programme comprised two weekly 1-h group sessions during a five-week period. Four participants (three in mindfulness and one in relaxation programmes) discontinued participation at some point of the intervention. The final number of participants was 15 in mindfulness and 17 in relaxation programmes.

Assessment procedure

Self-report measures

Clinical questionnaires. In addition to the PSWQ, participants completed the following clinical questionnaires before and after the intervention programme: (a) Beck Depression Inventory (BDI; Beck, Rush, Shaw, & Emery, 1979; Sanz & Vázquez, 1998); (b) Trait scale of the State-Trait Anxiety Inventory (STAI; Bermúdez, 1978a, 1978b; Spielberger, Gorsuch, & Lushene, 1970); (c) Positive and Negative Affect Schedule (PANAS; Sandín et al., 1999; Watson, Clark, & Tellegen, 1988); and (d) Subjective Health Complaints (SHC; Ericksen, Ihlebaek, & Ursin, 1999); this questionnaire consists of 29 items concerning severity and duration of several health complaints during the last two weeks (musculoskeletal pain and headache, gastrointestinal problems, pseudoneurological complaints such as dizziness and anxiety and allergy, flu and common cold). Except for the SHC, all these questionnaires have psychometrically validated Spanish versions.

Daily self-report of worry (Brosschot & Doef, 2006). Participants reported the number and duration of daily worry episodes during the five-week intervention programme. Scores on this scale were averaged for the first and the last week of the intervention programme.

Trait Meta-Mood Scale (TMMS-24; Fernández-Berrocal, Extremera, & Ramos, 2004). This Spanish version of the TMMS (Fitnes & Curtis, 2005; Salovey, Mayer, Goldman, Turvey, & Palfai, 1995) consists of 24 items intended to measure three cognitive dimensions of the emotional intelligence construct: perception (attention to feelings), comprehension (clarity and discrimination between feelings) and regulation (ability to control and repair negative emotional experiences). Internal consistency and test–retest reliability of the three scales are reported adequate (between .86 and .90 for internal consistency, and between .60 and .83 for test–retest reliability). Participants completed this scale before and after the intervention programme.

Physiological measures

Participants underwent a psychophysiological test before and after the intervention programme with the following sequence: (a) Baseline resting period: 8 min of rest with physiological recording during the last 5 min; (b) Non-cued defence response paradigm (Vila et al., 2007): after a baseline of 15 s, an intense white noise (105 dB intensity, 500 ms duration and instantaneous risetime) capable of eliciting cardiac defence, was presented through earphones, followed by an 80-s extended recording period; (c) Cued startle probe paradigm (Lang, 1995): 30 pictures selected from the *International Affective Picture System* (Lang, Bradley, & Cuthbert, 2008) according to the Spanish normative ratings (Molto et al., 1999; Vila et al., 2001) were presented for 6 s; the pictures differed both in valence and arousal scores (10 highly pleasant, 10 neutral, and 10 highly unpleasant); each picture was accompanied by an acoustic startle (the same white noise previously presented but reduced to 50 ms duration); three additional non-cued acoustic startles were also presented interspersed among the picture trials; and (d) Worry period: 5 min of self-induced worry with physiological recording. In the post-intervention assessment, a 5-min period of mindfulness/relaxation practice was added before the final self-induced worry period. Participants were given specific instructions prior to the test informing that they would hear brief intense noises but no indication of the exact moment of their presentation was given. They were also asked to look at the pictures during the entire period of their presentation. Concerning the mindfulness/relaxation practice in the post-intervention assessment, participants in the relaxation group were asked to evoke relaxation sensations without muscle tension and to postpone worrying, if any, to the subsequent worry period. Participants in the mindfulness group were asked to practice mindfulness as trained during the sessions (see below). Specific details on this psychophysiological test are reported in Delgado et al. (2009).

Intervention procedure

Training was conducted in small groups. In the first session, participants in both intervention procedures were given a working definition of worry (Borkovec et al., 1983) to facilitate identification of worry episodes. They were told that "worrying involves thinking about a subject that has or can have negative consequences for you and for which there is not, or not yet, a solution; it often, but not always, consists of a chain of negative thoughts, about the same or different topics, and often concerns something in the future, and the thought often takes shape as 'Imagine that…' or 'What would happen if…? '; The same thoughts often return; when you are engaged in worrying it is difficult to stop or hold. It definitely occupies your mind, and it is often disturbing and intensive." In this initial session, participants were also given the *Daily Self-Report of Worry* questionnaire with instructions to report the daily number and duration of worry episodes. The remainder of the session was different for each intervention group.

Mindfulness training programme

Session one continue with a brief explanation of the basic principles behind Mindfulness followed by a 15–20 min guided meditation. In subsequent sessions, the meditation period was gradually increased up to 40–45 min in the last session. The guided meditation was structured with the following sequence: (1) Attention was directed to the body position, giving instructions to adopt an upright sitting posture on the ischial bones with a non-rigid spinal cord; in order to facilitate achieving the correct posture, participants were invited to become aware of their proprioceptive sensations and gently move their body into a balanced posture. (2) Attention was focussed on awareness of their present mental and emotional state with the intention of accepting the affective value of the experience, whether positive, neutral, or negative. Whenever attention wandered from present state to past or future thoughts, attention was returned to the present by using breathing as an anchor: participants had to focus attention on the sensation of

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breath entering and leaving the body only at the nostrils or abdomen; respiration had to be smooth and natural, with no intention of controlling or manipulating it. (3) After session three, the participant's attention was also directed to interoceptive consciousness of all parts of the body, scanning sensations from feet to head with openness and equanimity, accepting all sensations beyond their affective valence and noting their transitory nature; priority areas were the abdomen, thorax, neck and head. (4) After session five, the meditation practice also incorporated the possibility of briefly labelling the present experience (i.e., 'thinking', 'wandering', 'worrying', 'remembering', 'anticipating', etc.); this labelling had to be free of any judgement or analysis, solely a direct re-cognition of the experience of the present mental state. (5) Finally, meditation ended with the intention of generating positive feelings of acceptance, comprehension and empathic compassion and love towards oneself, people close to one and all living beings, in this order. The end of each session was dedicated to (a) identifying difficulties during the meditation practice and suggesting strategies for coping with them, and (b) encouraging participants to practice daily at home and to generalize the mindfulness attitude to everyday situations, including their worries. Participants had to keep a daily written record of the number and duration of these practice sessions, indicating the level of attention, level of mental silence, level of equanimity, subjective achievement and generalization to daily life.

Relaxation training programme

Session one started with a brief explanation of the basic principles of Progressive Muscle Relaxation followed by a 15–20 min guided relaxation practice based on the adapted version proposed by Bernstein and Borkovec (1973). In subsequent sessions, the relaxation practice was gradually increased to 40–45 min. The relaxation programme included training 16 muscle groups during the initial sessions and then 8 muscle groups and 4 muscle groups until only recall relaxation was used in the final sessions. Besides this standard muscle relaxation, the programme also added relaxation training of speech and imagination, following the original procedure proposed by Jacobson (1938). In each session, participants were also instructed to be aware of their thoughts during daily activities in order to detect any worry and, if detected, immediately give themselves the instruction to 'postpone this worry to my later worry time'. Participants had to programme a short period of 10–20 min everyday when they could consciously worry about their postponed worries. The end of each session was dedicated to: (a) identifying difficulties during the relaxation practice, suggesting strategies to cope with them; and (b) encouraging participants to practice relaxation daily at home following the same procedure used in the most recent session. Participants had to keep a daily written record of the number and duration of practice sessions, indicating level of physical relaxation, level of mental relaxation, subjective achievement, and generalization to daily life.[1]

Instruments and measures

Heart Rate Variability (HRV) and *Cardiac Defence* were derived from the EKG (lead II) recorded using a Grass polygraph (Rps 7c 8b) with a 7P4 preamplifier. High Frequency (.15–.5 Hz) HRV amplitudes during the resting, mindfulness/relaxation, and self-induced worry periods were obtained using spectral analysis on the R–R interval time series of the EKG (Perakakis, Joffily, Taylor, Guerra, & Vila, 2010; Task Force of the European Society, 1996). *Cardiac Defence* was defined as the second-by-second heart rate (HR) to the defence stimulus during 80 s after stimulus onset expressed as differential scores from a 15 s baseline, and reduced to 10 progressively longer intervals (Vila et al., 2007). The following accelerative and decelerative components of the response were then defined: (a) short-latency acceleration: highest heart rate at intervals 1–2; (b) short-latency deceleration: lowest heart rate at intervals 3–4; (c) long-latency acceleration: highest heart rate at intervals 5–7; and (d) long-latency deceleration: lowest heart rate at intervals 8–10.

Eye-blink startle was measured by recording EMG activity from the orbicularis oculi region beneath the left eye using a Coulbourn bioamplifier V75-04 with two small Ag/AgCl electrodes filled with hypertonic electrolyte paste. The signal was filtered using a frequency band of 90–1000 Hz and integrated using a Coulbourn V76-23 integrator with a time constant of 75 ms. The startle reflex magnitude was defined as the difference in microvolts between the peak of the integrated response and the response onset occurring between 20 and 100 ms following the initiation of the startle stimulus.

Skin conductance (SC) was recorded using a Coulbourn bioamplifier V75-23 with two standard Ag/AgCl electrodes, filled with isotonic electrolyte paste, placed on the left hypothenar eminence. The SC response to the defence noise in the non-cued defence paradigm was obtained by following the same procedure as applied to cardiac defence. The SC response to the pictures in the cued defence paradigm was defined as the maximum change between 1 and 4 s after picture onset, expressed as deviations from a baseline period of 1 s preceding the picture. These values were log transformed (log[value + 1]) in order to normalize the distribution.

Respiration measures were recorded using a pneumographic transducer around the participant's chest, at the xiphoid cartilage level, connected to a Coulbourn respiration amplifier V75-25A. The following breathing parameters were obtained: Mean respiratory rate, mean inspiratory period and mean expiratory period. A log transformation was applied to these data to normalize the distribution.

The sequence of stimuli presentations and the acquisition and analysis of physiological data were controlled by the VPM software programme (Cook, 1994) using the *Advantech*-PCL812PG A/D converter and input-output data card run by a Pentium 4 computer. The white noise was presented binaurally through earphones (Telephonic TDH Model- 49) using a Coulbourn audio system model V85-05 with an IMQ Stage Line amplifier. The intensity of the sound was calibrated using a sonometer (Bruel & Kjaer, model 2235) and an artificial ear (Bruel & Kjaer, model 4153). Pictures were presented with a Canon LV-53 projector. The projector presented 145 × 95 cm images 3 m away from the participant.

Statistical analysis

The data were analyzed by means of mixed between groups with repeated-measures ANOVAs using the multivariate test statistic (*Wilks' lambda*) generated by SPSS. This method is free of sphericity assumptions and is therefore more suitable for repeated-measures designs (O'Brien & Kaiser, 1985). Results are presented reporting the *F* value associated to the *Wilks' lambda* statistic. The between-groups factor was always the two intervention groups. For the self-report data, the repeated-measures factor was Pre-Post intervention. For the physiological data during resting/mindfulness-relaxation/self-induced worry, the repeated-measures factor was Periods. For the physiological data in the non-cued defence paradigm, repeated-measures factors were Pre-Post intervention and Time (the 10 time intervals). Specific tests were performed for each cardiac

[1] Both training programmes were conducted by the first author (MSc and PhD in Clinical and Health Psychology), who has more than 10 years experience in meditation and relaxation techniques.

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component. Finally, for the physiological data in the cued defence paradigm, repeated-measures factors were Pre-Post intervention and Picture Content (the three picture categories). Trend analysis was applied to test the expected affective modulation of eye-blink startle (linear trend) and skin conductance (quadratic trend), followed by pairwise comparisons using *Student's t* statistic. The level of significance was set at .05 for all analyses.[2]

Results

Self-report measures

Clinical questionnaires

Table 1 shows the mean and (standard deviation) of participants' scores in the clinical questionnaires before and after each intervention programme. No significant pre-intervention differences were found. Significant Pre-Post effects appeared in worry (PSQW: $F(1, 26) = 26.37$, $p < .001$), trait anxiety (STAI-T: $F(1, 26) = 8.72$, $p < .008$), depressive symptoms (BDI: $F(1, 26) = 4.53$, $p < .04$) and some health complaints (SHC Pseudoneurological subscale: $F(1, 23) = 7.63$, $p < .012$). No significant Pre-Post effects were found in positive and negative affect (PANAS-P: $p > .22$; PANAS-N: $p > .54$) and other health complaints (SHC-total score: $p > .07$). After the intervention, participants in both groups significantly reported less worry, trait anxiety, depressive symptoms and some health complaints (dizziness and anxiety). No group differences were found in any of the questionnaires.

Daily self-report of worry

Table 1 shows the mean (standard deviation) of the number and duration of worry episodes during the intervention programme (week 1 versus week 5). Significant differences appeared in number of worry episodes ($F(1, 25) = 16.16$, $p < .001$) and duration of the episodes ($F(1, 25) = 10.11$, $p < .004$) during the intervention. In the last week of intervention, participants of both groups reported significantly fewer and shorter worry episodes than in the first week.

Daily self-report of practice sessions

Participants reported a high level of adherence to their respective intervention programmes, with 89.5% of daily practice, as average, in the mindfulness group, and 87.1% in the relaxation group. No significant differences were found between the groups ($p > .6$).

Trait Meta-Mood Scale

Table 1 also shows the mean (standard deviation) of participants' scores in the perception, comprehension and regulation subscales and total score of the TMMS. Significant Pre-Post × Group interactions were observed in the comprehension subscale ($F(1, 26) = 5.97$, $p < .02$) and in the total score ($F(1, 26) = 6.99$, $p < .014$). After the intervention, comprehension subscale and total questionnaire scores significantly increased in the Mindfulness group, compared to the Relaxation group. Participants in the Relaxation group had higher pre-intervention scores in these scales that significantly decreased after intervention, compared to the Mindfulness group.

Physiological measures

Resting/mindfulness-relaxation/self-induced worry periods

Fig. 1A and B plot the physiological results for both intervention groups during the resting, mindfulness/relaxation and self-induced worry periods after the intervention programme.

Respiratory parameters. Respiratory rate yielded significant main effects of Group ($F(1, 27) = 4.59$, $p < .04$) and Periods ($F(2, 26) = 3.54$, $p < .03$). Respiratory rate was lower during mindfulness/relaxation than during resting and self-induced worry. The mindfulness group had a significantly lower mean respiratory rate during all three periods in comparison to the relaxation group. *Inspiratory period* yielded a significant effect of Periods ($F(2, 26) = 3.87$, $p < .03$). Inspiratory period was significantly higher during mindfulness/relaxation than during resting and self-induced worry. Finally, *expiratory period* revealed significant effects of Group ($F(1, 27) = 4.63$, $p < .04$) and Group × Periods interaction ($F(2, 26) = 3.79$, $p < .04$). Expiratory period was in general larger for mindfulness participants, with a greater increase during the mindfulness/relaxation period, whereas the expiratory period of relaxation participants decreased during mindfulness/relaxation (see Fig. 1A).

Heart rate and heart rate variability. The 2 (Group) × 3 (Periods) ANOVAs showed significant Periods effects for HR ($F(2, 28) = 6.86$, $p < .004$) and high frequency (HF) HRV ($F(2, 28) = 6.29$, $p < .006$). Mean heart rate was significantly lower and mean HF heart rate variability was significantly higher during mindfulness/relaxation than during resting and self-induced worry periods. No significant group differences were found (see Fig. 1B).

Skin conductance. The 2 × 3 ANOVA did not show any significant effect (all $p > .10$). In the relaxation group, skin conductance tended to be higher during mindfulness/relaxation and self-induced worry periods than during resting period, although the differences did not reach significance (see Fig. 1B).

Non-cued defence paradigm

Cardiac defence

Fig. 2 plots the cardiac defence response before and after the intervention as a function of the groups. The 2 (Group) × 2 (Pre-Post) × 10 (Time) ANOVA yielded significant effects of Pre-Post ($F(1, 29) = 4.15$, $p < .05$) and Time ($F(2, 21) = 17.65$, $p < .0001$). As seen in Fig. 2, both groups showed the expected pattern of cardiac defence before the intervention (a short-latency acceleration/deceleration followed by a long-latency acceleration/deceleration). After the intervention, both groups showed a reduced response, especially during the short- and long-latency accelerations. Analysis of the Pre-Post differences in each group, along the short- and long-

Table 1
Mean (standard deviation) of participants' scores in the self-report measures as a function of intervention group and assessment moment.

	Mindfulness group		Relaxation group	
	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
PSQW	67.0 (4.1)	58.9 (7.9)	66.7 (3.6)	58.8 (8.6)
STAI-T	29.7 (10.7)	26.3 (11.2)	31.6 (11.6)	26.9 (10.9)
BDI	9.0 (6.2)	4.9 (6.5)	9.8 (8.6)	6.9 (7.3)
PANAS-P	30.2 (4.8)	31.6 (5.3)	28.5 (7.9)	29.9 (6.6)
PANAS-N	23.2 (6.5)	22.7 (6.8)	23.4 (9.0)	21.7 (7.4)
SHC-Total score	15.9 (7.4)	13.9 (7.0)	18.4 (9.3)	14.8 (7.3)
SHC-Neurological scale	7.7 (4.0)	6.2 (3.4)	8.0 (4.3)	4.9 (3.1)
TMMS-Perception	24.7 (5.4)	24.2 (5.2)	28.1 (4.4)	23.0 (7.1)
TMMS-Comprehension	21.0 (6.3)	27.1 (8.5)	26.3 (7.6)	24.3 (7.9)
TMMS-Regulation	22.2 (5.2)	25.6 (86.2)	23.7 (3.6)	24.6 (6.1)
TMMS-Total Score	67.9 (12.8)	76.9 (12.9)	78.1 (9.4)	72.6 (11.0)
	Week 1	*Week 5*	*Week 1*	*Week 5*
Daily Self-Report of Worry-number	7.8 (3.6)	6.4 (2.6)	8.5 (4.1)	6.0 (3.9)
Daily Self-Report of Worry-duration	59.6 (52.5)	44.4 (37.6)	70.7 (38.2)	37.6 (31.4)

[2] Six participants had physiological artefacts or missing data on some measures. They were excluded from the specific analyses for these measures.

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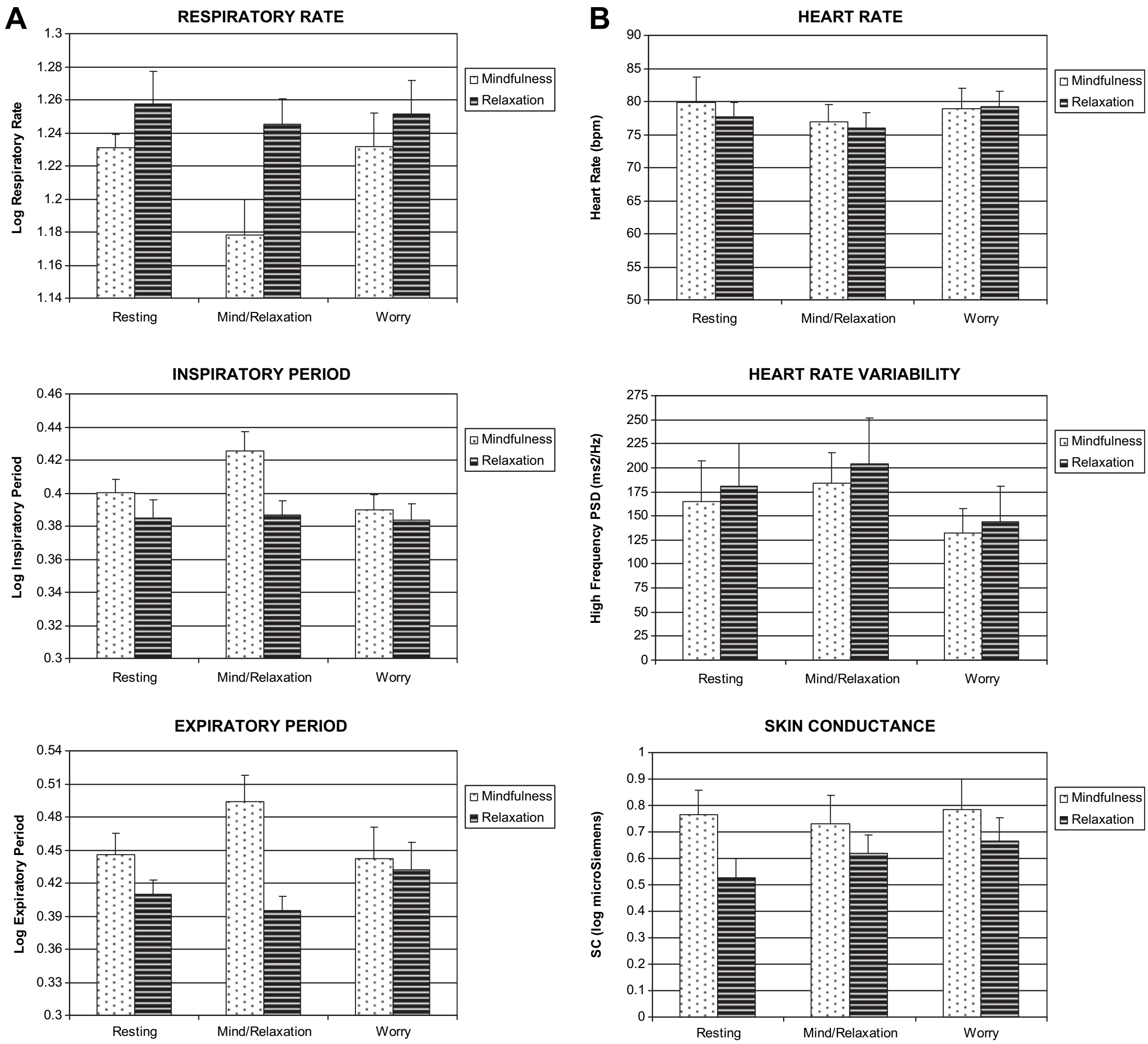

Fig. 1. (A). Respiratory parameters during the resting, mindfulness/relaxation and self-induced worry periods after the intervention programme as a function of the intervention groups (bars are standard error of the mean). (B). Heart rate, heart rate variability, and skin conductance during the resting, mindfulness/relaxation and self-induced worry periods after the intervention programme as a function of the intervention groups (bars are standard error of the mean).

latency components, revealed significant differences in the short-latency acceleration (Time intervals 1–2: $p < .03$) and in the long-latency acceleration (Time intervals 5–7: $p < .04$) in the mindfulness group. In the relaxation group, none of the differences were significant. Both groups also differed in the long-latency deceleration at post-intervention (Time intervals 8–10: $p < .05$), with the mindfulness group showing a larger deceleration.

Skin conductance

The 2 × 2 × 10 ANOVA yielded only a significant effect of Time ($F(9, 21) = 4.47$, $p < .002$). None of the other factors and interactions was significant. Both groups showed a large response to the defence noise that did not recover along the 10 Time intervals. The response did not significantly change after the intervention.

Cued defence paradigm

Eye-blink startle

The 2 (Group) × 2 (Pre-Post) × 3 (Picture_Content) ANOVA yielded a significant effect of Picture_Content ($F(2, 22) = 6.56$, $p < .006$). None of the other factors and interactions was significant. The Picture_Content effect, with a significant linear trend ($F(1, 23) = 9.47$, $p < .005$), reflects the expected affective modulation of eye-blink when averaged across groups and assessment conditions: reduced magnitude for pleasant, intermediate magnitude for neutral, and increased magnitude for unpleasant pictures (see Fig. 3). Significant differences were found between pleasant and neutral ($p < .03$) and pleasant and unpleasant ($p < .005$), but not between neutral and unpleasant ($p > .07$).

Skin conductance

The 2 × 2 × 3 ANOVA yielded a significant effect of Picture_Content ($F(2, 27) = 3.56$, $p < .04$). None of the other factors and interactions was significant. The Picture_Content effect, with a significant quadratic trend ($F(1, 28) = 7.01$, $p < .01$) when averaged across groups and assessment conditions, reflects the expected affective modulation of skin conductance: increased magnitude for pleasant, reduced magnitude for neutral and increased magnitude for unpleasant pictures (see Fig. 3). Significant differences were found between pleasant and neutral ($p < .03$) and unpleasant and

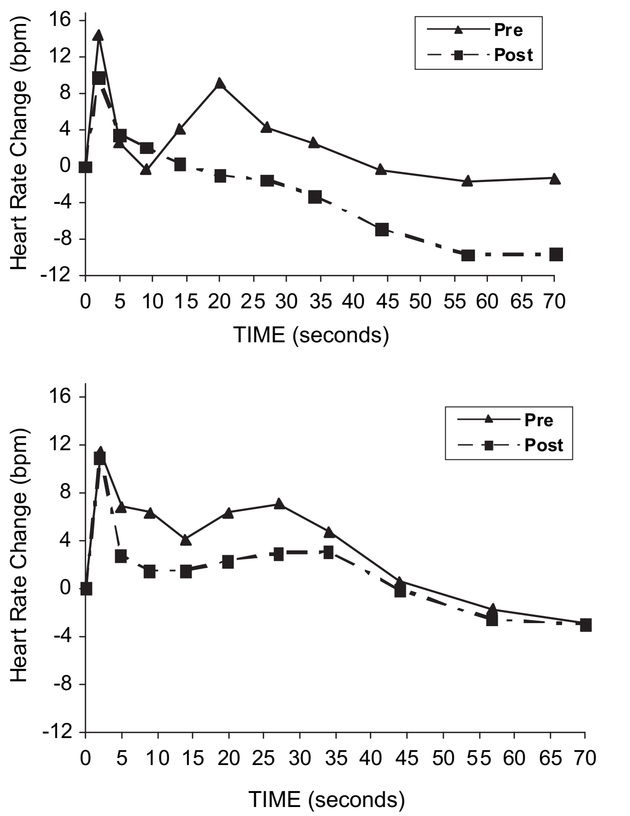

Fig. 2. Cardiac defence response in the non-cued defence paradigm before and after intervention in the mindfulness (top) and relaxation (bottom) groups.

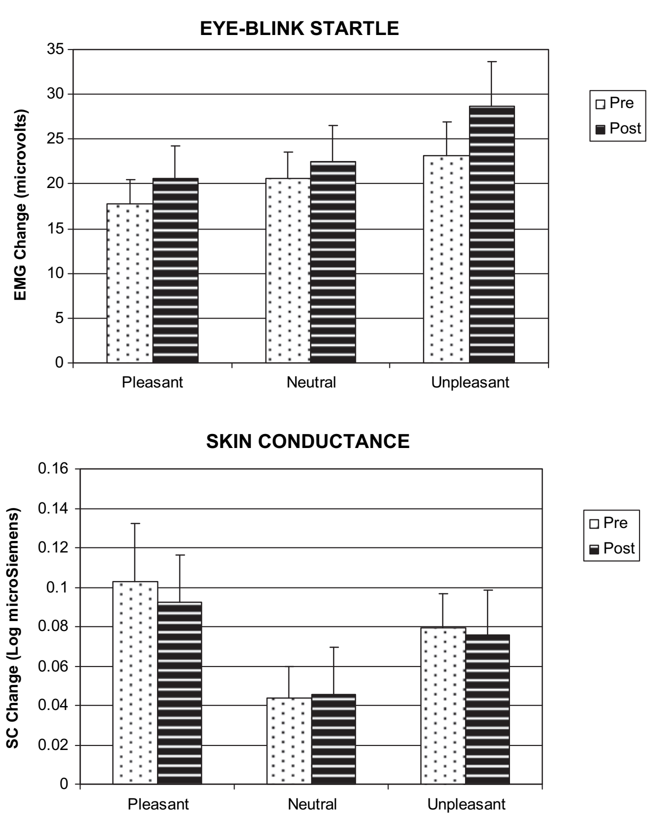

Fig. 3. Affective modulation of eye-blink startle (top) and skin conductance (bottom) in the cued defence paradigm before and after the intervention (bars are standard error of the mean).

neutral pictures ($p < .03$), but not between pleasant and unpleasant pictures ($p > .16$).

Discussion

The major findings of our study can be summarized as follows: (a) *Self-report measures of worry, trait anxiety, depressive symptoms, and some health complaints*, pre- and post-intervention, as well as *daily self-reports on the number and duration of worry episodes* throughout the intervention, showed significant reductions in our mindfulness and relaxation (plus instruction to postpone worrying) groups, suggesting that the two intervention programmes were equally successful in producing a clinical improvement; (b) *Self-report measures of emotional meta-cognition* showed that the mindfulness group had significantly higher post-intervention emotional comprehension subscale and total scores versus the relaxation group; (c) *Physiological measures during resting, mindfulness/relaxation, and worry* demonstrated a significantly slower respiratory rate (during all three periods) and longer expiratory period (during mindfulness/relaxation) in the mindfulness group; both groups showed significant increases in high frequency HRV and inspiratory period and decreases in heart rate and respiratory rate during mindfulness/relaxation, relative to resting and worry periods, consistent with the expected positive effects of both training programmes; (d) *Physiological measures in the non-cued defence paradigm* demonstrated a significant overall post-intervention reduction in the magnitude of cardiac defence with both programmes, although the mindfulness group had a larger reduction in the maximum peaks of short- and long-latency accelerations; and (e) *Physiological measures in the cued defence paradigm* showed no significant pre-post intervention differences, with participants in both programmes manifesting the expected modulation of eye-blink startle and skin conductance while viewing pleasant, neutral and unpleasant pictures.

The significant differences between the mindfulness and relaxation groups in post-intervention emotional meta-cognition (emotional comprehension and total score) and the absence of inter-group differences in the self-report indices of clinical improvement (worry, trait anxiety, depressive symptoms, and health complaints) are consistent with our study hypotheses. Both intervention programmes were equally successful in reducing these clinical outcome measures, while mindfulness proved superior in increasing the clarity and discrimination of feelings and emotions (emotional comprehension subscale). The mindfulness group also tended to show better scores for the perception and regulation of emotions (the other two subscales), although the two groups only significantly differed in total score. Hence, in comparison to relaxation (plus instruction to delay worrying), mindfulness training is better able to modify important aspects of emotional experience that have been associated with behavioural adaptation and well-being (Fitnes & Curtis, 2005). This finding might be relevant to our understanding of chronic worry and its long-term effective treatment (Chambers et al., 2009).

The few differences in physiological measures between our mindfulness and relaxation groups were also consistent with our hypothesis. Mindfulness participants showed superior indices of respiratory parameters during resting, mindfulness/relaxation and worry periods, as predicted, reflecting a tendency to reduce ventilation (slower respiratory rate and larger expiratory period). However, no differences were found in HF heart rate variability during these periods (vagal tonic measures). Both programmes produced similar patterns of higher variability during mindfulness/relaxation and of lower variability during worrying versus resting periods. A difference in high frequency heart rate variability (or respiratory sinus arrhythmia) between high and low chronic

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worriers is a consistent finding in the literature (Thayer et al., 1996; Hofmann et al., 2005; Thayer & Brosschot, 2008). Delgado et al. (2009) also found lower respiratory sinus arrhythmia, together with faster respiratory rate and shorter expiratory period, in the present participants than in a group of low chronic worriers. Our findings suggest that mindfulness is better than relaxation (plus instruction) as a procedure to reduce the breathing pattern that differentiates high from low worriers but not to improve their reduced vagal control as a tonic mechanism. However, due to respiratory confounds results on vagal tonic control are not conclusive.

The physiological measures in the non-cued defence paradigm also offer some evidence regarding the effect of both programmes on the physiological mechanism underlying chronic worry. As also observed by Delgado et al. (2009), high worriers showed a greater cardiac defence in the non-cued defence paradigm in comparison to low worriers, confirming chronic worry as a state of contextual fear or anticipatory anxiety. These differences were identified in the short- and long-latency acceleration/deceleration of the cardiac response. The short-latency component is vagally mediated (Reyes del Paso et al., 1993; Reyes del Paso et al., 1994), suggesting that reduced vagal reactivity may be the physiological mechanism underlying the potentiating effect of chronic worry on cardiac defence. Our results indicate that both intervention programmes were successful in reducing non-cued cardiac defence, presumably by the same physiological mechanism but in an opposite direction, i.e., by increase in vagal activation. However, the larger post-intervention cardiac decelerations at the short- and long-latency components of the response in the mindfulness versus relaxation group suggest that mindfulness was more effective than relaxation (plus instruction) in increasing vagal control as a phasic mechanism.

The negative results in the cued defence paradigm are also relevant in this context. Affective modulation of eye-blink startle and skin conductance by viewing pleasant, neutral and unpleasant pictures did not differentiate high and low chronic worriers in Delgado et al.'s study, reinforcing the notion of chronic worry as a non-cued rather than cued fear reaction (Hofmann et al., 2005). This conclusion is supported by our finding that neither programme had a significant effect on cued defence procedures. However, they found a significantly depleted skin conductance in high versus low worriers, irrespective of the affective content of the pictures, confirming previous reports of reduced sympathetic activation indices in chronic worriers and GAD patients (Hoehn-Saric & McLeod, 1988; Hoehn-Saric, McLeod, & Zimmerli, 1989; Thayer et al., 1996). Consequently, our finding of no significant change in skin conductance after either intervention programme suggests that the clinical improvement obtained was not mediated by changes in sympathetic control. This autonomic mechanism, which is significantly reduced in chronic worriers, appeared unaltered despite significant reductions in clinical symptoms of worry, trait anxiety, depressive symptoms, and health complaints.

Evaluation of the theoretical and clinical implications of our findings should take account of some methodological limitations. First, our study did not include a non-treatment group to control for the non-specific effects of the time elapsed between assessments. Second, we did not follow up the participants, since our aim was to examine the short-term effects of mindfulness on the psychological and physiological mechanisms underlying chronic worry. Future research is warranted to confirm whether the specific changes observed in our study persist over time. Third, our participants were all female, and the final number of participants in each programme was unequal and relatively small due to experimental attrition. The absence of males in our study clearly limits the generalizability of our findings. Although similar sample sizes have proved adequate to reliably demonstrate differential effects on the physiological measures used in the present study (Bradley, Cuthbert, & Lang, 1996; Ramírez, Sánchez, Fernández, Lipp, & Vila, 2005), the relative small sample size might have increased the probability of type II errors in some analyses. And fourth, some potential confounding might have occurred associated with the fixed sequence of the physiological test as regards the non-cued and cued defense reaction paradigm, as well as the fact that the same therapist applied both intervention programmes. However, proper assessment of cardiac defense requires a single intense noise not preceded by other noises (as it would occur if both paradigms are presented in counterbalanced order). Similarly, using different therapists, while helping to control some confounding variables, might also introduce others.

Bearing in mind these limitations, our study contributes evidence that a training programme based on mindfulness reduces the clinical symptoms of chronic worriers through a process of learning new emotional and physiological regulatory mechanisms contrary to those that generate and sustain chronic worry. This claim is supported by the differential effects of mindfulness on emotional meta-cognition (emotional comprehension) and on physiological indices of somatic and autonomic regulation (reduced breathing pattern and increased phasic vagal reactivity). These effects were probably facilitated by the two key elements of mindfulness, awareness and acceptance of present experience, together with the attentional focus on respiration. A similar conclusion was drawn by a recent fMRI study of metabolic changes in brain function after a mindfulness-based intervention aimed at reducing social anxiety (Goldin et al., 2009). In our study, however, mindfulness was not superior to progressive muscle relaxation (with a specific instruction to postpone worrying to a specific time of the day) in achieving a short-term post-intervention reduction in worry and other clinical symptoms. It is possible that mindfulness may have greater beneficial effects over the long term if the positive post-treatment changes persist. However, this is a novel hypothesis that will require empirical confirmation.

Indeed, the superiority of mindfulness as a therapeutic tool in comparison to other psychological treatments continues to be a controversial issue (Allen et al., 2006; Arch & Craske, 2009; Lau & Yu, 2009; Toneatto & Nguyen, 2007). Despite its popularity and widespread application, the scientific status of mindfulness is compromised by the paucity of experimental research on the psychological and neurophysiological mechanisms underlying its reported clinical effectiveness. Moreover, mindfulness has rarely been tested in relation to well-established psychological treatments based on similar theoretical principles. For instance, it has not been properly compared with traditional exposure treatments for specific disorders (Craske & Mystkowski, 2006; Delinsky & Wilson, 2006), or with classical relaxation techniques based on meditation, such as Benson's Relaxation Response (Benson, 1975; Kutz, Borysenko, & Benson, 1985). In the absence of appropriate and rigorous comparisons, the superiority of mindfulness as a therapeutic tool will remain in doubt.

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