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Abstract

During mindfulness-based interventions participants can be invited to bring aversive stimuli to mind while practicing mindfulness. This is thought to help the stimuli become less aversive. However, the mechanisms underlying this process are not fully understood. In this study we explored these by examining the effects of mindfulness practice and stimulus visualization on stimuli associated with electric shocks. Participants were trained on a discrimination between two visual stimuli using a standard electrodermal conditioning procedure, in which one stimulus (CS+) was paired with shock and the other (CS-) was not. They then visualized either the CS+ or CS-, while practicing mindfulness or performing a control activity. Following a number of extinction trials, the impact of these manipulations was assessed during a reacquisition test-phase. Both mindfulness and visualization of the CS+ led to slower reacquisition of the CS+/shock association, when measured physiologically, and their effects were additive. Moreover, these effects dissociated from participants' expectancy of shock. If confirmed in future work, these findings may have implications for the treatment of stimulus-specific anxiety.

Keywords: mindfulness, associative learning, extinction, reacquisition

Introduction

In recent years there has been a rapid growth of interest in mindfulness (e.g. Mindfulness All-Party Parliamentary Group, 2015). This has been driven in part by the growing evidence for the efficacy of mindfulness-based therapeutic interventions, such as mindfulness-based cognitive therapy (Segal, Williams & Teasdale, 2013), which has been shown to reduce the risk of relapse of depression relative to treatment as usual and more active controls (Kuyken et al., 2015). However, much remains to be understood about the nature and mechanisms of action of mindfulness (Tang, Holzel & Posner, 2015; van der Velden et al., 2015). In this paper, we attempt to further this understanding in one particular area, namely how mindfulness interacts with basic human learning processes (cf. Treanor, 2011). To set the stage for this, it is helpful to first consider mindfulness in more detail.

Mindfulness

Kabat-Zinn's (1994) frequently cited definition of mindfulness describes it as 'paying attention in a particular way: on purpose, in the present moment, and non-judgmentally'. Mindfulness meditation practice is seen as a means of cultivating this way of attending. In a typical practice, 'mindfulness of the breath', participants are invited to pay attention to and be curious about their moment-by-moment experience of breathing, and to be gentle with themselves should their attention wander away from this (Kabat-Zinn, 1990).

In mindfulness-based interventions, such as mindfulness-based cognitive therapy, after participants have developed some experience at practicing mindfulness, they are invited to deliberately bring attention to a difficult experience during mindfulness practice (Segal et al., 2013). Frequently this can be a memory or image associated with feelings of anxiety and/or low mood. This is thought to help participants learn to not engage in unhelpful rumination and worry when faced with a difficulty (cf. Segal et al., 2013), and to help them to build their ability to tolerate distress (cf. Lotan, Tany & Bernstein, 2013). In addition, theories of associative learning would suggest that basic associative learning processes should be in play (cf. Treanor, 2011). However, the latter aspect has yet to be adequately investigated empirically. A laboratory model that can be used to examine such processes further is the electrodermal fear conditioning paradigm.

Electrodermal Fear Conditioning

In this paradigm, a neutral stimulus, referred to as the conditioned stimulus (CS), becomes capable of eliciting fear through its repeated pairing with an aversive unconditioned stimulus (US), such as electric shock (see McAndrew et al., 2012 for details of the procedure used here). Participants' learning of this CS-US association is typically measured in two ways. The first is through their 'conditioned response' (CR), which in this case usually includes increased arousal following the CS, due to increased anxiety at the prospect of being shocked. This can be detected by measuring the

Table 1: The study's design

Group	Training	Manipulation	Extinction	Reacquisition
MV+	A+ B-	Mindfulness & A	A- B-	A+ B-
MV-	A+ B-	Mindfulness & B	A- B-	A+ B-
CV+	A+ B-	Control & A	A- B-	A+ B-
CV-	A+ B-	Control & B	A- B-	A+ B-

conductance of electricity between two electrodes on the skin, and is typically referred to as the skin conductance response (SCR). Secondly, when presented with the CS, participants can be asked to rate how much they expect a shock.

Under certain conditions, dissociations can be obtained between SCRs and expectancy ratings (e.g. Knight, Nguyen, & Bandettini, 2003; Tabbert, Stark, Kirsch, & Vaitl, 2006; McAndrew et al., 2012). These can be explained by dual process models of human learning, such as that proposed by McLaren, Green and Mackintosh (1994), and further developed in McLaren, Forrest, McLaren, Jones, Aitken and Mackintosh (2014). They argue that people can learn using both associative processes, which are similar to those found in other animals, and through rule-based processes capable of symbolic manipulation (though Lovibond and Shanks, 2002 take an alternative view). Thus, as well as having the potential to provide a useful laboratory model to investigate mindfulness further, the fear conditioning paradigm enables an examination of the degree to which mindfulness interacts differently with different learning processes.

The current study

Therefore, in the current study we aimed to embed mindfulness practice in a human electrodermal, fear conditioning procedure. More specifically, we planned to train people to learn a 'CS'-> shock association (along with an appropriate comparison) before inviting them to practice mindfulness while visualizing the CS, in a similar way to how distressing events can be brought into attention during mindfulness practice. We then planned to examine what effects, if any, this mindfulness visualization had on the learning of the CS -> shock relationship, relative to various comparison groups. Furthermore, we sought to examine whether such mindfulness-based visualization had differential effects on the different learning processes tapped by SCR and expectancy. We hoped that this investigation would provide us with a better understanding of the learning processes in play during mindfulness practice, which in turn could help contribute to improving the efficacy of mindfulness-based interventions for anxiety.

Method

Participants

Ninety-six University of Exeter students participated in this experiment. There were 72 women and 24 men and their ages ranged from 18 to 30 years, with a mean of 20.4 years (SD=2.75). All were paid £6. Participants were randomly allocated to the groups described below, constrained to ensure equal group sizes (N=24 in each group). The study received ethical approval from the University of Exeter, Psychology Ethics Committee.

Design

The study began with a training phase during which all the participants learnt an A+ B- discrimination; that is, they learnt that one conditioned stimulus (the CS+), which we will refer to as A, was always followed by an electric shock, while a second, the CS- (B), never was.

Following this, each of the four groups received a different manipulation, as illustrated in Table 1. In the mindfulness visualization plus (MV+) condition, participants were invited to visualize the CS (i.e. A) that had been previously paired with shock while they practiced mindfulness. In the mindfulness visualization minus (MV-) condition, they visualized the unpaired CS (i.e. B) while practicing mindfulness. The two control conditions were identical to the mindfulness ones, with the exception that, instead of practicing mindfulness, participants were asked to listen to an excerpt from an audio book. Thus, in the control visualization plus (CV+) condition, participants listened to the audiobook while visualizing stimulus A, and in the control visualization minus (CV-) condition, participants listened to the audiobook while visualizing stimulus B.

Following this manipulation, all the groups received an extinction test phase, during which A and B were presented but neither were paired with shock. This was followed by a reacquisition test phase, during which all participants were again trained on the original A+ B- discrimination; that is, A was once again followed by a shock, whereas B was not. This second test phase was included, as pilot work suggested it was more sensitive to the effects of the manipulation. This may be because extinction happens relatively quickly in this paradigm, resulting in very few trials that provide useful data from the extinction test phase.

Therefore, there were three independent variables; namely *practice type* (mindfulness vs. control), *stimulus visualized* (A vs. B), and *stimulus tested* (A vs. B), with the former two being between-subject factors and the later being a within-subject factor.

Stimuli

The two CSs were a brown cylinder 4.5 x 6cm onscreen, and a pink square 5.5 x 5.5cm onscreen. Each CS presentation lasted for 5 seconds. The use of these stimuli as CS A and CS B was counterbalanced across participants.

The unconditioned stimulus (US) was a 500ms shock administered with a PowerLab 26T generator using stainless steel electrodes attached to the left proximal and medial phalanges of the index finger. At the beginning of the experiment, participants set their own shock level between 5 and 20mA, to a level that was "definitely uncomfortable but not painful".

Visualization Guidance

Mindful Visualization This period of practice began with 7.5 minutes of 'mindfulness of the breath' guided by audio CD. This practice was of the sort used in mindfulness-based cognitive therapy (Segal et al., 2013), and the CD had been recorded by the first author (who has a postgraduate qualification in teaching mindfulness). The intention of this initial period of practice was to help establish a more mindful state of mind before the participant began stimulus visualization. After 7.5 minutes, the CD guidance asked the participant to open their eyes, if they were closed, and look at the name (either 'pink square' or 'brown cylinder', as appropriate to the condition) that the experimenter had placed in front of them. The audio CD then invited them to close their eyes and continued as follows:

'... as best you can, remembering what this shape looked like in the first part of the study, and seeing if it is possible to hold an image of this shape in your mind. [pause] Don't worry if you find it hard to picture this shape, as this is more difficult for some of us than others, [pause] just doing your best to bring to mind whatever memories and images you have of this shape from the first part of the study. [pause] And if it seems to help, you might want to sometimes say the name of the shape to yourself. [pause] And if there are any feelings or bodily sensations that accompany the memory or image of the shape, just acknowledging those and allowing them to be present as you hold this shape in mind. [pause] And if at any point you forget which one of the shapes you are being invited to hold in mind, opening your eyes again briefly and re-reading the piece of paper.'

The CD guidance subsequently invited participants to expand their attention so that they both held in mind an 'image or memory' of the shape and attended to 'the experience of breathing'. This was followed by periods of silence, interspersed with guidance to the same effect. In total, the audio CD lasted 13 minutes 20 seconds.

Control Visualization In the control visualization conditions, participants were asked to listen to an excerpt from an audiobook by Bill Bryson. This material was chosen as the calm tone of delivery was similar to that for the mindfulness visualization guidance and the content was likely to be experienced as engaging but uncontroversial. As with the mindfulness visualization conditions, after 7.5 minutes participants were asked to look at the name of the shape that the experimenter had placed in front of them, and then hold an image of this shape in mind. The wording and timing of the stimulus visualization instructions were identical to the mindfulness visualization conditions, with the exception that guidance pertaining to attending to the breath was omitted. In between visualization guidance, the audiobook continued to play. Each control visualization condition lasted for the same amount of time as each mindfulness visualization condition.

Measures

Skin conductance Skin conductance response (SCR) was measured using LabChart software via MLT116F GSR electrodes attached to the medial phalanges on the left third and fourth fingers.

Expectancy Expectancy ratings for the US were recorded using a Contour Shuttle Xpress device. Participants were required to make an expectancy rating about the extent they thought the shock would happen during presentation of the CS. The device had five buttons and fitted nicely into one hand such that one button corresponded to one finger. The different expectancy values were: 1 "There will definitely not be a shock", 2 "There might not be a shock", 3 "Not sure either way", 4 "There may be a shock", and 5 "There will definitely be a shock". A continuously available legend explained which buttons represented which ratings.

State mindfulness As a manipulation check, the State Mindfulness Scale (Tanay & Bernstein, 2013) was administered to all participants immediately after the visualization stage. This 21-item, self-report measure asks participants to rate how well each item (e.g. 'I felt closely connected to the present moment') describes their experience over the past 15 minutes. It has satisfactory psychometric properties, for example Cronbach's α = .95 (Tanay & Bernstein, 2013). Higher scores indicate higher levels of state mindfulness. Therefore, if the mindfulness visualizations were successful at inducing a more mindful state of mind than the control visualizations, participants in the former conditions should score significantly more highly on this measure than those in the latter.

Procedure

With the exception of the visualization stage (see below), the participants were told they would receive shocks to some of the visual stimuli throughout the experiment. They were asked to rate their expectancy that the shock would occur during each stimulus presentation, using the Shuttle Xpress device. Otherwise they were asked to remain still to avoid motion artefacts in the SCR. On shock (A+) trials, a 500ms US was administered after 4500ms of CS A being on screen, whereas on no shock (B–) trials no US occurred.

SCR recordings were taken on every trial, during the five seconds prior to CS onset (Pre-CS), five seconds while the

CS was on screen and five seconds after the CS (Post-CS). The inter-trial interval (ITI) was randomly varied between 30 and 40 seconds in order to stop participants timing the onset of the CS. Long ITIs were required to allow the SCR recording to reach baseline after the previous US.

This experiment had an initial training phase of 12 trials: six each of A+ and B-, in a random order. This was followed by either the mindfulness visualization guidance or control visualization guidance, as appropriate for the condition. Participants were advised that there would be no stimuli on the screen and no shocks, during this stage of the experiment. Participants were then given a copy of the state mindfulness scale, with its name removed. They were asked to tell the experimenter their rating of each statement, rather than write it, so that they could keep their hands still and remain wired to the electrodes.

After this, participants were advised that the stimuli would be appearing on the screen again, and that some of these would be accompanied by shock. They were asked to rate their expectancy of shock in the same manner as previously. There were four extinction trials, in the order A, B, B, A, (counterbalanced) during which no shocks were administered. These were followed immediately by eight trials of re-acquisition, comprising four A+ trials and four B- trials, in a random order. During this reacquisition phase, CS A was accompanied by shock and CS B was not, in exactly the same manner as during the initial training. Participants were then asked whether they had previous experience of mindfulness practice. The word mindfulness had not been used up to this point, in case it influenced participants' responding, given the frequency with which this topic is currently covered in the UK mainstream media. Finally, participants were debriefed, thanked for their time and paid.

Data Preparation

The SCR data were recorded in micro-Siemens in LabChart and exported to Excel. For each trial, a mean SCR was calculated for both the 'pre-CS' and 'CS' periods. These data were then transformed using a log transformation to reduce the variability between participants. In order to measure the change in SCR associated with the occurrence of the CS, for each trial a 'CS-SCR minus pre-CS-SCR' difference score was then calculated. This score was taken to be a measure of the conditioned response to the CS, and henceforth is simply referred to as the ΔSCR (change in skin conductance response). For the expectancy data, the rating in the CS period was used as the participant's expectancy of the US on that trial. Subsequent data analysis was conducted using SPSS version 22.

Results

Training Data

The ΔSCR data from training were analyzed using a *stimulus* (A vs. B) by *group* (MV+, MV-, CV+, CV-) ANOVA. The main effect of *stimulus* was significant ($F(1,92)=12.46$, $p<0.005$), with participants exhibiting higher SCR scores after A+ (mean=0.069, SE=0.007) than B- (mean=0.048, SE=0.007). This difference in SCR scores did not significantly differ between the groups ($F(3,92)=1.14$, n.s.), as their training regime was the same.

This pattern was also observed in a *stimulus* by *group* analysis of the expectancy ratings from training. Specifically, participants had a significantly ($F(1,92)=396.56$, $p<0.001$) higher expectation of shock on A+ training trials (mean=4.1, SE=0.06) than on B- training trials (mean=1.9, SE=0.07). Furthermore, this difference did not significantly differ across the groups ($F(3,92)=0.37$, n.s.). Thus, as expected, participants showed learning of the A+ B- discrimination in both the ΔSCR and expectancy data, and this did not differ between groups.

Manipulation Check

The state mindfulness scale data were analyzed using a *practice type* (mindfulness vs. control) by *stimulus visualized* (A vs. B) ANOVA. Participants in the mindfulness conditions had significantly higher state mindfulness scores than those in the control conditions ($F(1,92)=9.37$, $p<0.01$; respective means: 76.2 (SE=1.72) and 68.7 (SE=1.72)). This difference did not significantly differ across *stimulus visualized* ($F(1,92)=0.01$, n.s.). Thus, as intended, the mindfulness practice appeared to have increased state mindfulness levels relative to control, and regardless of whether stimulus A or B was visualized.

Test Data

The focus here is on the ΔSCR and expectancy data from the reacquisition test-phase, as pilot work suggested this would provide a more sensitive test of any effects than the data from the extinction phase. It also included twice as many trials as the extinction phase, and so should produce less noisy data.

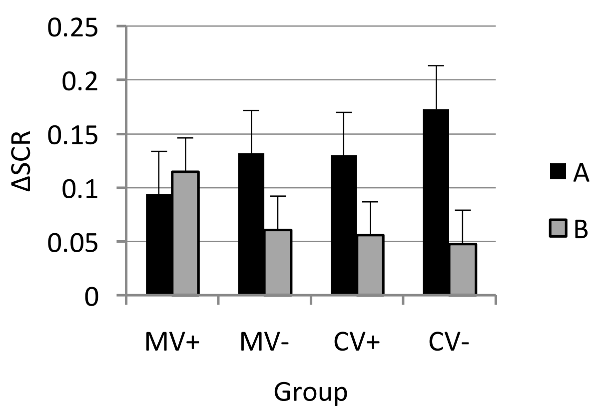

Figure 1: Mean change in skin conductance by Group and by CS tested, from the reacquisition test-phase. Error bars represent the standard error.

Considering the ΔSCR data first, these were analyzed using a *stimulus tested* (A vs. B) by *practice type* (mindfulness vs. control) by *stimulus visualized* (A vs. B)

ANOVA. The means can be seen in Figure 1; note that in this figure the four combinations of *practice type* and *stimulus visualized* are represented by the four groups on the x-axis. As would be expected given the contingencies, there was a significant main effect of *stimulus tested* ($F(1,92)=18.32$, $p<0.001$), with higher ΔSCRs to stimulus A than stimulus B. In addition, there were significant two-way interactions between *stimulus tested* and *practice type* ($F(1,92)=6.71$, $p<0.05$), and between *stimulus tested* and *stimulus visualized* ($F(1,92)=6.10$, $p<0.05$). None of the other main effects, nor the three-way interaction, were significant (all $p>0.4$). Thus the findings suggest that *practice type* and *stimulus visualized* had additive effects on the difference in ΔSCR between A and B. More specifically, practicing mindfulness appeared to decrease the difference in ΔSCR between the two, as did visualizing stimulus A. Hence the condition (MV+) containing both mindfulness and visualization of stimulus A had the smallest difference between A and B; the condition containing neither (CV-) had the biggest difference between the two; and the other two conditions were somewhere in between.

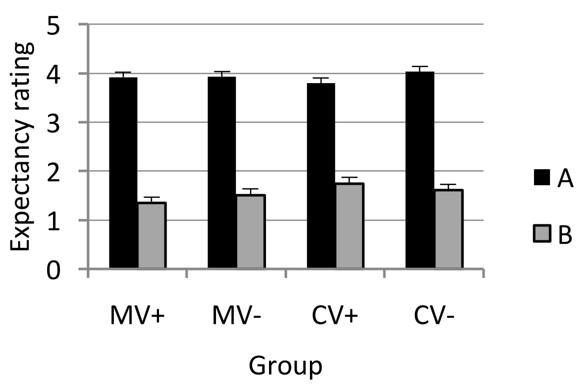

Figure 2: Mean expectancy ratings by Group and by CS tested, from the reacquisition test-phase. Error bars represent the standard error.

Turning to the reacquisition expectancy data (Figure 2), these were analyzed using the same three-way ANOVA as above. As with the ΔSCR data, there was a main effect of *stimulus tested* ($F(1,92)=677.26$, $p<0.001$), with a correct, higher expectation that a shock would follow stimulus A than B. However, none of the other main effects or interactions were significant (all $p>0.1$). Thus, in contrast to the ΔSCR data, none of the manipulations had a measurable effect on the participants' expectation of shock.

Discussion

There are a number of results that emerge from this study. Perhaps the first point to make is that training was very effective, and produced good conditioning both in terms of conscious cognitive expectancy and in terms of change in skin conductance. There were no confounding differences during training across groups, and the manipulation check at the end of the interposed activity indicated that mindfulness practice was also successful. We can be fairly confident, then, that the study we set out to conduct has actually taken place. We can now ask what the effects of mindfulness practice and visualization are on differential fear conditioning.

Starting with expectancy ratings for shock to the CS+ and CS- during re-acquisition, the answer is equally straightforward. Our manipulations had no differential effect. All groups showed the same (highly significant) level of differential conditioning on this measure. Any account that would claim that conscious expectancy is what drives changes in skin conductance would thus have to postulate a similar pattern of results in the ΔSCR measure, but this was not what we observed. Instead, ΔSCR varied across groups, and in particular the extent to which differential conditioning was re-acquired differed across groups. Group MV+, which received mindfulness practise and visualised the CS+ at the same time, showed no differential conditioning. Group CV-, which listened to the audio book and visualised the CS- at the same time, showed strong differential conditioning, actually stronger than that during initial training. The difference, then, between these groups was considerable, and our analysis produced results that suggested that both mindfulness practise and visualisation of the CS+ had some protective effect against re-acquisition of differential fear conditioning.

This contrast between effects on expectancy and on ΔSCR suggests that after mindfulness practise and visualisation of the CS+, even though people knew that a shock was likely to occur to A and not to B, this had no effect on their physiological response to those stimuli. In some sense, then, their autonomic response has become decoupled from their conscious cognitive appraisal of the situation. We can argue that this has happened to a lesser extent for Groups MV- and CV+, and not at all for CV-. This is not the only possible interpretation of these results, however, and we need to consider others that might generate the same pattern on our two measures.

One such possibility is that rather than visualisation of the CS+ having a protective effect, it was in fact visualisation of the CS- that simply extinguished any fear generalising to that stimulus and so led to stronger differential conditioning. We cannot rule this possibility out, but would expect visualising the CS+ to have had an even stronger effect than visualising CS-. This is because the CS+ would have had stronger associations to shock after training, and the extinction would be expected to have been proportional to the strength of the association. This mechanism could, then, explain why visualising the CS+ seemed to impair differential conditioning, and visualising the CS- seemed to (relatively speaking) help it. On this account, the visualisation effect was just one of imagined extinction feeding through into re-acquisition. But understanding the effect of mindfulness practise in this way is probably not helpful. The effect was additive with visualisation, which indicates a different source for it, and claiming that listening to Bill Bryson potentiated fear conditioning does seem a little unlikely (as well as unkind).

We can ask, however, why the effect we observed was on differential conditioning, and why the ΔSCR for B was so high in the MV+ group. This was undoubtedly a contributory factor to our result, though the stronger effect across groups may have been the effect of our manipulations on A. In fact, it is quite striking that the average ΔSCR to A and B was roughly the same in each group. Thus, we can argue that the overall physiological reactivity of each group was approximately constant, it was just how that was distributed over A and B that varied. If it was the case that the training data were mostly based on conscious expectancy of shock (and that would not be surprising in such a simple preparation), then the implication is that this factor was no longer effective in Group MV+ during re-acquisition, since if participants' expectancies had driven their physiological reactivity in that case, we would have seen a difference in ΔSCR to A and B equivalent to that in the other groups, but we did not. It is possible that instead we observed the effects of the underlying associative learning as a result of training, extinction and re-acquisition and that this had become decoupled from control by conscious cognitive expectancy. It is also possible that one belief about the contingencies had been replaced by another, though our expectancy rating data argues against this. Further research will be needed to establish exactly what the effective contribution of the mindfulness practise is here.

Conclusion

We ran this experiment to try to understand what effect mindfulness might have on the processes underlying conditioned fear (and hence anxiety). We can be confident that it does have an effect, and that this effect appears to be separate from that of visualisation. Whatever the exact mechanism involved, mindfulness practise appears to protect against re-acquisition of conditioned fear after extinction, a result that must be worth pursuing and that may have implications for the treatment of stimulus-specific anxiety.

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