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Look Before You Regulate: Differential Perceptual Strategies Underlying Expressive Suppression and Cognitive Reappraisal

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Successful emotion regulation is important for maintaining psychological well-being. Although it is known that emotion regulation strategies, such as cognitive reappraisal and expressive suppression, may have divergent consequences for emotional responses, the cognitive processes underlying these differences remain unclear. Here we used eye-tracking to investigate the role of attentional deployment in emotion regulation success. We hypothesized that differences in the deployment of attention to emotional areas of complex visual scenes may be a contributing factor to the differential effects of these two strategies on emotional experience. Eye-movements, pupil size, and self-reported negative emotional experience were measured while healthy young adult participants viewed negative IAPS images and regulated their emotional responses using either cognitive reappraisal or expressive suppression. Consistent with prior work, reappraisers reported feeling significantly less negative than suppressers when regulating emotion as compared to a baseline condition. Across both groups, participants looked away from emotional areas during emotion regulation, an effect that was more pronounced for suppressers. Critically, irrespective of emotion regulation strategy, participants who looked toward emotional areas of a complex visual scene were more likely to experience emotion regulation success. Taken together, these results demonstrate that attentional deployment varies across emotion regulation strategies and that successful emotion regulation depends on the extent to which people look toward emotional content in complex visual scenes.

Keywords: emotion regulation, cognitive reappraisal, expressive suppression, gaze

Humans experience a spectrum of emotions, ranging from pleasure and joy to fear and sadness. One of our most basic adaptive challenges is to regulate our emotions to maintain mental health (for review, see Gross, 2007). To meet this challenge, we have the ability to exert control over the emotions we experience. Emotion regulation entails controlling or changing one's emotions through extrinsic means (managing overt behaviors and social situations) and intrinsic means (recruiting cognitive and neurophysiological systems Gross, 2007). Unsuccessful emotion regulation can lead to psychological disorders, such as major depressive disorder (Davidson, Putnam, & Larson, 2000; Jackson, Malmstadt, Larson, & Davidson, 2000).

Among the myriad emotion regulatory strategies we might deploy, two of the most common are cognitive reappraisal and expressive suppression. Cognitive reappraisal involves rethinking the meaning of an emotion-eliciting event. For example, when you spill milk on the floor, you may initially be angry at yourself for creating a mess, however, you can reappraise the situation to decrease your anger by thinking that the floors were already quite dirty and in need of a good cleaning. In contrast to cognitive reappraisal, expressive suppression involves inhibiting motor or bodily responses to it (Gross, 2007). For example, when your boss makes you angry, social norms dictate that you should hide your outward expressions of anger from your boss, even though you are seething with anger at an experiential level. According to the process model of emotion regulation, these two strategies target different stages in a cyclical emotion generation sequence in which a stimulus is perceived and appraised in terms of its significance to one's goals, wants, and needs, and elicits a multicomponent response (Gross, 1998; Goldin, McRae, Ramel, & Gross, 2008). Cognitive reappraisal involves cognitively changing or altering one's interpretation of an emotional stimulus at the appraisal stage in ways that can have downstream impacts on experiential, behavioral and physiological responses. Expressive suppression, by contrast, involves active attempts to change only the behavioral com-

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ponent of one's emotional response, such as overt emotional expressions, which may result in little or no impact on experience and even boost physiological responding (Gross & Levenson, 1997). The divergent consequences associated with these two strategies may explain why cognitive reappraisal is associated with greater interpersonal functioning, positive emotional experience and expression, and well-being (Gross & John, 2003); whereas expressive suppression is associated with decreased positive emotional expressive behavior but increased negative emotional experience (Gross & John, 2003).

As the behavioral consequences of cognitive reappraisal and expressive suppression have become increasingly well understood, our knowledge of their underlying cognitive and neural mechanisms has similarly begun to take shape. Both behavioral and functional imaging data suggest that both strategies depend upon multiple kinds of cognitive processes (Goldin et al., 2008; Gross, 1998; Ochsner & Gross, 2005, 2007). One cognitive process common to both strategies is attention. According to the modal model of emotion, attentional deployment is an antecedent-focused emotion regulation strategy (Gross, 1998). Both directing attention toward (i.e., concentration) and away from (i.e., distraction) emotionally evocative stimuli may be used to regulate emotions.

Little research has directly addressed the nature of the role and importance of attention in determining overall emotion regulatory success. One recent neuroimaging study of cognitive reappraisal found that gaze patterns made during cognitive reappraisal accounted for nearly 35% of the variance in amygdala response, suggesting that attentional deployment during cognitive reappraisal may be particularly critical to emotion regulation success, inferred from the magnitude of amygdala response (van Reekum et al., 2007). By contrast, Urry (2010) recently found that changes in visual attention did not influence emotion regulation success, as measured by autonomic physiology and ratings of emotional intensity, during cognitive reappraisal. Such inconsistent findings suggest that our understanding of the role of attentional deployment in cognitive reappraisal and emotion regulation, more generally, remains unclear. Specifically, it remains unknown whether visual attention varies as a function of the type of emotion regulation strategy, and whether attentional deployment predicts emotion regulation success as indexed by behavioral self-reports for cognitive reappraisal and expressive suppression strategies.

Here we sought to examine the specific role of attentional deployment in two distinct emotion regulation strategies: cognitive reappraisal and expressive suppression. We hypothesized that attention is deployed in different ways for cognitive reappraisal and expressive suppression. For cognitive reappraisal, two possibilities were salient. One possibility is that cognitive reappraisal shifts attention away from emotional triggers, perhaps while reframing the context of negative information (Ochsner & Gross, 2005; van Reekum et al., 2007). A second possibility is that cognitive reappraisal focuses greater attention on emotional triggers to facilitate reinterpreting the meaning of the emotionally charged aspects of a stimulus (McRae et al., 2010). Because emotion regulation success, as indexed by behavior self-reports, during cognitive reappraisal has been shown to occur independently of visual attention (Urry, 2010), we hypothesized that emotion regulation success would not be predicted by attentional deployment.

For expressive suppression, we also considered two possible ways in which attention may be deployed during emotion regulation. One possibility is that attention may be directed away from the emotional aspects of the stimulus to reduce emotionally elicited motor responses. A second possibility is that attention is sustained to the emotional trigger or emotional aspects of the stimulus. This may, in part, explain why suppression may not reduce—or may even enhance—experiential and physiological responses to emotional stimuli. We hypothesized that attentional deployment would not predict emotion regulation success if expressive suppression occurs independently of visual attention.

Additionally, it is possible that differences in attentional deployment between cognitive reappraisal and expressive suppression may occur during distinct temporal phases of emotion regulation due to the differences in the temporal dynamics with which cognitive reappraisal and expressive suppression are applied when a stimulus is encountered (Gross, 1998; Goldin et al., 2008). Cognitive reappraisal may involve the initial effortful selection and implementation of a cognitive strategy to decrease emotional experience that requires relatively less effort to maintain over time. Expressive suppression, by contrast, may require sustained or increasing efforts to minimize the ongoing expression of facial and behavioral emotions that are continuously evoked for the duration of emotional stimuli presentation. Supporting this view, prior neuroimaging evidence indicates that cognitive reappraisal results in "early" prefrontal cortex responses occurring within the first five seconds of a 15 second stimulus presentation, whereas expressive suppression produces "late" prefrontal responses, appearing approximately 10 seconds after the process of emotion regulation has begun (Goldin et al., 2008). Given evidence of differences in temporal dynamics of neural processes underlying these two emotion regulation strategies, we hypothesized that attentional deployment during cognitive reappraisal compared to expressive suppression may similarly vary across early and late phases of emotion regulation.

To address these hypotheses regarding the role of attentional deployment in cognitive reappraisal and expressive suppression, we measured emotional experience, eye movements, and pupil size while participants were instructed to either reappraise or suppress their emotional reactions to negative emotional scenes. We predicted that perceptual strategies deployed during emotion regulation would vary as a function of type of strategy and temporal phase of emotion regulation. Specifically, we predicted that suppressers would look away from negative aspects of a visual scene during the late phase of emotion regulation, relative to reappraisers, who would rely on cognitive reframing, rather than gaze avoidance, to reduce negative emotional experience. Given that cognitive reappraisal is typically a more successful strategy relative to expressive suppression, we further predicted a relationship between attentional deployment and emotion regulation success, such that the degree of emotion regulation success would be negatively correlated with the degree of looking away from emotional scenes.

Additionally, we also examined pupil size as an index of emotional arousal associated with sympathetic nervous system activity (Bradley, Miccoli, Escrig, & Lang, 2008). We hypothesized that pupil size would remain stable or decrease during successful emotion regulation as a result of decreased emotional arousal. If pupil size served as an index of emotional arousal in this study, we further predicted that degree of emotion regulation success would be negatively correlated with pupil size enlargement. Alternatively, previous studies have observed increased pupil size during cognitive reappraisal, most likely as a result of the increased cognitive processing required to reappraise (Urry et al., 2006; van Reekum, et al., 2007). Thus, the alternative hypothesis was that pupil size may increase during successful emotion regulation as an indicator of increased cognitive processing. If pupil size served as an index of cognitive processing in this study, we further predicted that degree of emotion regulation success would be positively correlated with pupil size enlargement.

Method

Participants

Eighty-four healthy college-aged students (40 females; age in years: $M = 19.67$, $SD = 2.08$) with normal or corrected-to-normal vision completed this study for course credit or monetary compensation. Participants were randomly assigned to either a reappraise ($N = 40$; 23 females) or suppress ($N = 44$; 21 females) group.[1]

Stimuli

Twenty digital IAPS color images (1024 × 768 pixels; Lang, Bradley, & Cuthbert, 2005) were selected to be unpleasant ($M = 3.04$, $SD = 0.60$), dominating ($M = 4.60$, $SD = 0.52$) and arousing ($M = 5.15$, $SD = 0.59$) according to standardized IAPS ratings. Twenty neutral images—valence ($M = 6.02$, $SD = .56$), dominance ($M = 4.52$, $SD = .48$), arousal ($M = 5.41$, $SD = .48$)—were also selected to prevent habituation to the negative images.

Eye-Tracking Apparatus

Eye-movements and pupil size were recorded throughout the experiment by an SR Research Eyelink 1000 eye-tracker. The eye-tracker was controlled by a PC, which simultaneously recorded event codes transmitted by a stimulus generation computer. A 9-point calibration was performed prior to the experiment, and drift correction was performed before each trial during the experiment. Images were displayed on a 19" LCD monitor approximately 60 cm from the participants' eyes.

Emotion Regulation Training

Prior to the experiment, participants listened to verbal descriptions of how to use their assigned emotion regulation strategy and concrete examples of the strategy (see Gross, 1998; Ochsner et al., 2004). For regulate trials, participants in the suppress group were instructed to inhibit facial emotional expressions so that someone watching them would not be able to tell what they were feeling. As an example of expressive suppression, the experimenter described a "poker face to the participants—" while you may be upset that you have a losing hand of cards while playing poker, you must hide this information from your opponents by suppressing your facial expressions of emotion: Participants in the reappraise group were instructed to reinterpret the images in ways that decrease their negative emotional response. For example, an image of a woman crying in a church may initially be interpreted as an expression of mourning at a funeral. When reappraising the image to feel more positive, the experiment described that the picture could be reinterpreted as depicting a woman crying tears of joy at a wedding. All participants were instructed to avoid using any other type of strategy other than the assigned strategy during the experiment. As a baseline for comparison with the regulate trials, during "Attend" trials, both groups were instructed to let themselves respond naturally to the images without attempting to alter their response.

Participants then practiced their assigned strategy while viewing IAPS images not seen during the experiment. After practicing, the experimenter verbally verified the participants' ability to use their assigned strategy and reminded participants to use the assigned strategy to the best of their ability and to accurately report their emotional experience after performing the task, regardless of how successful they felt they had been when using their assigned strategy.

Procedure

For each trial participants first saw an instructional cue, presented for two seconds, to either attend or to regulate emotions elicited by the next image in the trial (see Figure 1). After seeing the instructional cue, participants followed the instruction while viewing an IAPS image for 10 seconds. Eye-movements and pupil size were recorded during image viewing. Participants then rated how negative they felt on a scale from 1 (*not negative*) to 7 (*strongly negative*) as a measure of subjective emotional experience. Finally, a screen with the instruction to "relax" appeared for four seconds.

The experiment consisted of four blocks that varied by type of instruction (attend or regulate) and type of image valence (negative or neutral): (a) Attend to negative images, (b) Attend to neutral images, (c) Regulate to negative images, (d) Regulate to neutral images. There were 10 trials in each of the four blocks (40 total trials), and the block order was counterbalanced between participants. The order of negative and neutral images was randomized within each block.

Emotional Area-of-Interest Definition (eAOI)

Given prior work showing that different areas of emotional scenes vary in the degree of emotional content (van Reekum et al., 2007), we conducted a separate two-part norming experiment in order to identify and validate emotional areas of interest (eAOIs) for the 20 negative IAPS images used in this study.

The first part of the norming experiment involved defining eAOIs by obtaining self-report descriptions from raters. Ten participants (age in years: $M = 18.7$, $SD = 0.7$; 5 F) with normal or corrected to normal vision participated in this study for course credit. Participants were given unlimited time to cover emotional areas from each negative IAPS image with freeform shapes in Microsoft Powerpoint™. Importantly, participants were instructed specifically to use the smallest, most concise shapes possible to cover the emotional areas of each image until they no longer felt the image was emotional. We combined ratings from each participant into a two-dimensional matrix of average negativity ratings across each pixel in the image for all 10 negative IAPS images (Figure 2b).

[1] The reappraise and suppress groups do not have an equal number of participants because four participants failed to meet preselection criteria.

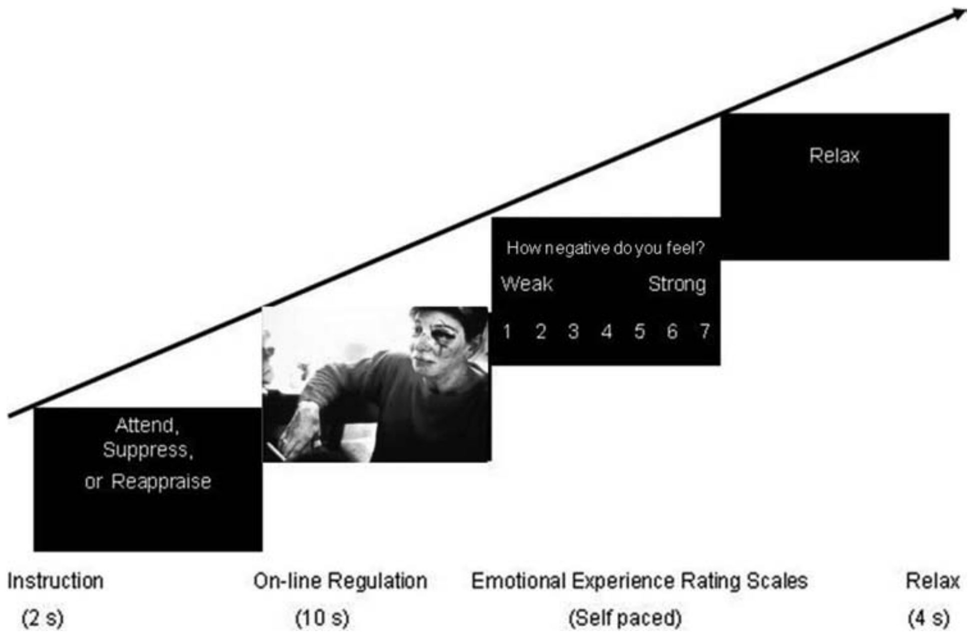

Figure 1. Example trial of the emotion regulation task. For the first 2 seconds of the trial, a cue appeared with the instructions to either attend or to regulate emotions during the trial. Next, participants followed the task instructions while viewing a negative or neutral IAPS image for 10 seconds. Participants then provided a self-report rating of "How negative do you feel" on a scale from 1 (*weak*) to 7 (*strong*). At the end of the trial, a screen with the instruction "Relax" appeared for 4 seconds.

In the second part of the norming experiment, frequently fixated regions were recorded with an SR Research Eyelink 1000 eyetracker in a free-viewing control task. A separate group of 16 participants (age in years: $M = 22.8$, $SD = 2.6$; 8 F) with normal or corrected to normal vision participated in this study for monetary compensation. Participants passively viewed each intact IAPS image for 10 seconds, providing a two-dimensional histogram of fixation frequency (Figure 2c). Each fixation added a Gaussian kernel with a 14 pixel *SD* and 3 *SD* cutoff radius.

To combine the matrix of average negativity ratings and the histogram of fixation frequency into a single eAOI, we sequentially selected the most negatively rated pixels until those pixel locations accounted for at least half of the fixations in the free-viewing control task (Figure 2d). This procedure ensures that eAOIs will cover approximately the 50% *most* negative areas of each scene out of all of the frequently fixated locations. For an example of this method, consider the original IAPS image in Figure 2a. The caretaker's hand holding the baby's head is frequently fixated in the control task (Figure 2c) but is not rated as negative (Figure 2b), and thus, does not become a part of the final eAOI (Figure 2d). The percentage of the eAOIs and the number of discrete areas of interest (at least 100 pixels in size) in each IAPS image are displayed in Appendix A.

Validation of eAOIs. To quantify the affective dimensions of the eAOIs within each image, a different set of 20 participants (*M* in years = 19.3, *SD* in years = 1.1; 11 F) rated intact IAPS scenes and IAPS images with covered eAOIs (i.e., eAOIs were covered over with black shading to obscure viewing, see Figure 2D for an example) along three emotion dimensions previously used to describe the emotional content of IAPS scenes: arousal, dominance, and valence (Lang et al., 2005). Intact and covered eAOIs IAPS images were presented in a block design, and the order of blocks was counterbalanced between participants. Images within each block were randomized and presented following the standard IAPS rating procedure. Each trial began with a "Get ready to rate the next slide" screen presented for five seconds. Next, an image was presented on a computer screen for six seconds. After viewing each image, participants rated their feelings of arousal (How aroused do you feel? 1 = *very calm*, 9 = *very aroused*), dominance (How in control do you feel? 1 = *very controlled*, 9 = *very in control*), and valence (How happy do you feel? 1 = *not at all happy*, 9 = *very happy*). Responses were recorded with DirectRT software (Jarvis, 2006).

Three separate one-way (*Image modification*: None, covered eAOIs) repeated measures ANOVAs were performed on the arousal, dominance, and valence ratings. Consistent with our hypotheses, there were significant main effects of image modification on arousal, $F(1, 16) = 22.42$, $p < .001$, dominance, $F(1, 16) = 23.61$, $p < .001$, and valence, $F(1, 17) = 38.27$, $p < .001$, ratings. Raters viewing images with covered eAOIs felt significantly less aroused ($M = 4.58$, $SD = 0.09$), more dominant/in control ($M = 4.05$, $SD = 0.06$), and more pleasant ($M = 3.31$, $SD = 0.06$) than when viewing unmodified images (arousal: $M = 5.32$, $SD = 0.07$; dominance: $M = 3.25$, $SD = 0.06$; valence: $M = 2.49$, $SD = 0.06$).

Data Analysis

Trials with neutral images primarily served to prevent habituation to the negative images and thus the data for these trials was not analyzed. Three negative images were not included in the final

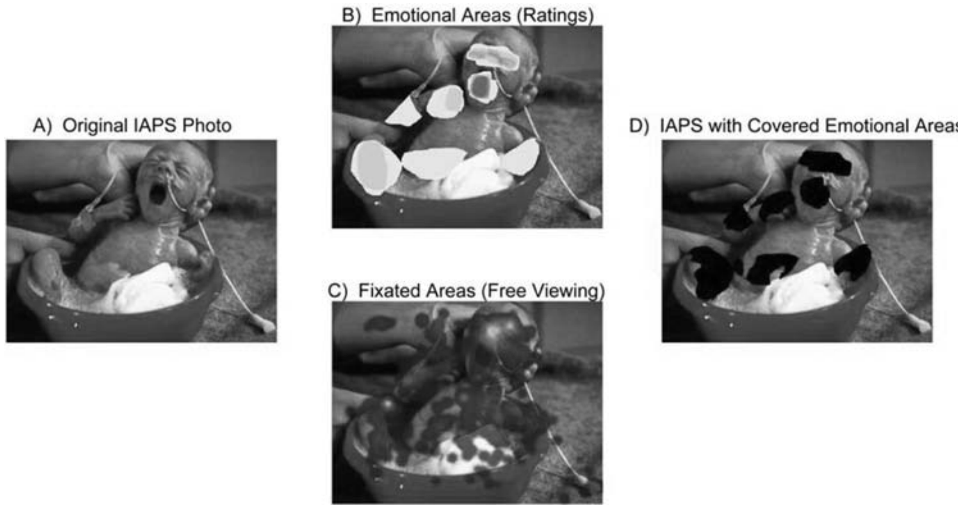

Figure 2. Example of the method for identifying emotional areas of interest (eAOI) within IAPS images (A) Original IAPS image; (B) Self-report Control Task: Free-form shapes were drawn on emotionally negative regions to remove the affective qualities of the image, yielding a matrix of average negativity ratings; (C) Free-Viewing Control Task: Eye-movements were recorded during free-viewing of images to identify emotionally salient areas, creating a histogram of fixation frequencies; (D) Creation of eAOI: To rank emotionally salient areas in order of rated negativity, we selected the negative areas in order from most negative to least negative until those areas of the image included 50% of the total number of fixations made in the free viewing control task. Please refer to the Methods section for a more detailed description of the eAOI creation and validation.

analysis because less than the 50% of the fixations made on the image were within the eAOIs.[2]

Behavioral Ratings

To assess the effectiveness of each emotion regulation strategy, a one-way repeated measures ANOVA with Task (Attend, Regulate) as a within subject variable and Group (Reappraise, Suppress) as a between-subjects variable, was conducted on the negative valence ratings.

Pupil Size

To calculate a standardized pupil size measure, each participant's average pupil size during the experimental phase was divided by average baseline pupil size during eye-tracker calibration. A repeated measures ANOVA (Task: Attend, Regulate; Time: Early, Middle, Late; Image Area: Background, eAOI) was then conducted on the standardized pupil size data. Group (Reappraise, Suppress) served as a between-subjects variable.[3]

Eye Movements in Emotional Areas of Interest (eAOIs)

Given the known variability in neural responses during emotion regulation as a function of time (Goldin et al., 2008), we analyzed fixations made to eAOIs across three discrete times: early, middle, and late. Average percentage of fixations made to eAOIs for early (1–3 s), middle (4–6 s), and late (7–10 s) times were calculated. A repeated measures ANOVA was conducted on the fixation data with task (Task: Attend, Regulate) and time (Time: Early, Middle, Late) as a within-subjects variables, and Group (Reappraise, Suppress) as a between-subjects variable.

Results

Behavioral Measure: Self-Reported Negative Valence Ratings

Consistent with prior work, there was a significant main effect of task on negative valence ratings, $F(1,82) = 62.16$, $p < .001$. Participants reported feeling less negative during regulate trials than during attend trials, $t(82) = 6.76$, $p < .001$.

There was also a significant interaction between task and group, $F(1, 82) = 24.90$, $p < .001$, (Table 1A). Both reappraisers, $t(39) = 8.33$, $p < .001$, and suppressers, $t(43) = 2.24$, $p < .05$, felt significantly less negative during regulate trials relative to the attend trials. Reappraisers rated feeling significantly less negative during regulate trials relative to the suppressers, $t(82) = 3.63$, $p < .001$. Both groups made equally negative ratings for the attend trials, $p > .05$, indicating that cognitive reappraisal was the more effective emotion regulation strategy.

There was no significant main effect of group on ratings of negative emotions, $p > .05$.

[2] When the 3 excluded images are included in the analysis, similar significant results are obtained.

[3] One participant was excluded from the pupil size analysis due to missing pupil data in the eAOIs during the late time of emotion regulation.

Table 1

Dependent variable	Task	Time	Emotion regulation: Cognitive reappraisal	Expressive suppression
A. Negativity rating	Attend		4.73 ± 1.11	4.61 ± 1.14
	Regulate		3.34 ± 1.10*	4.29 ± 1.30*
B. Pupil size	Attend	Early	0.81 ± 0.02	0.80 ± 0.02
		Middle	0.85 ± 0.03	0.87 ± 0.03
		Late	0.88 ± 0.03	0.90 ± 0.03
	Regulate	Early	0.79 ± 0.02	0.78 ± 0.02
		Middle	0.84 ± 0.03	0.82 ± 0.02
		Late	0.87 ± 0.03	0.84 ± 0.03
C. Fixation Count	Attend	Early	69.59 ± 1.24	69.01 ± 1.51
		Middle	61.86 ± 1.68	58.58 ± 1.82
		Late	61.40 ± 1.42	54.95 ± 2.06
	Regulate	Early	67.85 ± 1.59	65.98 ± 2.16
		Middle	62.87 ± 1.45	55.03 ± 2.60
		Late	61.21 ± 1.51	51.09 ± 2.50

Note. * indicates $p < .001$; Early time (1–3 secs), Middle time (4–6 secs), Late time (7–10 secs). A) Average self-reported negative valence ratings as a function of task and type of emotion regulation ($M \pm SE$). Negative Valence Ratings were made on a scale from 1 (*I Do Not Feel Negative*) to 7 (*I Feel Very Negative*). Reappraisers rated feeling significantly less negative during regulate trials than the suppressers. No significant group differences were found for negative valence ratings in the attend task condition. B) Proportion of pupil size relative to baseline as a function of task, time, and type of emotion regulation ($M \pm SE$). C) Average Percent Fixation Count in EAOIs as a function of time and type of emotion regulation ($M \pm SE$).

Physiological Measures: Pupil Size Results

Pupil size increased throughout the duration of each trial, $F(2, 162) = 75.35$, $p < .001$. Specifically, pupil size increased from the early time to the middle time, $t(81) = 9.39$, $p < .001$, and from the middle time to the late time, $t(81) = 7.13$, $p < .001$.

Pupil size also significantly differed between tasks, $F(1, 81) = 11.61$, $p = .001$, and image location, $F(1, 81) = 8.22$, $p < .005$. Pupil size was larger during the attend trials relative to regulate trials, $t(81) = 3.83$, $p < .001$, and in background areas relative to eAOIs, $t(81) = 2.90$, $p < .005$.

There was a significant three way interaction between time, task, and group, $F(2, 162) = 3.78$, $p < .05$ (Figure 3A, Table 1B). For the reappraise group, pupil size increased over time during both the attend (early and middle, $t(39) = 5.01$, $p < .001$, and middle and late, $t(39) = 3.00$, $p < .005$), and regulate (early and middle, $t(39) = 5.49$, $p < .001$, middle and late times, $t(39) = 7.07$, $p < .001$) trials. Similarly, the suppressers' pupil size also increased over time during both the attend (early and middle, $t(42) = 6.42$, $p < .001$, and middle and late times, $t(42) = 4.06$, $p < .001$) and regulate (early and middle, $t(43) = 4.81$, $p < .001$, middle and late times, $t(42) = 3.26$, $p < .005$) trials. For the reappraise group, pupil size was larger during attend trials relative to the regulate trials in the early, $t(39) = 2.27$, $p < .05$, time but not in the middle, $p = .053$, or late time, $p = .21$. In contrast, for the suppress group, pupil size was larger during the attend trials compared to the regulate trials during the middle, $t(42) = 23.64$, $p < .001$ and late time, $t(42) = 4.24$, $p < .001$, but not in the early time ($p = .053$). There was no main effect of emotion regulation group or additional two-way interactions for pupil size (all ps $> .05$). There were no interactions between group, time, and image location for pupil size (all ps $> .05$).

Eye-Movement Measure: Percent Fixation Count in eAOIs

To analyze fixations made to eAOIs across the entire image viewing time (10 s), we calculated the average percentage of fixations made to eAOIs for early (1–3 s), middle (4–6 s), and late (7–10 s) times. There was a significant main effect of group on the percent fixation count in eAOIs, $F = (1, 82) = 6.26$, $p < .05$. Reappraisers looked more at eAOIs relative to suppressers, $t(82) = 2.45$, $p < .05$. There was also a significant main effect of time on the percent fixation count in eAOIs, $F(2, 164) = 119.59$, $p < .001$. Participants looked more at eAOIs during the early relative to middle, $t(82) = 11.22$, $p < .001$, and late $t(82) = 12.89$, $p < .001$, times. Participants also looked more at eAOIs during the middle than during the late time, $t(82) = 3.15$, $p < .005$.

There was a significant interaction between time and group on the percent fixation count in eAOIs, $F(2, 164) = 11.47$, $p < .001$ (Figure 3B, Table 1C). Reappraisers looked more at eAOIs during the early relative to middle, $t(39) = 8.50$, $p < .001$, and late times, $t(39) = 7.56$, $p < .001$. By contrast, suppressors looked more at eAOIs during both the early, $t(43) = 11.73$, $p < .001$, and middle, $t(43) = 3.46$, $p < .005$, times relative to the late time. There were no additional significant main effects or two-way or three-way interactions (all ps > 0.05).

Relationship Between Pupil Size and Self-Reported Negative Affect

To determine the relationship between affect ratings and pupil size for each type of emotion regulation strategy, a one-tailed bivariate correlation was conducted for the reappraise and suppress groups on the following variables: task difference (attend−regulate) in negative valence ratings (regulatory success); task difference (attend−regulate) in the pupil size for the early, middle, and late times; and task difference (attend−regulate) in overall pupil size (average pupil size collapsed across time).

For the suppress group, there was a significant negative correlation between the overall pupil difference and regulatory success, $r(44) = -.26$, $p < .05$ (Figure 4A). More successful regulators showed a smaller increase in pupil size during regulation relative to the attend condition. This correlation also was independently significant during the middle time period of emotion regulation, $r(44) = -.28$, $p < .05$. All other correlations for the suppress group were not significant, $p > .05$. There were no significant correlations between pupil size and emotional experience for the reappraise group. When collapsing across both emotion regulation groups, there were no significant correlations between the regulatory success and pupil size variables, $p > .05$.

To determine the relationship between affect ratings and pupil size in relation to image location, a one-tailed bivariate correlation was conducted for the reappraise and suppress groups on the following variables: task difference (attend−regulate) in negative valence ratings (regulatory success); task difference (attend—regulate) in the pupil size for the early, middle, and late times in the background areas and in the eAOIs. There were no significant correlations for the reappraise group, the suppress group, and both groups collapsed together, all *p*s > .05.

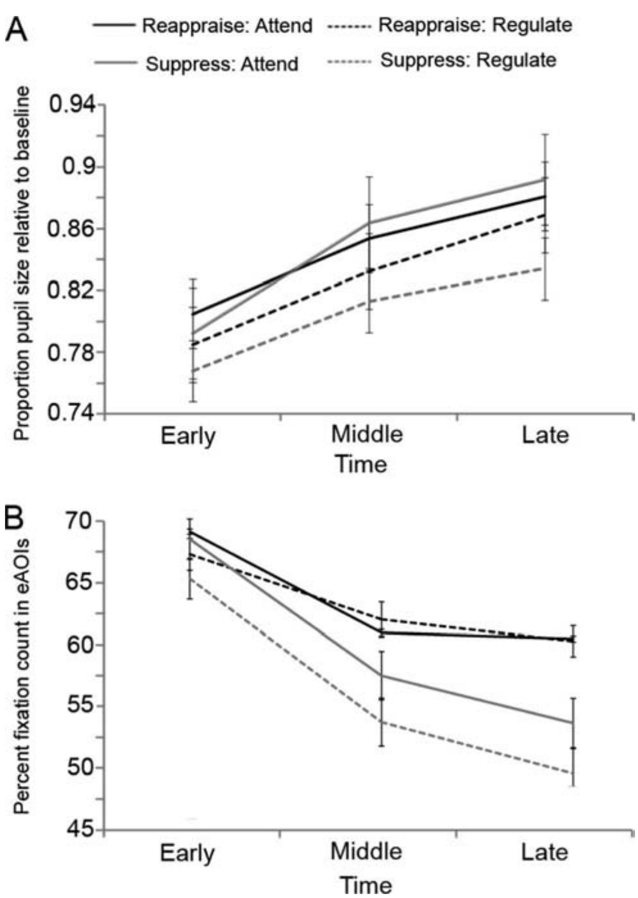

Figure 3. (A) Proportion pupil size relative to baseline as a function of time: Early (1–3 secs), Middle (4–6 secs), Late (7–10 secs); task (Attend, Regulate); and group (Reappraise, Suppress, $M \pm SE$). (B) Percent fixation count in emotional areas of interest (eAOIs) as a function of time, task and group ($M \pm SE$).

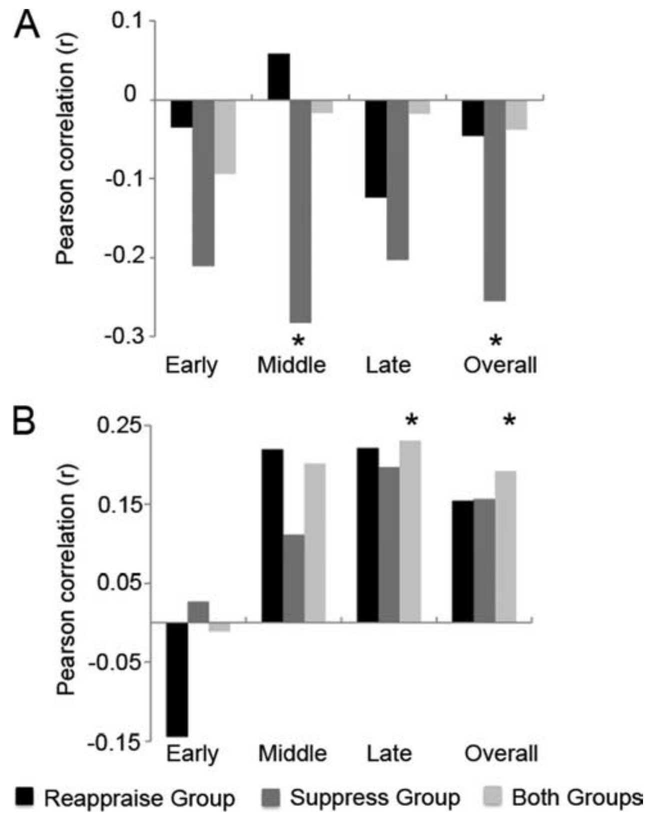

Figure 4. Correlation coefficients between emotion regulation success (Regulate negative valence ratings–Attend negative valence ratings) and the differences (Regulate–Attend) in (A) proportion pupil size relative to baseline, (B) Percent fixation count in emotional areas of interest (eAOIs).

Relationship Between Eye Movement and Self-Reported Negative Affect

To determine the relationship between affect ratings and fixations, a bivariate correlation (one-tailed) was conducted on the following variables: difference in negative valence rating between attend and regulate trials (regulatory success); difference in the percent fixation count in eAOIs between attend and regulate trials for the early, middle, and late times (fixation difference); and difference in percent fixation count in eAOIs between attend and regulate trials collapsed across time (overall fixation difference).

Across all participants, there was a significant positive correlation between regulatory success and overall fixation difference, $r(84) = .192$, $p < .05$. More successful regulators looked more often at emotional areas of a scene. There was also independently a significant positive correlation between the regulatory success and overall fixation difference in the middle, $r(84) = 20$, $p < .05$, and late, $r(84) = .23$, $p < .05$, time periods (Figure 4B)[4]. All other correlations across participants were not significant, $p > .05$.

[4] One participant was greater than 3 standard deviations from the mean for the percent fixation count in eAOIs during the middle and late times. However, this participant was not greater than 3 standard deviations from the mean for the overall percent fixation count in eAOIs.

There were no significant correlations specifically for the suppress group, all $p > .05$ or reappraise group, all $p > .05$.

Discussion

Summary

The goal of the current study was to investigate the role of attentional deployment in cognitive reappraisal and expressive suppression. We hypothesized that differences in the deployment of attention to emotional areas of stimuli may contribute to the differential effects of these two emotion regulation strategies on emotional experience. To address our hypothesis, we measured emotional experience, eye movements, and pupil size while individuals either reappraised aversive images or suppressed behavioral expression elicited by the aversive images.

Consistent with prior research (see Gross, 2007, for a review), cognitive reappraisal decreased negative emotional experience more than expressive suppression. Although suppression usually maintains or enhances negative emotional experience (see Gross, 2007, for review), suppression decreased emotional experience relative to the baseline attend condition in this experiment. Goldin and colleagues (2008) reported similar findings and suggested that decreased negative emotional experience may reflect the redirection of attention away from the emotional experience elicited by the stimuli and toward minimizing facial expressivity during suppression.

Novel to this study, we found that attentional deployment toward emotional areas of stimuli differ between cognitive reappraisal and expressive suppression. Both emotion regulation groups directed visual attention toward emotional areas of scenes during initial viewing and gradually looked away from emotional areas of scenes over time. However, suppressors looked away from emotional scenes to a greater extent than reappraisers during emotion regulation. Critically, across both strategies, the degree of emotion regulation success, measured as decreasing negative affect when reappraising or suppressing, was greater for individuals who directed visual attention toward, rather than away from, the emotional regions of scenes. Taken together, these data provide the first direct evidence of a relationship between attentional deployment and emotion regulation success as well as strategy-specific attentional deployment between reappraisers and suppressors.

The Role of Attentional Deployment in Emotion Regulatory Success

Reappraisers rated feeling less negative emotions and viewed the emotional areas of negative scenes more, over time, relative to the suppressers. However, irrespective of emotion regulation strategy, emotion regulation success was predicted by looking more, over time, at emotional regions of a scene. Similar to Urry's findings (2010), the results of the current study support the process model of emotion regulation, which separates attentional deployment, cognitive reappraisal, and expressive suppression into distinct emotion regulation families. The current study suggests that attentional deployment influenced emotion regulation success independently of the other emotion regulation strategies.

The current findings complement and challenge findings from prior research examining the role of attentional deployment in emotion regulation. First, here we observed that attentional deployment varies during emotion regulation, a finding complementary to prior work on cognitive reappraisal (van Reekum et al., 2007). However, whereas prior work has documented a negative correlation between emotion regulation success and duration of looking at emotional areas of a complex scene (van Reekum et al., 2007), the current study reveals a positive correlation between emotion regulation success and duration of looking at emotional areas of a complex scene. More specifically, in prior work when emotion regulation success was indexed by decreased amygdala activity, emotion regulation success was correlated with *looking away* from emotional areas of interest. However, the current study found the reverse correlation whereby emotion regulation success as indexed by decreases in self-reported negative emotional experience was correlated with *looking at* emotional areas of interest.

Several issues in study design may explain this discrepancy between the prior study and the current findings. First, the prior and current studies used two different dependent measures of emotion regulation success. The prior work measured emotion regulation success via amygdala activation, while the current study measured emotion regulation success via self-reports of emotional experience. Recent neuroimaging evidence indicates that emotion regulation success measured via self-report is predicted by at least two mediated subcortical pathways (Wager et al., 2008), suggesting a more complex relationship between neural response during emotion regulation and decreases in self-reported emotional experience. We suggest that discrepancies in observed relationships between emotion regulation success and attentional deployment between studies are likely due, in part, to using different endophenotypes (e.g., behavioral vs. neural activity) as markers of emotion regulation success. Second, age differences may have contributed to inconsistencies between the prior and current studies. Participants in the prior study were elderly whereas participants in the current study were college-aged participants. Older adults experience a decline in various cognitive (e.g., inhibitory function, working memory, speed of processing) and neural capacities (e.g., cortical size, white matter integrity) (Park & Reuter-Lorenz, 2009). For the elderly, the psychological and neural mechanisms recruited to reappraise or cognitively change the meaning of an emotional event may be altered and possibly even impaired relative to young adults. We suggest that differences in age of participants across the two studies are another likely factor driving differences in reported observations.

Another possible explanation for this difference between prior and current findings is that age may modulate attentional deployment during emotion regulation. Relative to young adults, older adults tend to show an age-related positivity effect for emotional information such that they allocate more attention toward positive information than toward negative or neutral information (Carstensen & Mikels, 2005). Thus, compared to the young adults in this study, the older adults in the previous study may have allocated more attention toward nonemotion relevant details during cognitive reappraisal (van Reekum et al., 2007) from an age-related positivity effect.

Finally, timing differences in the study design may have also contributed to inconsistencies between the studies. In the current study, we presented the emotion regulation instruction before image presentation, so the participants regulated their emotions for the entire ten seconds of image presentation. In the prior study, participants viewed the emotional scenes for eight seconds but only regulated emotions during the last four seconds of image presentation.[5] When given a short period of time to reappraise, one may rely more on shifting attention away from emotional areas of scenes than one would when more time is available. Supporting this possible explanation, our data indicates that during the first three seconds of image presentation, reappraisers began to look away from emotional areas of interest, but over the last seven seconds of image presentation, to the extent that they keep focusing on the emotional areas of interest, they become increasingly successful at reappraising. Hence, the relationship between attentional deployment and emotion regulation success likely hinges on the amount of time one is given to regulate emotions.

Arousal, Pupil Diameter, and Their Relation to Emotion Regulation

Pupil size was smaller during cognitive reappraisal for early and middle times relative to the attend baseline condition, suggesting decreased emotional arousal while reappraising negative emotions.[6] During the late time, however, there was not a significant pupil size difference between reappraise and baseline for the reappraise group, possibly because cognitive reappraisal does not always decrease physiological responses (Gross, 1998; Steptoe & Vogele, 1986). It is also possible that cognitive reappraisal generates a positive and arousing response to counteract the negative and arousing response to the emotional stimuli, and thus, no pupil size difference was observed.

The current findings are inconsistent with prior studies examining the role of pupil size in emotion regulation, whereby larger pupil size was interpreted as evidence of greater use of cognitive resources during cognitive reappraisal as compared to experiencing emotions (Urry et al., 2006; van Reekum et al., 2007). Differences in the relationship between pupil size and emotion regulation may be due to a number of factors. For instance, pupil size results may differ between the current and prior studies due to age differences between the studies' samples. While the previous studies used older adult samples (Urry et al., 2006; van Reekum et al., 2007), the current study used a sample of young adult college students. Because pupillary size and reflex decline with age in healthy older adults (Bitsios, Prettyman, & Szabadi, 1996), pupil size differences between studies may be related to age differences between the studies' samples. Alternatively, pupil size inconsistencies between studies may be due to differences in experimental design. Previous studies presented the emotion regulation instruction 3–6 seconds after image presentation, and calculated pupil size as a proportional change in pupil diameter for time points after instruction presentation: post-pre/pre (Urry et al., 2006; van Reekum, et al., 2007). In contrast, the current study presented the emotion regulation instruction before image presentation and calculated a standardized pupil size for each time period and condition (experimental pupil size/baseline pupil size).

In the current study, the suppress group showed a pupil size response pattern similar to that shown by the reappraisers. For the suppressers, pupil size was larger during the attend trials than the suppress trials over all three time periods, suggesting decreased emotional arousal while suppressing negative emotions as compared to experiencing emotions. This was surprising because suppression is usually associated with increased sympathetic nervous system activity (Gross & Levenson, 1993, 1997), such as pupil dilation. We suggest that the suppressers in the current study anticipated the aversive nature of the negative images, leading to a decrease in the pupillary light reflex (Bitsios, Szabadi, & Bradshaw, 2004).

Novel to this study, we found that emotion regulation success was correlated with pupil size for expressive suppression, such that smaller pupil size was associated with greater emotion regulation success. These results are consistent with prior findings in which expressive suppression results in little or no impact on emotional experience and increases physiological responding, suggesting that a decrease in pupil size indicates greater emotion regulation success (Gross & Levenson, 1997). In contrast, there was not a significant correlation between pupil size and emotion regulation success for cognitive reappraisal. This may be due to a cancellation effect in which the cognitive effort used for reappraisal boosts arousal, while successful emotion regulation decreases arousal.

Limitations and Future Directions

A potential limitation of the current study was the lack of formal measurement of degrees of expressive suppression, such as videotaped recording of facial expressions. Because of the configuration of the eye-tracker apparatus, video camera recordings had limited footage of facial expressions, and thus, precluded the use of a video camera during the experiment. As a result, it is unknown to what extent facial expressivity diminished from the baseline (attend) condition to the suppress condition. That being said, there is reason to believe that facial expressions should have been minimized during the suppress condition in this experiment. Prior research has demonstrated a relationship between decreased negative emotion ratings and decreased facial expressivity during expressive suppression (Goldin et al., 2008). Since negative emotion ratings also decreased during suppression in this study, it is possible that facial expressivity also was attenuated.[7]

Future research examining perceptual strategies underlying emotion regulation may benefit from using a remote eye-tracker, which does not require the head to be restrained, and thus, may not preclude the display of facial expressions during the experiment. Simultaneous recording of additional physiological measures, such as the skin conductance response or respiration, may also be useful in future research as an additional index of physiological arousal. Finally, future work may directly manipulate gaze to emotional areas of interest during emotion regulation. Controlling gaze may further reveal characteristics in the relationship between gaze and the emotion regulation strategies of cognitive reappraisal and expressive suppression.

Basic Research and Clinical Applications

From a basic research perspective, this work complements and extends the process model of emotion regulation (Gross, 1998),

[5] After 8 seconds the image disappeared, and the participants continued regulating for an additional 4 seconds, resulting in a total of 8 seconds of emotion regulation.

[6] Cognitive reappraisal does not always decrease physiological responses (Gross, 1998; Steptoe & Vogele, 1986), such as pupil size, possibly as a result of the minimal cognitive processing necessary to translate negative emotional stimuli into physiological response (Gross, 2007).

[7] Debriefing measures also suggest that the suppress group participants were suppressing their facial expressions of emotions.

which suggests the possibility that multiple emotion regulation processes can occur simultaneously. The findings from this experiment also provide the first evidence that attentional deployment can occur in conjunction with either cognitive reappraisal or expressive suppression. Because gaze was not experimentally controlled, we cannot determine the order of emotion regulation processes (i.e., did attentional deployment occur before reappraisal) or the direction of feedback (i.e., did reappraisal feedback to modulate attentional deployment). Future work will be needed to clarify these possibilities.

Results from this study also have clinical applications. The findings suggest that directing attention toward emotionally evocative stimuli may facilitate adaptive emotion regulation. In some instances, increased attention toward emotional stimuli can lead to maladaptive emotion regulation, such as rumination (Campbell-Sills & Barlow, 2007); however, our findings suggest that the redirection of attention toward emotional stimuli in the short-term may facilitate adaptive emotion regulation. Thus, in a clinical setting, clinicians could teach patients to use both attentional deployment and cognitive reappraisal strategies to regulate emotions. For example, clinicians could use emotional image "flashcards" to train patients to view and reappraise emotionally arousing visual stimuli. When patients have achieved emotion regulation success using the flashcards in a treatment setting, they could then advance to practicing these strategies in real-world settings.

Conclusion

The current work builds on prior emotion regulation research by demonstrating how attending to emotional areas of visual scenes is associated with one's emotional experience. Our findings reveal the importance of attentional deployment in emotion regulation and in particular, how attention may be drawn toward or away from emotional areas of a visual scene depending on whether one attempts to regulate emotional experience via cognitive reappraisal or expressive suppression.

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(*Appendix follows*)

Appendix A

Mean Ratings (M ± SE) of Valence (VAL), Dominance (DOM) and Arousal (AR) For Intact IAPS images, EAOI IAPS images, and The Difference Between The Intact and EAOI images

IAPS ID#	Intact IAPS			eAOI IAPS			Intact — eAOI Difference		
	VAL	DOM	AR	VAL	DOM	AR	VAL	DOM	AR
1019	2.9 (1.8)	3.5 (1.9)	5.7 (2.2)	4.2 (1.7)	4.2 (1.9)	5(1.7)	−0.6	−0.7	0.7
1280	2.2 (1.4)	3.2 (1.9)	5.6 (2.7)	3.1 (1.4)	3.8 (1.7)	4.7 (1.9)	−1.0	0.1	0.9
1300	2.7 (1.4)	2.7 (1.4)	6.4 (2.2)	2.8 (1.4)	4.1 (1.5)	4.7 (2.2)	0	−0.1	1.7
2120	2.9 (1.6)	3.4 (1.3)	6.1 (1.9)	3.5 (1.4)	4.5 (1.2)	4.3 (1.9)	−0.5	−0.1	1.8
2455	3.3 (1.5)	4.2 (1.5)	3.7 (2.1)	3.3 (1.3)	4.3 (1.6)	4.1 (2.0)	0	−0.1	−0.4
2661	3.1 (1.9)	3.4 (2.2)	5.7 (1.9)	2.5 (1.5)	2.7 (1.5)	5.9 (2.3)	−0.3	0.9	−0.2
2715	3.2 (11.7)	4.5 (1.8)	4.2 (1.7)	3.4 (1.4)	4.6 (1.3)	4.4 (1.7)	−1.3	1.1	−0.2
3181	1.8 (1.2)	2.5 (1.3)	5.4 (2.8)	3.5 (1.4)	4.4 (1.6)	4.5 (1.9)	−0.7	−1.0	0.9
6561	3.5 (1.8)	4.1 (1.8)	5.4 (1.7)	3.9 (1.6)	4.8 (1.4)	5.2 (1.3)	−0.6	0.2	0.2
6610	3.3 (1.8)	4.5 (1.7)	5.1 (1.8)	3.6 (1.8)	4.5 (1.9)	4.4 (2.1)	−1.2	0.9	0.7
7361	2.4 (1.9)	3.1 (1.8)	5.4 (2.9)	3.1 (1.8)	3.3 (1.7)	4.4 (2.6)	−0.7	0	1.0
9008	2.6 (1.8)	4.1 (1.7)	4.7 (2.7)	3.5 (1.7)	4.3 (1.8)	4.2 (2.3)	−1.5	0.6	0.5
9181	1.7 (0.9)	2.4 (1.3)	5.6 (2.8)	2.9 (1.6)	3.5 (1.5)	4.8 (2.5)	−0.7	−0.5	0.8
9182	2.4 (1.4)	2.9 (1.4)	5.2 (2.5)	3.3 (1.7)	3.8 (1.6)	4.2 (1.7)	−0.5	−0.4	1.0
9265	1.4 (0.7)	2.1 (0.8)	6.5 (2.7)	2.0 (1.2)	3.2 (1.8)	5.7 (2.6)	−0.6	−1.1	0.8
9301	1.8 (1.1)	2.9 (1.5)	5.6 (2.8)	2.3 (1.2)	4.1 (1.8)	4.7 (2.1)	−1.1	0.6	0.9
9320	2.1 (1.4)	3.3 (1.5)	5.3 (2.5)	3.5 (1.8)	4.5 (2.1)	4.4 (2.1)	−1.2	−0.2	0.9
9561	1.8 (0.9)	2.4 (1.6)	5.8 (2.6)	4.5 (1.6)	5.4 (2.1)	4.3 (1.8)	−0.6	−2.1	1.5
9571	1.7 (1.1)	3.2 (1.8)	5.7 (2.5)	2.7 (1.8)	3.7 (1.7)	4.7 (2.3)	−1.5	0.5	1.0
9920	2.7 (1.5)	2.7 (1.3)	4.4 (2.1)	3 (1.3)	3.4 (1.8)	4.4 (1.9)	0	−0.3	0

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Correction to Krumhuber and Scherer (2011)

In the article, "Affect Bursts: Dynamic Patterns of Facial Expression," by Eva G. Krumhuber and Klaus R. Scherer (*Emotion*, Advance online publication, June 27, 2011. doi: 10.1037/a0023856), Table 1, there was several errors. The ◆ for AU6/Sadness was shifted to the F value. The ◆ for AU11/Sadness was shifted to the F value. The ◆ for AU24/Hot anger was shifted to Relief. Additionally, in Table 4, spaces were omitted from the rows between data for anger, fear, sadness, joy, and relief. All versions of this article have been corrected.

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