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Attenuating Physiological Arousal Through the Manipulation of Simple Hand Movements

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Abstract The current study tests whether manipulating simple motor movements can regulate one's physiological reactivity to negative images. Healthy college age participants were randomly assigned to no tapping, steady tapping, or slow tapping conditions and viewed two sets of 15 negative images from the international affective picture system. Participants viewed the first image set without manipulation. During the second image set, they were instructed to tap at a steady pace, a slow pace or not at all. Steady tapping suppressed the vagal component of the cardiovascular defense response, and produced a significant increase in respiration rate and skin conductance level (SCL). Slow tapping suppressed the sympathetic and enhanced the vagal components of the cardiovascular defensive response, and produced a decrease in heart rate, SCL and skin conductance responses to negative images. Results suggest that manipulating simple motor movements is an effective way to both up-regulate and more importantly, down-regulate one's physiological response to negative affective images. Manipulation of slow and simple motor movements may be an effective means to attenuate autonomic arousal.

Keywords Emotion regulation · Sympathetic arousal · Negative images · Stress · Anxiety · Coping · Biofeedback

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Introduction

Emotion regulation involves changes in behavioral, experiential, and/or physiological responses (Gross 1999). Emotion regulation can be conscious (explicit) and deliberate or unconscious and relatively automatic (implicit). Explicit processes are goal-driven and require attentional resources, while automatic processes are stimulus driven, occur outside of awareness and are less effortful forms of emotion regulation (Gyurak et al. 2011). Explicit emotion regulation processes require conscious effort for initiation, demand a level of monitoring during implementation, and are associated with some degree of insight and awareness (Koole and Rothermund 2011). Explicit emotion regulation also attempts to alter the course and intensity of emotional responses, but is considered to be a heavy consumer of cognitive resources, and requires a great deal of effort and mental resources (Gyurak et al. 2011; Mauss et al. 2007). In contrast, implicit emotion regulation operates at little cost, it is evoked automatically by the stimulus itself and runs to completion without monitoring, and can happen without insight or awareness (Fitzsimons and Bargh 2004; Hopp et al. 2011; Koole and Rothermund 2011; Mauss et al. 2006). A method has yet to be developed, using explicit coping strategies, which would provide a strong physiological benefit and doesn't incur a cost to the individual.

Techniques have been developed to impinge upon automatic implicit emotion regulation including strategic reappraisal, effortful distraction, and emotional priming to name a few (Gross 1999; Koole and Rothermund 2011); the hope with these techniques is to give a degree of control to the individual to regulate his or her emotional response and avoid the inherent physiological cost of explicit control (i.e., emotional suppression). Explicit control increases sympathetic cardiovascular activity, skin conductance level

(SCL) and negative affect (Gross and Levenson 1997; Gross 1998). A meta-analysis found that individuals who used suppressive coping were also more likely to suffer from cardiovascular diseases and cancer (Mund and Mitte 2012). The physiological benefits for implicit coping strategies seem to apply to low-intensity conditions and often fail during high-intensity conditions (Sheppes et al. 2011). Stress also impairs the effectiveness of implicit coping strategies (Raio et al. 2013). Raio and associates found that participants who were not subjected to stress using implicit coping (reappraisal) were able to regulate their emotional and physiological response to a fear conditioning paradigm, while participants who were exposed to an experimental stressor (cold presser) were not able to regulate response.

One's response to metabolic demand has been overlooked as a mechanism of autonomic regulation and possibly coping. It was classically established that when motor commands are engaged (effort), muscles become activated and the body will up or down regulate cardio-respiratory activity to match the metabolic demand (Obrist 1975). Cardio-respiratory adaptation can become coordinated in time to changes in movement during physical activities such as cycling, running and rowing (Bramble and Carrier 1983; Kohl et al. 1981; Mahler et al. 1991a). This metabolic adaptation is a natural physiological phenomenon designed to conserve and efficiently utilize energy; adaptation also occurs when metabolic demand is minimal to nonexistent.

Finger tapping is another basic action that produces cardio-respiratory adaptation. Kirby et al. (1990) instructed participants to tap a telegraph key at a comfortable rate for 10 min, while simultaneously measuring their Heart rate (HR). The results revealed that the simple act of tapping one's finger was enough to affect cardiovascular adaptation, yet occurred outside of the influence of any physically demanding activity. Wilke et al. (1975) found that adaptation to finger tapping also occurs with respiration. The authors had participants increase and decrease their rate of tapping by observing blips on an oscilloscope, in which they tapped their index finger after every fifth blip. As participants' tapping rate increased, their respiration rate increased and as they tapped slower, participants' respiration rate likewise decreased. They also found that at the fastest and slowest tapping rate, time dependent coordination between tapping and breathing would momentarily cease and then quickly resume, indicating that the regulatory mechanism adapted to extremes. Interestingly, when the participants were told to consciously time their tapping to their respiration, the time dependent adaptation ceased. They also found a similar result with HR, in which participants tapped closest to the previous R spike when tapping at their own pace, as opposed to tapping when they thought a heart beat was occurring (Davidson et al. 1981). The act of tapping caused changes in homeostatic demands regulated by the autonomic nervous system, and there is a possibility these changes could be used to create a more or less favorable autonomic response to negative stimuli. Instead of actively suppressing negative emotion and consequently increasing physiological arousal, it may be useful to engage a simple behavior (such as tapping one's fingers) to diminish the physiological arousal related to negative stimuli.

When confronted with negative stimuli, people respond by freezing (parasympathetic) and then action (sympathetic) (Cuthbert et al. 1996). The cardiovascular system reflects this defensive orientation in a sequence of four components. The first two components reflect changes in HR mediated by sympathetic and parasympathetic activity; an acceleration of short latency at stimulus onset and sharp deceleration significantly lower than baseline (bradycardia of attention) (Fernández and Vila 1989; Vila et al. 1997). The final two components reflect changes in HR mediated by the sympathetic nervous system; a prolonged post stimulus acceleration and a second short latency deceleration. A sharp increase in SCL and skin conductance responses (SCR) also occurs during the sympathetic component of the cardiovascular defensive response, further providing evidence of sympathetic activation following vagal cardiovascular inhibition (Lang et al. 1997). The response is a dynamic transition from attentive freezing (attention) to active defense (fight or flight). The response occurs when exposed to unexpected loud noises and/or other stimuli that could pose a threat to survival and requires extra allocation of attention resources. Arousing images, such as mutilation and violence, also produced the attentional bradycardia and cardiovascular defense response pattern (Cuthbert et al. 1996; Ramírez et al. 2010).

The objective of this study is to determine if simple movements (finger tapping) can be used to alter the cardiovascular defensive response to images of mutilation and violence. We hypothesized that (1) tapping at a slow pace would decrease sympathetic activity and the sympathetic components of the cardiovascular defense response, while enhancing the vagal components; (2) tapping at a steady pace would increase sympathetic activity and attenuate the vagal components of the cardiovascular defense response; and (3) the no tapping control group would not experience significant changes during the second image set, compared to the first.

Methods

Participants

The protocol for the current study was reviewed and approved by the institutional review board of the University

of Wisconsin Milwaukee human research protection program. Undergraduate psychology students were recruited through email and class announcements. Following completion of a recruitment survey, 48 participants were recruited from 663 potential participants. There were 10 male participants and 32 female participants with a mean age of 22.3 (SD = 5.23); all but four were Caucasian. Participants received extra credit in their course of choice for involvement in the study. Only participants without diagnosed cardiovascular and respiratory conditions were recruited. Participants were excluded if they had previous experience with meditation, in order to eliminate the possible effects of prior meditation experience on physiological arousal. Initially, 48 participants were randomly assigned to three groups (control, slow tapping and steady tapping) with 16 participants randomly assigned to each group. However, data from six participants were not included in the final analyses either because of technical issues with physiological recordings or lack of compliance with condition instructions. Of the 42 participants included in the final statistical analyses, there were 16 in the control group, 12 in the slow tapping group and 14 in the steady tapping group.

Materials

The images[1] (10 mutilation, 10 violence and 5 neutral) were chosen from the international affective picture system (IAPS) to create two image sets containing five mutilation, five violence, and five neutral images each. From the "international affective picture system (IAPS): affective ratings of pictures and instruction manual" negative images were chosen with arousal (energy) scores greater than six, valence (negative emotion) scores less than two and dominance (feeling of control) scores less than three, ratings were based on a 9-point scale (Lang et al. 2008). The mutilation images depicted dead and/or grievously injured bodies and large amounts of blood. The violence images depicted women held at knife-point, close-ups of guns and masked assailants holding knives facing the participants. The neutral images depicted mushrooms; the same five neutral images were presented during both image sets.

Respiratory parameters and electrocardiogram (ECG) were recorded by the Lifeshirt ambulatory system (Vivometrics; Ventura, CA). After taking size measurements, all participants were fitted with a tight fitting Lycra garment (Lifeshirt) and sensors were connected to a small computer the size of a personal data assistant (PDA) or large smart phone. Abdominal and upper thoracic inductance plethysmography bands (imbedded in the garment) recorded respiratory volume (50 Hz), from which respiratory rate was calculated. Inductance plethysmography was calibrated and automatically adjusted according to the guidelines stated in the manufacturers manual for each individual participant. A lead(II) configuration was used to record cardiovascular measures with two pre-gelled 35 mm disposable Ag/AgCI electrodes attached near both shoulders and one on the left lower abdominal area. The raw ECG signal was recorded at a sample rate of 250 Hz. Accelerometers imbedded in the Lifeshirt continuously recorded movement. The Biopac MP35 (Biopac Systems Inc.; Santa Barbara, CA) was used to record electrodermal activity (EDA) and finger tapping rate at a sample rate of 1000 Hz. EDA transducers were connected to pre-gelled 35 mm disposable Ag/AgCI electrodes attached to the middle phalanx of the index and middle fingers of the left hand. Superlab (Cedrus Corp.; San Pedro, CA) was used to present instructions, image warning tones and audio presentations of instructions. A plexiglass platform was also developed to record tapping data. A pressure transducer, attached to the plexiglass platform, was altered to interface with a Biopac MP35 EDA transducer to record rate of tapping.

Positive and Negative Affect

A 16-item version of the positive and negative affective schedule (PANAS) was used to collect emotional affect throughout the study (i.e., interest, energized, anger, confusion, relief, embarrassment, amusement, contentment, fear, contempt, tension, upset, sadness, happiness, disgust, and surprise) (Gross and Levenson 1997). The PANAS consists of emotion words and asks participants to rate how they are feeling in the moment on a 5-point Likert Scale ranging from 1 (Very slightly or Not at all) to 5 (extremely). A principal components analysis of the 16-item PANAS revealed two subscales: positive emotion (interest, energized, relief, amusement, contentment and happiness) and negative emotion (anger, fear, tension, upset, sadness and disgust) other PANAS items (confusion, embarrassment, contempt, and surprise) were not included in the final analysis. Internal consistencies in the current study were good for both the positive (baseline $\alpha = 0.745$, image set 1 $\alpha = 0.714$ and image set 2 $\alpha = 0.774$) and the negative subscales (baseline $\alpha = 0.815$, image set 1 $\alpha = 0.890$ and image set 2 $\alpha = 0.929$).

Procedure

Participants who met the inclusion criterion were invited to participate in the study and were randomly assigned to one

[1] IAPS images used: violence (6260, 6300, 6230, 6370, 6570.1, 6550, 6510, 9410, 6313, 6250.1) Mutilation (3068, 3053, 3060, 3010, 3064, 3170, 3130, 3063, 3069, 3080). Neutral (5500, 5510, 5520, 5530, 5531).

of the three conditions (control, slow tapping and steady tapping). A research assistant explained the nature of the study and the images the participants would be viewing. After completing the informed consent, participants were fitted for a Lifeshirt, ECG transducers were attached and inductive plethysmography was calibrated. The participants were then seated in a comfortable chair, had their non-dominant hand connected to EDA transducers, completed an initial 16-item PANAS assessment and began a 5-min baseline recording of their physiology.

Following the baseline, each group viewed a pre-training set of 10 negative images (five mutilation and five violence) and five neutral images (mushrooms). No instructions or manipulations were provided. All participants simply viewed the first set of 15 images. Each image had a 6 s anticipation period indicated by a tone, a 6 s image presentation period and a 20 s recovery period before the next image. After the images, participants completed a second 16-item PANAS. Order of image set presentation was counterbalanced to control for the possibility that one image set could be perceived as more negative than the other. Following the 15 images, participants received one of three training conditions, based on the group participants were assigned to. The *no tapping group* (control) watched a scuba video for 10 min and then viewed a second image set of 15 different images (no additional instructions were given).

The *slow tapping group* was given direction on how to correctly tap with their dominant hand from the pinky finger continuously to the thumb, one finger at a time, as an individual would naturally tap his/her fingers on a surface. The research assistant gave participants a standardized example of the correct tapping pace, starting at a fast tapping pace and decreasing to a pace that was as slow and as soft as comfortable. Aside for the previous example, participants were given complete control over their tapping rate. Participants started tapping at a rate slightly faster than normal and began listening to a 2 min recording, which guided them to their slowest and softest tapping rate at 30 s intervals. At each interval, participants were instructed to "…decrease your tapping rate" and at the final interval, participants were instructed to "…tap as slow and softly as possible." The instructions and example were then repeated, and the participants completed another training. After the participants indicated they felt comfortable with the technique, a longer 6 min recording was started. During the recording, the first two intervals were 30 s in duration, the third interval lasted 1 min and the final interval lasted for 4 min. At the end of the recording, participants were instructed to "....continue tapping as slow and as softly as possible throughout the following set of images", and the second set of 15 images automatically began. Participants completed a final 16-item PANAS after the images.

Participants in the *steady tapping group* were instructed to begin tapping with their right hand (pinky to thumb) at a pace that was comfortable. The research assistant demonstrated a steady tapping rate, so participants did not start at a slow pace. Participants were then told not to worry if their tapping rate and/or velocity changed throughout the condition, but that it was important to continue tapping. They were then instructed to begin tapping and to continue tapping through the second set of 15 images. At the conclusion of the study, Participants completed a final 16-item PANAS after the images.

Participants were not told the nature of the slow or steady tapping. They were not given any expectations about what they may experience during the trial.

Data Reduction and Analysis

We calculated second by second variations in HR from interbeat-intervals (calculated from the raw ECG waveform). We processed SCR for phasic responses >0.02 μS during the presentation period for each image and averaged SCL in 32 s intervals throughout each 15-image set. We calculated respiratory rate from the respiratory volume raw signal and then calculated a single averaged value for respiratory volume and respiratory rate from each 15-image set. After the raw ECG signal was visually inspected for noise and inconsistencies, the milli second distance between successive R-spikes were automatically calculated and converted into HR. Changes in HR were then accumulated to provide 2 s averages throughout each image type and 32 s mean values for each image set. Finger tapping rate was calculated as the number of finger taps per minute.

We conducted a 2 (steady tapping and slow tapping) by 32 (time: 32 s) mixed-design repeated measures ANOVA to analyze differences in tapping rates during the second image set, as well as mean differences between slow and steady tapping groups. We also conducted a 3 (group: control, steady tapping and slow tapping) by 3 (baseline, image set 1 and image set 2) mixed-design repeated measures ANOVA to analyze changes in the positive and negative components of the 16-item PANAS. We conducted a similar analysis using a 3 (steady tapping and slow tapping) by 2 (image set 1 and image set 2) mixed-design repeated measures ANCOVA, with baseline as a covariate, to analyze mean changes in physiological variables (HR, respiratory volume, respiratory rate and SCR) for neutral and negative images. To analyze cardiovascular changes, we ran a 2 (neutral and negative images) by 16 (2 s averages) repeated measures ANOVA separately for each group. To compare changes in SCL throughout each image set, we ran a 15 (images) by 2 (image set 1 and image set 2) repeated measures ANOVA separately for each group. Analyses were followed up with planned comparisons (Critical p values were

corrected and adjusted for each analysis using the false detection rate (FDR) method) to determine group differences in physiological variables (Benjamini and Hochberg 1995). We used Greenhouse-Geisser epsilon correction for all repeated measures ANOVAs and reported effect sizes as partial eta-squares (small effect size: $\eta_p^2 = 0.01 - 0.05$, medium effect size: $\eta_p^2 = 0.06 - 0.14$ and large effect size:$\eta_p^2 > 0.14$).

Results

Manipulation Check

It was found that the steady and slow tapping groups tapped at a consistent rate (no difference from the beginning to the end of the image set). Planned follow-ups for group differences in tapping rate revealed that the steady tapping group (Neutral $M = 375.63$, $SD = 209$, Negative $M = 394.38$, $SD = 243.07$) tapped faster than the slow tapping group (Neutral $M = 56.74$, $SD = 24.16$, Negative $M = 60.33$, $SD = 27.40$) for neutral images, $F(1,24) = 15.84$, $p < .001$, $\eta_p^2 = 0.40$ and negative images $F(1,24) = 14.23$, $p < 0.001$, $\eta_p^2 = 0.37$.

With regard to emotion, analyses revealed a significant effect of phase for the negative affect subscale of the PANAS $F(1.76, 63.51) = 73.23$, $p < .001$, $\eta_p^2 = 0.67$. Planned comparisons revealed that all groups felt more negative after image set 1 ($M = 2.77$, $SD = 1.20$) compared to baseline ($M = 0.74$, $SD = 0.75$) (control: $t(36) = 3.82$, $p < 0.001$, steady tapping: $t(36) = 6.66$, $p < 0.001$, and slow tapping: $t(36) = 7.70$, $p < 0.001$). Analyses revealed a significant effect of phase for the positive affect subscale of the PANAS $F(1.39, 50) = 32.50$, $p < 0.001$, $\eta_p^2 = 0.67$. Planned comparisons revealed that all groups felt less positive after image set 1 ($M = 1.70$, $SD = 0.90$) compared to baseline ($M = 2.60$, $SD = 0.79$) (control $t(36) = 3.67$, $p < 0.001$, steady tapping $t(36) = 3.36$, $p = 0.002$, and slow tapping $t(36) = 2.64$, $p = .012$). There were no significant changes in the either subscale of the PANAS from image set 1 to image set 2.

Changes in Physiology from Image Set 1 to Image Set 2

For *neutral images*, a significant phase (image set 1 and image set 2) by group (control, steady tapping and slow tapping) interaction was found for changes in HR $F(2, 38) = 3.85$, $p = .047$, $\eta_p^2 = 0.17$. Planned comparisons (Table 1) revealed that HR for the slow tapping group during image set 2 was significantly lower than HR during image set 1, there were no other significant differences. There was a significant phase by group interaction for changes in respiratory rate $F(2, 38) = 7.62$, $p = 0.002$, $\eta_p^2 = 0.23$. Planned comparisons (Table 1) revealed that respiratory rate during image set 2 for steady tapping and slow tapping groups was significantly higher than image set 1. There was no significant change in respiratory volume, nor was there a significant change in SCR.

For *negative images*, there was a significant phase by group interaction for changes in respiratory rate $F(2, 38) = 4.86$, $p = .013$,$\eta_p^2 = 0.20$. Planned comparisons (Table 1) revealed that respiratory rate during image set 2 for the steady tapping group was significantly higher than image set 1. There were no significant differences in respiratory volume or HR. There was a significant phase by group interaction for changes in SCR $F(2, 38) = 4.43$, $p = 0.019$, $\eta_p^2 = 0.19$. Planned comparisons (Table 1) revealed that SCR during image set 2 for slow tapping and control groups were significantly lower than image set 1.

Attentional Bradycardia Response

For *neutral images*, there was no significant bradycardia of attention for the steady tapping and control groups. The slow tapping group demonstrated a significant difference in phase and time (16 averaged 2 s time points), though there was no interaction. Overall, HR during image set 2 was lower than image set 1 for the slow tapping group (see Tables 1, 2), though there was no significant bradycardia of attention.

For *negative images*, there was no effect of phase or phase by time, though there was a significant effect of time for the control group $F(4.32, 75.28) = 6.09$, $p < .001$, $\eta_p^2 = 0.29$. Follow up comparisons (Table 3; Fig. 1) revealed that there was a significant bradycardia of attention for both image sets, though there was no significant change from image set 1 to image set 2. For the steady tapping group, there was no effect of phase or phase by time interaction, though there was a significant effect of time $F(3.65, 64.59) = 3.78$, $p < 0.05$, $\eta_p^2 = 0.23$. Planned comparisons (see Table 3; Fig. 1) revealed that there was a significant bradycardia of attention during image set 1, though there was no significant bradycardia of attention during image set 2. For the slow tapping group, there was a significant effect of phase $F(1, 11) = 5.59$, $p = 0.037$, $\eta_p^2 = 0.34$, and a significant effect of time $F(2.55, 27.99) = 5.94$, $p = .004$, $\eta_p^2 = 0.35$, but no interaction. Planned comparisons (Table 3; Fig. 1) revealed a significant bradycardia of attention during both image sets. During image set 2 there was no increase in HR at image presentation (second 6) or after image presentation (seconds 20–22), in contrasts to image set 1. Heart rate was also significantly lower during image presentation for image set 2, as evidenced by significantly lower HR (second 12) compared to image set 1 (see Fig. 1).

Table 1 Mean differences in physiology from image set 1 to image set 2

	Neutral images				Negative images			
	Image set 1[a]	Image set 2[a]	F^b	η_p^2	Image set 1[a]	Image set 2[a]	F^b	η_p^2
Control								
HR	73.58 (7.96)	72.24 (7.47)	3.57	0.09	72.86 (7.80)	72.20 (7.53)	0.87	0.02
RESP	15.26 (3.24)	15.03 (2.37)	0.23	0.01	14.92 (3.01)	14.82 (2.71)	0.02	0.00
VOL	560.00 (142.72)	489.53 (97.81)	3.55	0.09	491.13 (71.94)	554.38 (159.32)	3.13	0.08
SCR	0.31 (0.41)	0.35 (0.58)	0.21	0.01	0.50 (0.41)	0.28 (0.34)	7.59*	0.17
FDR[c]			*NS*[d]				$p \leq .013$	
Steady tapping								
HR	76.74 (12.22)	77.36 (11.39)	0.45	0.01	76.14 (11.72)	77.15 (11.38)	1.22	0.03
RESP	15.51 (2.80)	17.90 (2.11)	22.32***	0.37	15.37 (2.58)	18.05 (2.56)	16.91***	0.31
VOL	521.04 (225.96)	469.78 (99.66)	0.71	0.02	507.74 (167.70)	464.95 (81.58)	0.68	0.02
SCR	0.24 (0.45)	0.25 (0.26)	0.01	0.00	0.36 (0.31)	0.39 (0.32)	0.06	0.00
FDR[c]			$p \leq .013$				$p \leq .013$	
Slow tapping								
HR	80.68 (19.39)	77.67 (18.11)	9.56*	0.20	78.98 (18.90)	76.83 (17.78)	4.32	0.10
RESP	15.25 (2.37)	16.78 (3.67)	8.29*	0.18	15.76 (2.81)	16.80 (3.74)	2.84	0.07
VOL	540.72 (134.05)	502.37 (11.18)	2.20	0.06	520.10 (88.97)	495.11 (129.04)	0.84	0.02
SCR	0.19 (0.28)	0.11 (0.20)	0.57	0.02	0.45 (0.36)	0.11 (0.21)	14.39**	0.28
FDR[c]			$p \leq .013$				$p \leq .013$	

*$p < .05$,

**$p < .01$,

***$p < .001$

[a]Means (standard deviation)

[b]Degrees of freedom (1, 38)

[c]Critical p value for false detection rate (FDR)

[d]FDR could not be calculated because of no significant differences (NS). *F*-score adjusted for baseline covariates

Skin Conductance Levels

Analyses performed for skin conductance revealed a significant phase by group interaction $F(2, 36) = 11.75$, $p < .001$, $\eta_p^2 = 0.40$. Follow-up analyses (Table 4) revealed that for the slow tapping group, the mean SCL during image set 2 was significantly lower than SCL during image set 1. For the steady tapping group, the mean SCL during image set 2 was significantly higher than image set 1 and was not significantly higher for the control group. Throughout image set 2, SCL for the slow tapping group was significantly lower than image set 1 at each 32 s interval (Table 4), SCL for the steady tapping group was significantly higher than image set 1 at each 32 s interval and SCL was not significantly different for controls. There were also significant between group differences $F(2,36) = 11.60$ $p < 0.001$, $\eta_p^2 = 0.39$. Participants in the slow tapping group demonstrated lower SCL than the steady tapping group $t(36) = 4.19$, $p < 0.001$ and the control group $t(36) = 4.26$, $p < .001$ throughout the second image set. These differences were also significant at each 32 s interval (Fig. 3). There was no difference between the steady tapping and control groups.

Discussion

The results of this study support the notion that simple movements can be used to attenuate physiological arousal in response to negative stimuli. In support of the first hypothesis, when participants tapped slowly there was an overall decrease in HR, and the second by second changes in attentional bradycardia indicated diminished sympathetic activity at image presentation and during post image recovery (Fig. 1). Slow tapping participants also demonstrated decreases in SCL (Fig. 2) and SCR during image presentation (Table 1). Lower SCR during image presentation indicates a decreased startle response, while the overall decrease in SCL indicates a maintained state of decreased sympathetic activity. The change in SCL for the slow tapping group was also significantly greater than both the steady tapping group and control group (Fig. 3). Overall,

Table 2 Sec by sec differences in HR response to neutral images

	Control			Steady tapping			Slow tapping		
	Image set 1[a]	Image set 2[a]	*t*	Image set 1[a]	Image set 2[a]	*t*	Image set 1[a]	Image set 2[a]	*t*
Sec 2	72.5 (8.06)	71.64 (7.87)	0.79	75.91 (12.80)	76.48 (1.72)	0.61	79.78 (19.47)	77.85 (18.34)	2.04
Sec 4	73.16 (8.39)	71.47 (8.33)	1.10	75.80 (12.48)	76.13 (11.14)	0.33	80.62 (19.89)	76.96 (17.69)	3.38*
Sec 6	73.45 (8.58)	72.23 (7.56)	1.14	76.88 (12.34)	76.16 (11.55)	0.67	82.32 (19.27)	76.49 (17.81)	3.00*
Sec 8	73.01 (8.22)	71.76 (7.99)	1.28	77.49 (12.07)	76.90 (11.22)	0.66	81.37 (18.50)	77.31 (18.10)	1.97
Sec 10	72.84 (8.27)	71.94 (8.22)	0.94	77.11 (12.38)	77.27 (11.42)	0.17	79.76 (18.80)	76.64 (18.23)	2.13
Sec 12	71.89 (8.68)	71.78 (8.49)	0.10	76.87 (12.65)	77.27 (11.95)	0.39	78.76 (19.76)	77.16 (18.20)	1.48
Sec 14	73.43 (8.20)	72.62 (8.14)	0.79	76.87 (12.62)	77.77 (11.72)	0.88	79.98 (2.71)	77.47 (18.67)	2.31
Sec 16	74.23 (8.73)	72.45 (8.20)	1.58	76.94 (12.98)	78.16 (12.09)	0.87	80.28 (2.49)	77.35 (19.00)	2.51
Sec 18	74.78 (8.10)	72.90 (7.52)	1.47	77.82 (12.73)	78.31 (11.54)	0.35	80.09 (18.66)	77.96 (18.89)	1.41
Sec 20	74.43 (8.25)	73.44 (6.76)	0.67	77.46 (12.76)	77.65 (11.09)	0.14	80.74 (17.95)	77.84 (19.35)	1.69
Sec 22	74.31 (8.73)	72. 45 (7.89)	1.05	76.33 (11.61)	77.75 (11.30)	1.28	81.34 (18.91)	78.16 (17.92)	2.38
Sec 24	74.66 (8.47)	72.35 (8.35)	1.38	76.37 (12.15)	77.33 (11.65)	1.13	81.83 (19.03)	78.16 (17.92)	1.40
Sec 26	73.89 (6.82)	71.95 (7.82)	1.60	75.92 (12.03)	77.98 (11.60)	2.20	81.35 (19.67)	78.39 (17.25)	1.82
Sec 28	73.72 (7.33)	72.07 (7.43)	1.42	76.20 (11.96)	77.53 (11.12)	2.02	81.20 (2.37)	76.83 (17.25)	3.14*
Sec 30	72.91 (8.51)	72.09 (7.51)	0.73	76.61 (13.45)	77.31 (11.52)	0.57	80.96 (2.69)	77.45 (18.28)	3.08*
Sec 32	74.01 (9.10)	72.69 (9.04)	0.98	77.26 (11.85)	77.76 (12.12)	0.41	80.48 (2.34)	78. 25 (19.03)	1.96
FDR[c]			*NS*[d]			*NS*			$p \leq .013$

*$p < .05$

**$p < .01$

***$p < .001$

[a]Means (standard deviation)

[b]Degrees of freedom (15)

[c]Critical p value for false detection rate

[d]FDR could not be calculated because of no significant differences (NS)

the differences in SCL for the slow tapping group indicated a decrease in sympathetic activity that was above and beyond that of the steady tapping and control groups.

In support of the second hypothesis, steady tapping produced an increase in sympathetic activity. Those participants in the steady tapping group showed an increase in SCL throughout the second image set (Fig. 2), no decrease in SCR during image presentation, and demonstrated no decrease in HR during image presentation (Fig. 1). It was found that a diminished bradycardia during image presentation was associated with increased arousal ratings in response to negative images (Dunn et al. 2010). The steady tapping group showed no decrease in SCR during image presentation, which indicates that their startle response remained intact during the second image set.

In support of the third hypothesis, the control group demonstrated no change in HR, nor did they indicate any attentional bradycardia difference in response to the negative images. Participants in the control group did demonstrate lower SCR during image presentation, though their SCL during image set 2 was not significantly different than it was during image set 1. Results for the control group indicate a diminished startle response to the negative images, but overall their sympathetic response to the second image set was maintained. This study manipulated a simple behavior to reduce physiological arousal and effectively altered autonomic activity; both slow and steady tapping significantly changed autonomic nervous system responses to negative stimuli.

The act of tapping may impinge upon multiple biomechanical responses, combining the volitional act of tapping and the automatic physiological adaptation to the movement. The possible *explicit* mechanism causing the observed autonomic changes may involve the co-activation of various muscular efferents required to make motor movements (Vallbo and Wessberg 1993; Wessberg and Valbo 1995). The decrease in velocity and rate that occurs with slow and soft tapping may activate slow fatigue resistant muscular efferents, while the increased velocity and rate of the steady tapping would primarily activate fast fatigue resistant muscular efferents. The *implicit* mechanism automatically responding to changes in motor (efferent) activity may be sensory afferents (muscular stretch and touch). The change in velocity and rate of tapping movements may differentially activate sensory afferents, which quickly adapt to muscular use and changing metabolic demands. There

Table 3 Sec by sec differences in hr response to negative images

	Control			Steady tapping			Slow tapping		
	Image set 1[a]	Image set 2[a]	*t*	Image set 1[a]	Image set 2[a]	*t*	Image set 1[a]	Image set 2[a]	*t*
Sec 2	73.71 (8.52)	72.54 (8.30)	1.26	76.41 (11.84)	77.11 (11.67)	0.66	78.84 (19.72)	78.12 (17.92)	0.57
Sec 4	73.71 (8.26)	72.05 (9.58)	1.74	75.89 (12.69)	76.98 (11.79)	1.09	78.87 (19.63)	77.22 (17.70)	1.54
Sec 6	73.47 (8.62)	73.02 (7.83)	0.52	76.95 (12.83)	77.17 (11.69)	0.20	79.70 (18.62)	76.92 (16.85)	2.54
Sec 8	73.16 (8.49)	72.52 (7.83)	0.88	76.65 (13.23)	76.98 (11.35)	0.22	78.94 (18.19)	76.54 (17.45)	2.22
Sec 10	72.31 (8.13)	71.59 (8.18)	1.05	75.91 (11.93)	76.95 (11.13)	0.85	77.61 (18.66)	75.66 (17.52)	1.86
Sec 12	7.68 (7.87)	70.35 (7.69)	0.40	74.05 (1.72)	76.34 (11.12)	1.81	77.32 (18.18)	74.88 (17.31)	3.26*
Sec 14	71.10 (7.69)	70.01 (7.30)	1.22	73.74 (1.26)	76.36 (11.45)	2.05	76.97 (18.43)	75.26 (17.93)	1.79
Sec 16	71.74 (7.76)	7.31 (7.59)	1.62	74.44 (11.00)	76.56 (11.81)	1.75	77.11 (18.72)	75.43 (17.79)	1.87
Sec 18	73.20 (8.27)	72.58 (7.93)	0.71	76.74 (12.03)	78.01 (11.89)	1.04	78.03 (18.83)	76.40 (17.22)	1.57
Sec 20	73.97 (6.99)	73.37 (7.86)	0.67	77.29 (12.06)	78.22 (11.57)	0.93	79.84 (19.32)	76.90 (17.58)	3.57*
Sec 22	73.04 (7.15)	73.11 (7.10)	0.10	77.01 (11.78)	77.57 (11.33)	0.61	80.40 (19.27)	77.12 (17.78)	4.55*
Sec 24	72.63 (7.81)	72.70 (7.50)	0.00	76.63 (11.57)	77.57 (1.96)	0.94	79.70 (19.40)	77.57 (17.65)	1.93
Sec 26	72.90 (8.26)	72.41 (8.06)	0.39	76.47 (11.58)	77.53 (11.31)	0.93	79.83 (19.70)	77.49 (18.59)	2.22
Sec 28	73.23 (8.07)	72.58 (7.60)	0.54	76.34 (11.99)	76.78 (11.60)	0.44	80.24 (19.47)	77.64 (18.81)	1.88
Sec 30	73.42 (8.23)	73.09 (7.17)	0.28	76.89 (12.27)	76.96 (11.73)	0.10	80.41 (18.57)	78.03 (19.13)	1.38
Sec 32	73.48 (7.80)	72.92 (7.83)	0.67	76.88 (12.03)	77.28 (11.43)	0.42	79.83 (18.90)	78.17 (18.94)	1.08
FDR[c]			*NS*[d]			*NS*			$p \leq .009$

*$p < .05$

**$p < .01$

***$p < .001$

[a]Means (standard deviation)

[b]Degrees of freedom (15)

[c]Critical p value for false detection rate

[d]FDR could not be calculated because of no significant differences (NS)

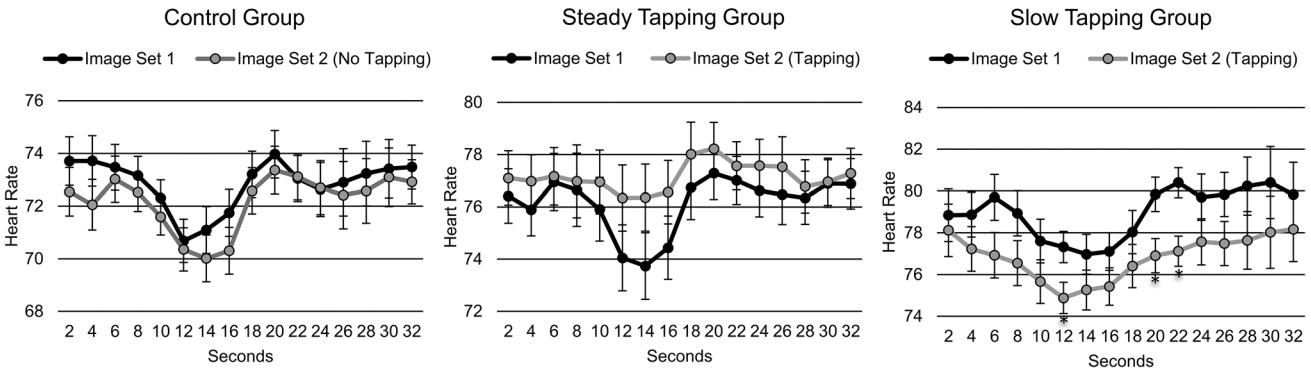

Fig. 1 Second by second differences in heart rate from image set 1 to image set 2 for negative images. *Note* Participants in the *tapping* groups, tapped throughout the second image set. *Error bars* are based on standard error of the mean. *$p < .05$, **$p < .01$, + $p < .001$

is also the possibility that sensory afferents responding to slow, weak mechanical stimulation were also activated by slow tapping. The sensory afferents during slow tapping would respond to lightly touching the platform, and the stretch of skin and muscles, these afferents may stimulate receptors also active during soothing touch (Craig 2002, 2003, 2008; McGlone et al. 2007). In contrast, the steady tapping group may be activating sensory afferents that are predominately active in the fast pain reflex arc (McGlone et al. 2007).

The slow and fast tapping could be differentially activating afferents that modulate both the sympathetic and parasympathetic responses to changes in physiological arousal. The accumulated muscular and sensory afferents

Table 4 Differences in skin conductance levels from image set 1 to image set 2

	Control			Steady tapping			Slow tapping		
	Image set 1[a]	Image set 2[a]	t[b]	Image set 1[a]	Image set 2[a]	t[b]	Image set 1[a]	Image set 2[a]	t[b]
SCL *avg*	9.01 (3.27)	1.07 (4.88)	1.98	7.21 (4.62)	8.91 (5.22)	3.44**	7.65 (3.14)	5.98 (4.18)	3.20**
SCL 1	1.18 (3.59)	11.79 (5.12)	3.02	7.70 (3.83)	9.45 (4.68)	3.58***	8.95 (3.27)	6.51 (4.27)	4.57***
SCL 2	9.88 (3.53)	11.17 (4.96)	2.54	7.67 (3.88)	9.13 (4.52)	3.18**	8.59 (3.44)	6.46 (4.41)	4.23***
SCL 3	9.62 (3.37)	1.62 (5.00)	1.85	7.60 (4.17)	8.92 (4.64)	2.86**	8.24 (3.50)	6.49 (4.49)	3.43**
SCL 4	9.43 (3.42)	1.12 (4.93)	1.24	7.43 (4.29)	8.90 (5.02)	3.16*	8.02 (3.36)	6.36 (4.45)	3.28**
SCL 5	9.35 (3.59)	9.90 (4.94)	0.94	7.36 (4.70)	8.72 (5.13)	2.60**	7.96 (3.42)	6.33 (4.55)	2.90*
SCL 6	9.00 (3.58)	9.92 (5.02)	1.68	7.41 (4.98)	8.95 (5.31)	2.91**	7.81 (3.37)	6.21 (4.31)	2.88*
SCL 7	8.70 (3.45)	9.73 (4.90)	1.86	7.26 (4.74)	8.84 (5.18)	3.02**	7.56 (3.23)	6.06 (4.23)	2.73*
SCL 8	8.67 (3.30)	9.77 (4.97)	1.70	7.22 (4.54)	9.13 (5.42)	3.18**	7.42 (3.17)	6.02 (4.20)	2.30*
SCL 9	8.67 (3.10)	9.76 (5.12)	1.65	7.11 (4.61)	8.91 (5.38)	2.98**	7.36 (2.96)	5.90 (4.18)	2.34*
SCL 10	8.65 (3.11)	9.91 (5.14)	1.89	6.98 (4.70)	8.86 (5.34)	2.94**	7.42 (3.32)	5.66 (3.96)	2.64*
SCL 11	8.45 (3.02)	9.70 (5.10)	1.88	7.02 (5.05)	8.88 (5.66)	3.06**	7.31 (3.20)	5.68 (4.18)	2.58*
SCL 12	8.66 (3.28)	9.58 (4.90)	1.47	7.04 (5.08)	8.80 (5.67)	3.04**	7.32 (3.40)	5.56 (4.01)	2.89*
SCL 13	8.77 (3.67)	9.61 (4.72)	1.39	6.81 (4.87)	8.67 (5.75)	3.10**	7.02 (3.06)	5.50 (3.92)	2.45*
SCL 14	8.56 (3.50)	9.63 (4.78)	1.75	6.85 (5.37)	8.61 (5.75)	2.91**	6.78 (2.99)	5.52 (4.04)	2.03*
SCL 15	8.63 (3.63)	9.83 (5.04)	2.04	6.61 (5.29)	8.86 (5.90)	4.00***	6.99 (2.98)	5.51 (3.90)	2.61*
FDR[c]			*NS*[d]			$p \leq .05$			$p \leq .047$

*$p < .05$,

**$p < .01$,

***$p < .001$

[a]Means (standard deviation)

[b]Degrees of freedom (14)

[c]Critical p value for false detection rate. *t*-score adjusted for baseline covariates

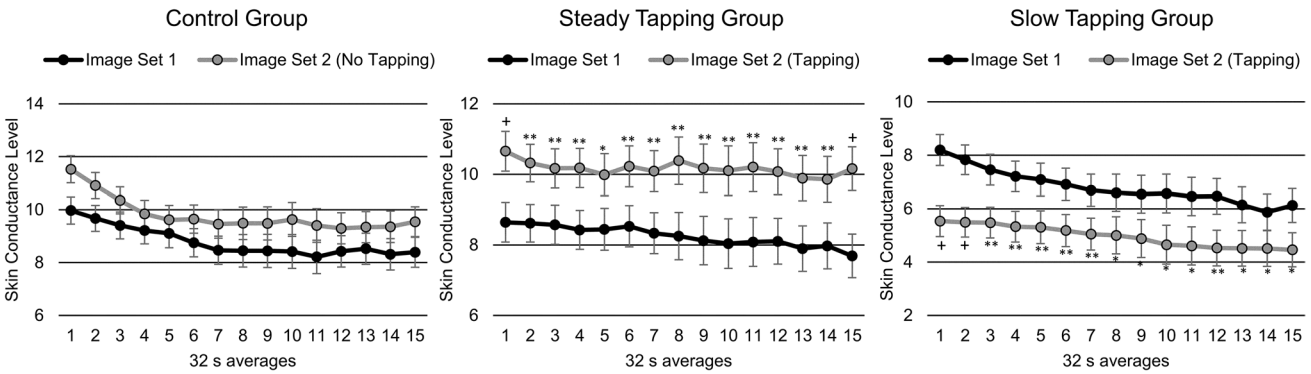

Fig. 2 Differences in skin conductance level from throughout image set 1 and image set 2. Each 32 s image presentation was averaged over the 8 min image presentation period. *Note* Participants in the *tapping* groups, tapped throughout the second image set. *Error bars* are based on standard error of the mean. *$p < .05$, **$p < .01$, + $p < .001$

could modify the autonomic activity related to the vagal and sympathetic centers of the brain stem, which represents all peripheral homeostatic input (Craig 2002, 2003, 2008; Mravec 2010). The accumulated signal, altered based on how the participant tapped, eventually arrives at the prefrontal cortex activating the anterior cingulate cortex (ACC) and the right anterior insula cortex (AIC), which are thought to have roles in subjective experiences of emotion and interoception. Therefore, the manipulation of tapping rate may be an effective means of attenuating the autonomic response to emotion stimulating images, impinging on both *automatic* and *volitional* regulatory processes.

Overall, it may be as important to change what one does in the face of challenging stimuli as how one thinks about it, and it may be easier as well. It took only 4 min of training to produce decreased sympathetic activity during the

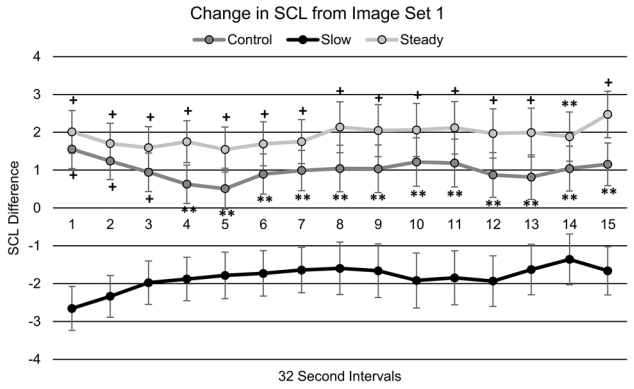

Fig. 3 Group differences in SCL from image set 1 to image set 2. *Note Asterisks above error bars* represent differences between slow tapping and steady tapping groups. *Asterisks below error bars* represent differences between slow tapping and control groups. *Error bars* are based on standard error of the mean. $*p < .05$, $**p < .01$, $+ p < .001$

presentation of negative images, and this "training period" was designed to make the participant comfortable with the movement requirements. Participants were instructed to tap slower and softer. No other meditation-like explanation or direction was given. Other techniques providing similar benefits manipulate breathing, require expensive equipment and take weeks or even months to properly master. Breathe focused mindfulness-based stress reduction (MBSR) instructs participants to breathe slower and more calmly, often requiring 1–2 months of training. Goldin and Gross (2010) found that breath focused MBSR increased activity in occipital brain regions associated with visual attention and decreased amygdala activity. Heart rate variability (HRV) biofeedback is another technique that shows promise, it requires maintaining a respiratory rate between 4 and 6 breaths per min (Prinsloo et al. 2013; Nolan et al. 2005). HRV biofeedback increases the body's cardio-respiratory autonomic response and most interventions are 4–8 weeks, since breathing at a 4–6 breaths per minute can initially be uncomfortable. A possible reason breath-focused MBSR and HRV biofeedback take time to master is that one must overcome his or her normal respiratory response, and adopt an alternative respiratory pattern. Respiration may have a voluntary component, but it is primarily regulated by homeostatic and environmental demands. In contrast, movement is predominantly voluntary, is not bound by homeostatic mechanisms, and *generates* homeostatic adaptations. The slow tapping group effortlessly demonstrated an improved autonomic response to negative images *despite* an increase in respiratory rate and negligible changes in respiratory volume. The lack of respiratory changes provides evidence that the observed autonomic response was due to movement-based modulation of afferent and efferent autonomic activity.

There were a few limitations that could have possibly affected the outcome of the current study. Participants in this experiment were required to tap for approximately 14 min, which is longer than they might have performed this action outside the laboratory. Although participants tapped for a longer period, the benefit observed from the beginning to the end of the second image set was consistent throughout, as changes in SCL indicate (Fig. 2). If the amount of time participants tapped had not produced positive effects, or if the effects diminished over time, the SCL during the second image set would have increased at some point, and this did not occur. In the real world, participants may not need to tap for 14 min to achieve the benefits reported in the current study.

Another limitation could be whether participants who tapped throughout the second image set were distracted by the tapping task, and less able to pay attention to the images. The effects demonstrated by the slow tapping group do not appear to be attributable to distraction. During the negative image presentations, heart rate decreased during image presentation for the slow tapping group, indicating they were paying attention. Not only was there a bradycardia of attention for the slow tapping group, but these decreases during negative image presentation were stronger than those experienced during the first image set (see Fig. 1). Before being trained to tap steadily (image set 1), the steady group showed a decrease in heart rate during the image presentation, demonstrating the expected bradycardia of attention. While tapping steadily during the second image set, participants showed no evidence of bradycardia of attention during image presentation. For controls (who did not tap during either image set), bradycardia of attention during image presentation was evident during both image sets, suggesting they also attended to the images. The change in heart rate from the first image set to the second image set may indicate that the slow tapping group paid *more* attention to the images, and also produced a diminished sympathetic response following image presentation. While distraction can't be completely ruled out, it doesn't account for the decreased arousal of the slow tapping group and the enhanced bradycardia of attention during the second image set.

In conclusion, the current study provides evidence that manipulating movement is an effective means to attenuate physiological arousal to negative stimuli. Future research should focus on what mechanism may be driving the changes observed with the act of slow tapping. The current study does not elucidate whether the muscular act of tapping and/or tactile stimulation are the most important contributor to the observed change, nor does it explore whether combining breathing instructions with movement could produce further benefits. Learning more about the mechanism may allow further development of novel methods to

cope with emotional arousal. It would also be of interest to determine if slow tapping would be effective in real world situations with active stressors and for those suffering from clinical disorders such as anxiety and/or post-traumatic stress disorder (PTSD). A pilot study (N = 9) has found that biofeedback combined with exposure therapy was noninvasive, and trended towards accelerating treatment progress above and beyond that of exposure therapy alone (Polak et al. 2015); results from this study suggests that techniques regulating physiological arousal can effectively be combined with clinical interventions. More research is needed to determine how and in what ways regulating physiological arousal can provide possible benefit.

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