Tables: 4

Figures: 3

An Eye-Tracking Examination of Emotion Regulation, Attentional Bias, and Pupillary Response to Threat Stimuli

Joseph R. Bardeen[1] & Thomas A. Daniel[2]

[1]Auburn University

[2]Westfield State University

Author Note

Correspondence concerning this article should be addressed to Joseph R. Bardeen, Department of Psychology, Auburn University, 226 Thach Hall, Auburn, AL 36849-5214. Voice: 334-844-6647, E-mail: jbardeen@auburn.edu

Acknowledgements

We thank Erin Stevens for her valuable feedback and assistance in editing this manuscript and Natasha Benfer, Danielle DeLoach, Darian Crowley, Bailey Hall, Travis Rogers, and Tyler Toledo for assistance with data collection.

Abstract

In the present study, we examined constructs of emotion regulation (emotion regulation difficulties, expressive suppression, and cognitive reappraisal) in relation to attentional bias to threat (ABT). Participants (*N* = 176) completed a battery of self-report measures and an eye-tracking task in which eye movements to neutral and threat images were recorded. Dwell time on threat was examined across six 500 ms intervals for each trial. We also examined pupillary response as a measure of emotional arousal. When accounting for cognitive reappraisal and emotion regulation difficulties, expressive suppression significantly predicted both ABT (from 1,500-3,000ms) and pupillary response to threat. However, the effect of expression suppression on ABT was significant only at lower levels of cognitive reappraisal. Emotion regulation difficulties did not significantly predict ABT or pupillary response. Findings suggest that those who use expressive suppression to the exclusion of other regulatory strategies may be at particularly high risk for ABT and relatively higher levels of threat-related emotional arousal. Clinical implications, as well as results of an exploratory analysis examining dimensions of emotion regulation difficulties as they relate to ABT and pupillary response, will be discussed.

Keywords: eye-tracking, attentional bias, suppression, reappraisal, emotion regulation, pupil, arousal

An Eye-Tracking Examination of Emotion Regulation,

Attentional Bias, and Pupillary Response to Threat Stimuli

Preferential processing of threat information (i.e., attentional bias to threat [ABT]) is linked to host of maladaptive psychological outcomes, especially anxiety-related pathology (e.g., social anxiety [Lee & Telch, 2008]; posttraumatic stress [Bardeen, Tull, Daniel, Evenden, & Stevens, 2016]; panic [McNally, Riemann, & Kim, 1990]). Although monitoring the environment to accurately identify threat is important for survival, difficulty disengaging from stimuli that do not pose an immediate objective threat may (a) have detrimental effects on one's ability to cope with the rigors of daily living, and (b) serve to maintain emotional distress. For example, Ellenbogen, Schwartzman, Stewart, and Walker (2006) found that relatively slower attentional disengagement from negatively-valenced images (i.e., International Affective Picture System [IAPS]; Lang, Bradley, & Cuthbert, 1999) predicted increased maintenance of negative mood following a laboratory stressor. Similarly, shifting attention from neutral to happy faces following negative mood induction results in increased positive mood (Sanchez, Vazquez, Gomez, & Joormann, 2014), whereas maintaining attention on sad faces following negative mood induction results in prolonged negative mood (Sanchez, Vazquez, Marker, LeMoult, & Joormann, 2013). Moreover, some evidence suggests that relative deficits in attentional disengagement, measured broadly (i.e., to neutral stimuli), may serve to maintain negative mood following negative mood inductions (e.g., Compton, 2000).

Despite theory suggesting a link between ABT and emotion dysregulation, there is relatively little direct empirical evidence demonstrating that these constructs are related. Lack of consensus regarding the definition of “emotion regulation” may, to some extent, account for the paucity of evidence directly linking ABT and emotion regulation difficulties. Although a number of models of emotion regulation have been posited, two conceptual models have received the large majority of focus in the extant literature (i.e., Gratz & Roemer, 2004; Gross, 1998). According to Gratz and Roemer (2004), emotion regulation is the ability to monitor, evaluate, and alter emotional experience in the service of one's goals. Multiple related, but distinct, domains of emotion regulation are articulated in Gratz and Roemer's (2004) conceptualization, including accurate identification and understanding of emotions, acceptance of negative emotions, ability to effectively regulate emotions, control of impulses, and engagement in goal-directed behavior when experiencing negative emotions. Gratz and Roemer (2004) developed the Difficulties in Emotion Regulation Scale (DERS) to provide a global measure of emotion regulation difficulties, as well as to assess difficulties in each of the lower-order domains described above.

To our knowledge, no published studies have examined direct associations between ABT and emotion regulation difficulties (i.e., DERS). However, there is some evidence of a link between threat-specific attention dysregulation and emotion regulation difficulties. Bardeen, Daniel, Hinnant, and Orcutt (2017) examined attention bias variability (i.e., variability in attentional focus, both toward and away from threat stimuli), measured via response times on a dot-probe task, in relation to the DERS in a sample of undergraduate participants (N = 200). Task stimuli consisted of standardized neutral and threat images that appeared side by side on a computer monitor. Bardeen et al. (2017) found that higher emotion regulation difficulties (i.e., higher DERS-Total score) were associated with greater variability in responding that was specific to the presence of threat stimuli; emotion regulation difficulties were not associated with response time variability on trials for which only neutral stimuli were presented. While this study provides evidence of a link between emotion dysregulation and threat-related attention dysregulation, it does not allow us to determine whether emotion regulation difficulties are associated with the preferential processing of threat information (i.e., ABT). If emotion regulation difficulties are found to be related to ABT, future research in this area could further clarify the hypothesized association by examining ABT in relation to specific domains of emotion regulation difficulties. Additionally, Bardeen et al. (2017) suggested using eye-tracking equipment in future research to provide a more precise and direct measure of attention allocation that is less susceptible to alternate explanations than indirect measures that use response times and are prone to poor reliability (Schmukle, 2005).

Gross's (1998) process model of emotion regulation has also received considerable attention in the extant literature. According to Gross (1998), "emotion regulation refers to the process by which individuals influence which emotions they have, when they have them, and how they experience and express these emotions" (p. 275). Gross (1998) asserts that emotions can be regulated during the emotion generative process at any of the following five stages: situation selection, situation modification, attentional deployment, cognitive change, and response modulation. Despite Gross's (1998) comprehensive conceptualization of emotion regulation, two specific emotion regulation strategies (i.e., expressive suppression, cognitive reappraisal) have received the large bulk of attention. Expressive suppression is defined as inhibiting emotion-expressive behavior, whereas cognitive reappraisal refers to efforts to alter one's interpretation of emotion-eliciting events to change their emotional impact (John & Gross, 2004).

In Gross's model (1998), the ability to flexibly control attention is essential for maintaining psychological well-being. Importantly, flexible control suggests a willingness to experience fluctuations in emotional states that rigid attempts at control do not. For example, the habitual use of suppression to regulate emotional distress, to the exclusion of other strategies, is associated with a host of maladaptive outcomes (see Aldao, Nolen-Hoeksema, & Schweizer, 2010). This makes sense in the context of ABT because of the paradoxical nature of suppression. As described by Wenzlaff and Wegner (2000), attempts to distract oneself from features of the environment (e.g., threat stimuli), or thought content, requires monitoring in such a way as to constantly return one's attention to that which is to be avoided. As such, individuals who habitually use suppression as a regulatory strategy may exhibit high levels of ABT. In contrast, those who are less apt to use suppression, which requires continual threat monitoring, may be less likely to attend to threat stimuli once they have reached an initial determination that they are in no immediate danger.

Although research examining associations among ABT and habitual expressive suppression and cognitive reappraisal is lacking, a number of studies have been conducted in which participants have been instructed to use specific emotion regulation strategies while attention to arousing and/or negatively-valenced stimuli has been measured. For example, following a disgust induction procedure, Vogt and De Houwer (2014) instructed participants ($N = 38$ undergraduate students) to either suppress or uphold (control condition) feelings of disgust in response to a dot-probe task with three types of visual stimulus pairings (disgust/neutral, disgust/clean, clean/neutral). Standard attentional bias indices were calculated using response times to probe detection. Vogt and De Houwer (2014) found that individuals in the suppression condition only directed attention away from disgust images when a "clean" image was available, but not when neutral images were paired with disgust images. They concluded that the relationship between emotion suppression and ABT might depend on whether or not suitable distracters are available. A number of limitations should be considered, including a small sample size with small effects, use of a response time aggregation method that has been shown to have notoriously poor reliability (see Zvielli, Bernstein, & Koster, 2015), and, based on participant report, a lack of consistency regarding the regulatory technique that was used (e.g., focused distraction, attention directed inward versus outward, etc.).

Eye-tracking technology has been used to address methodological concerns regarding the use of indirect measures of ABT in this line of research in two studies in which participants were provided with specific instructions meant to up- or down-regulate their emotional experience. Manera, Samson, Pehrs, Lee, and Gross (2014) instructed participants (*N* = 64 undergraduate students) to either up-regulate ("think about the person in the video as someone you know very well, and you are close to"), down-regulate ("think of the person in the video as a complete stranger or as someone you do not care about"), or attend naturally to 18, 12-second film clips depicting sadness. Eye movements were tracked across the entirety of each trial and the total mean fixation duration spent attending to the "emotional regions" of the film clips was calculated. Participants in the down-regulation condition spent less time, and participants in the up-regulation condition spent more time, focusing on the emotional regions of the film clips. Greater attention to emotional regions of the film clips was associated with increased negative affect. The authors concluded that attentional engagement and disengagement could be used to intentionally up- or down-regulate negative emotions.

Using a similar methodological approach, van Reekum et al. (2007) instructed participants (*N* = 29 community adults) to either attend freely (i.e., view without attempting to change affective experience), up-regulate (i.e., imagine that the situation in the picture is happening to either yourself or a loved one), or down-regulate (i.e., imagine that the situation in the picture is not real) while viewing IAPS images that were negatively-valenced and highly arousing. Participants who were instructed to down-regulate tended to direct their attention to the extremities of the images and to areas depicting the least relevant parts of the scenes. In contrast, participants instructed to up-regulate focused on the most salient features of the scenes. The authors interpreted these results as suggesting that down-regulation participants looked at more aspects of the image in an attempt to “construct a reappraisal narrative” that would reduce negative affect. It is also possible that participants who were instructed to imagine that the situation was not real, were able to down-regulate negative affect by averting their gaze from aspects of the image that were most indicative of a negative narrative. van Reekum et al. (2007) note a particularly important limitation of studies in which participants are instructed to use specific emotion regulation strategies, stating, “in studies of voluntary emotion regulation we rely on the participants performing the regulation strategies that we ask them to perform, without knowing whether and how well they perform this task. While self-report assessments of strategies adopted, thoughts related to the task, or feelings experienced while performing the task may provide the researcher with some potentially useful information, many of the processes of interest are implicit and thus opaque to conscious reports” (p. 1053). Manera et al. (2014) similarly noted that they could not confirm that participants were using intended strategies (i.e., cognitive reappraisal) rather than other regulatory strategies (e.g., distraction) during video viewing. Participants might be more inclined to use the instructed strategy at the beginning of a given task, but as the task goes on, may revert to the regulatory approach that they use most often, an approach that may be habitual, and thus, implemented with less conscious effort. As such, it may be particularly important to determine what emotion regulation strategies participants use habitually, and how the habitual use of these strategies relates to ABT.

As described, the habitual use of suppression as a regulatory strategy may be related to ABT. Because expressive suppression requires a great deal of cognitive resources to enact, it may be even more closely linked to ABT than other types of suppression strategies. Specifically, evidence suggests that, the ability to successfully suppress unwanted thoughts decreases as a function of increasing cognitive load (Nixon & Rackebrandt, 2016). With expressive suppression, one has to monitor behavior, as well as the stimuli and thought content related to the physical expression(s) of concern, thus resulting in relatively high cognitive load. Moreover, expressive suppression is associated with increased amygdala activation (e.g., increased stress response) as a result of attempting to inhibit dominant response tendencies to negative information (Vanderhasselt, Baeken, Van Schuerbeek, Luypaertd, & De Raedt, 2013). Cognitive reappraisal, on the other hand, appears to be inversely related to ABT (e.g., Strauss, Ossenfort, & Whearty, 2016; van Reekum et al., 2007). Additionally, higher levels of cognitive reappraisal are associated with activation in the prefrontal cortex (e.g., increased cognitive control), resulting in efficient inhibition of dominant response tendencies to negative information in favor of positive information (Scult, Knodt, Swartz, Brigidi, & Hariri, 2017; Vanderhasselt et al., 2013). Taken together, these findings suggest that the habitual use of expressive suppression is associated with enhanced stress response, but not cognitive control, whereas habitual use of cognitive reappraisal is related to enhanced cognitive control which may allow one to flexibly disengage attention from threat information in favor of pursuing goal-relevant behavior.

As discussed in a number of recent publications (Chesney & Gordon, 2017; Dixon-Gordon, Aldao, & De Los Reyes, 2014; Levi-Gigi, Bonanno, Shapiro, Richter-Levin, Keri, & Sheppes, 2016), it may be particularly important to examine maladaptive outcomes in relation to emotion regulation strategy repertoire rather than simply looking at associations between specific strategies and outcome variables. For example, it is possible to exhibit high levels of both expressive suppression and cognitive reappraisal. Given that we expect cognitive reappraisal to be negatively associated, and expressive suppression to be positively associated, with ABT, we also have to consider what ABT might look like in an individual that uses both of these strategies to a high degree. Some evidence suggests that the ability to flexibly shift between strategies based on contextual demands is psychologically healthy (Sheppes, Scheibe, Suri, & Gross, 2011). Denny, Inhoff, Zerubavel, Davachi, and Ochsner (2015) found that the use of reappraisal while viewing negative images, over multiple sessions, resulted in long-term attenuation of amygdala response. As such, cognitive reappraisal may interact with expressive suppression in such a way that the strength of the relationship between expressive suppression and ABT would become weaker as cognitive reappraisal increases. That is, among individuals with high expressive suppression, those with low cognitive reappraisal abilities may be most at risk for relatively high levels of ABT, whereas those with relatively higher cognitive reappraisal abilities may not exhibit ABT.

Emotion dysregulation is a well-documented transdiagnostic vulnerability factor. However, theoretical conceptualizations and related measures are sufficiently distinct. Whereas Gross and John's (2003) Emotion Regulation Questionnaire (ERQ) assesses two specific emotion regulation strategies (expressive suppression and cognitive reappraisal), Gratz and Roemer's (2004) DERS assesses emotion regulation difficulties as both a global construct and across the domains described above. Importantly, none of the DERS subscales assess strategies per se, but instead, assess one's subjective appraisal of the degree to which one is successful in each domain (e.g., success at regulating emotion without identifying the specific strategies used in regulation). Given these differences, we sought to examine emotion dysregulation, operationalized as per these two theoretical models, in the context of ABT.

As recommended (Bardeen et al., 2017), we used eye tracking technology in the present study to provide a more precise and direct measure of attention allocation over time (i.e., up to 3,000ms). We predicted that individuals who reported higher global emotion regulation difficulties (i.e., DERS-Total score) would exhibit significantly greater ABT due to prolonged vigilance resulting in repeated return to threat stimuli (Bardeen et al., 2017). Consistent with the above rationale, we predicted that the habitual use of expressive suppression in response to distressing stimuli would paradoxically increase attention to threat. Because expressive suppression also suggests prolonged vigilance for that which is to be avoided, we predicted that this effect would be most pronounced at relatively later stages of information processing. Some evidence suggests that instructed reappraisal (not habitual; Strauss et al., 2016; van Reekum et al., 2007) is inversely related to ABT. However, two meta-analyses examining associations among a wide variety of emotion regulation strategies and psychopathology (Aldao & Nolen-Hoeksema, 2010; Seligowski, Lee, Bardeen, & Orcutt, 2015) found that strategies characterized as being less adaptive (e.g., expressive suppression) shared robust associations with psychopathology, whereas correlations between strategies characterized as being more adaptive (e.g., cognitive reappraisal) and psychopathology were small in magnitude. As such, we anticipated that, if ABT was significantly associated with cognitive reappraisal, the relation would be negative and small in magnitude. However, as described, these main effects may be qualified by an interaction between cognitive reappraisal and expressive suppression, such that the positive association between expressive suppression and ABT may become significantly stronger as cognitive reappraisal becomes weaker. Given the current lack of empirical evidence to support this interaction effect, this examination should be considered exploratory in nature.

As a secondary aim, we also examined associations between pupillary response to threat stimuli and our three constructs of emotion regulation. Although pupil reactivity has a long history of being used as an indicator of emotional arousal (e.g., Bradley, Miccoli, Escrig, & Lang, 2008; Partala, & Surakka, 2003), evidence also suggests that pupil reactivity may reflect increased cognitive demand (Granholm, Asarnow, Sarkin, & Dykes, 1996). Thus, when determining what pupillary response represents, it is important to consider the nature of the task at hand (e.g., type of stimuli and task demands; Holmqvist, Nyström, Andersson, Dewhurst, Jarodzka, & Van de Weijer, 2011). In the present study, participants were not required to perform a demanding task, make calculations, or use a specific emotion regulation strategy. Instead, changes in pupil diameter were assessed in response to fixation on IAPS images that have been standardized based on valence and arousal ratings and used successfully in many studies to produce negative affective states (e.g., Erk et al., 2003; Pretz, Totz, & Kaufman, 2010). Importantly, Bradley et al. (2008) examined pupillary response, in combination with heart rate and skin conductance to determine whether pupillary changes in response to IAPS images were mediated by parasympathetic or sympathetic activation. They found that pupillary response covaried with skin conductance and concluded that their findings strongly supported the assertion that pupillary response to arousing IAPS images reflects emotional arousal related to increased sympathetic activity. Given that these findings are specific to the same standardized image database that was used in the present study, and our free-viewing task is relatively low in cognitive demand, we view pupillary reactivity in the context of the present study as an indicator of emotional arousal first and cognitive demand second.

Given evidence that expressive suppression is associated with elevated stress response to threat stimuli (Vanderhasselt et al., 2013) and may require substantial cognitive resources to enact, we predicted that those with higher expressive suppression would exhibit significantly larger pupillary response to threat stimuli in comparison to those with relatively lower expressive suppression. Consistent with evidence that suggests that instructed reappraisal (not habitual; Strauss et al., 2016; ven Reekum et al., 2007) is related to increased pupil dilation in response to unpleasant stimuli in passive viewing conditions, we predicted that cognitive reappraisal would also be positively associated with pupillary response to threat stimuli. Finally, as suggested by Bardeen et al. (2017), we conducted an exploratory analysis examining the DERS dimensions in relation to ABT. Given the exploratory nature of this examination, no a-priori hypotheses were made.

Method

Participants

The sample consisted of 181 undergraduate students recruited from a mass testing pool at a mid-sized Southeastern U.S. university. To be eligible, participants were required to be fluent in English, between the ages of 18-64, and have no visual impairment (e.g., color-blindness, uncorrected visual impairment). For five participants, the eye-tracker failed to capture eye movements, resulting in a final sample of 176 participants (129 [73%] females). The average age of the sample was 20.4 years (*SD* = 3.5) and 91% self-identified as White, 4% as Black, 2% as Asian, 1% as American Indian or Alaska Native, and 2% endorsed “other”. Additionally, 5% of the sample reported being of Hispanic ethnicity.

Self-report Measures

Modified-Difficulties in Emotion Regulation Scale (M-DERS). The M-DERS (Bardeen, Fergus, Hannan, & Orcutt, 2016) is a 29-item revised version of Gratz and Roemer's (2004) original 36-item self-report measure (14 of the original 36 DERS items were modified). The M-DERS was modified to address psychometric limitations of the original measure (see Bardeen, Fergus, et al., 2016; Bardeen, Fergus, & Orcutt, 2012; Lee, Witte, Bardeen, Davis, & Weathers, 2016). The items of the M-DERS can be summed to create a measure of global emotion regulation difficulties. Additionally, the M-DERS assesses five dimensions of emotion regulation for which once could experience difficulties, including nonacceptance of emotional responses (Nonacceptance), difficulty engaging in goal-directed behavior (Goals), impulse control difficulties (Impulse), perceived inability to effectively regulate emotion (Strategies), and difficulties in correctly identifying and understanding emotions (Identification). Participants are asked to rate the degree to which each item (e.g., "When I'm upset, I don't pay attention to how I feel") applies to them on a 5-point scale (1 = *almost never* to 5 = *almost always*). The M-DERS has shown adequate psychometric properties, including strong intercorrelations among the five dimensions, internal consistency for the total scale and subscales, and construct validity (Bardeen, Fergus, et al., 2016). In the present study, internal consistency was adequate for scores on both the M-DERS total scale (M = 56.3 [SD = 20.5], α = .96) and the five subscales (α values ranging from .86 to .95).

Emotion Regulation Questionnaire (ERQ). The ERQ (Gross & John, 2003) is a 10-item self-report measure that assesses the habitual use of two specific emotion regulation strategies. Six items assess the habitual use of cognitive reappraisal (e.g., "I control my emotions by changing the way I think about the situation I'm in") and four items assess the habitual use of expressive suppression (e.g., "When I feel negative emotions, I make sure not to express them").

Participants are asked to rate the degree to which they agree with each item on a 7-point scale (1 = *strongly disagree* to 7 = *strongly agree*). The ERQ has shown adequate psychometric properties in prior research (Gross & John, 2003), including sharing medium to large correlations with the DERS (Ehring & Quack, 2010). In the present study, internal consistency for both scales was adequate (reappraisal M = 29.7 [SD = 6.3], α = .85, and suppression M = 14.1 [SD = 5.2], α = .78).

Equipment

Participants completed self-report measures and the eye-tracking task on a Hewlett Packard Z230 desktop computer with a 24-inch BenQ XL2430 monitor. A computer keyboard was used to respond to questionnaires and the eye tracking task. Qualtrics (http://www.qualtrics.com/) was used to present self-report measures. Participants' eye movements were recorded using a Tobii X2-60 Eye Tracker. The visible portion of the eye tracker consists of a 10" long by 1" high by 1" wide black bar that is mounted to the bottom of the computer screen. Eye movement recording and stimulus presentation were controlled by Tobii Pro Studio and E-prime 2.0 software in combination with E-Prime Extensions for Tobii (Psychology Software Tools, Pittsburgh, PA). During tracking, the X2-60 uses infrared diodes to generate reflection patterns on the corneas of the participant's eyes. The X2-60 provides measures of gaze point coordinates, pupil size, and distance from the tracker every 16.7ms (60 HZ). Tobii Pro Studio offers the use of algorithm filters that take into account factors (e.g., distance of eye from the tracker) that can result in data distortions if not corrected. We used the I-VT fixation filter with standard settings, as this specific filter provides highly accurate fixation classifications for commonly used eye-tracking paradigms, such as our free-viewing task. In addition, we enabled the gap fill-in function which reduces data loss by using linear interpolation to fill gaps in gaze points that are less than 75ms in length. Tobii Studios uses 75ms as the cut point to ensure that longer gaps (e.g., 100ms and greater) that are more typical of blinking or looking away are not filled, but instead, are recorded as missing data. Tobii Studios software also uses an algorithm to compensate for corneal magnification effects and gaze angle changes as well as for distance of the eye from the tracker to ensure accurate measurement of pupil diameter. Missing gaze points due to blinking, temporarily looking away from the screen, or any other measurement error, were discarded. After discarding missing gaze points, 84.35% of observations were able to be used in data aggregation.

Eye-Tracking Task

Pictorial stimuli (IAPS; Lang et al., 1999) were used rather than word stimuli because they require less semantic processing (Pineles, Shipherd, Mostoufi, Abramovitz, & Yovel, 2009) and are resistant to familiarity related to frequency of use (Bradley et al., 1997). The set of images used in the present study included 40 threat (e.g., snake, man with knife) and 80 neutral images (e.g., umbrella, mushroom caps) and has been used in previous research (Bardeen, 2015; Bardeen, Tull et al., 2016). These images were identified as either general threat or neutral based on ratings of valence and arousal. General threat images had negative valence ($M = 2.17$) and high arousal ($M = 6.52$). Neutral images had neither negative nor positive valence ($M = 5.12$) and low arousal ($M = 2.96$; IAPS; Lang et al., 1999).

The eye tracking procedure started with a calibration/validation sequence in which each participant followed a dot, with their eyes, presented randomly at nine different locations on the screen. Following calibration of the eye tracking equipment, participants were presented with a standard set of instructions. To ensure central fixation at the beginning of each trial, participants were directed to respond to a fixation target at the beginning of each trial (either an “X” or an

"O") by pressing the corresponding keyboard button (Armstrong, Olatunji, Sarawgi, & Simmons, 2010). Next, two images appeared side-by-side on the screen (i.e., threat-neutral or neutral-neutral) for 3,000ms (Armstrong, Blisky, Zhao, & Olatunji, 2013). Neutral-neutral presentations were included to reduce threat expectancy. Participants completed five practice trials with a research assistant (RA) available to provide corrective feedback if needed. The RA communicated with the participant though the use of a microphone in an adjacent room for the remainder of the study. Participants then completed one block of 60 trials in which eye movements were recorded for use in data analysis (20 neutral-neutral and 40 neutral-threat stimulus pairs). The initial instructions appeared on the computer screen and told participants to freely view task images as they appeared, as "the purpose of this experiment is to measure parts of your eye, such as your pupil, while you view different pictures on the computer screen" (Buckner, Maner, & Schmidt, 2010). The order of image type was randomized across participants. IAPS images subtended a visual angle of 13.3° × 12.4° and a vertical distance of 14 cm separated the centers of the two images, resulting in a visual angle of separation of 12.4° at a viewing distance of 60 cm.

Total dwell time was calculated as the percent of time attending to threat versus neutral stimuli for neutral-threat presentations (total dwell: $M = 0.57$ [$SD = .09$], $\alpha = .65$). Consistent with previous research that has examined within-trial variation in dwell time (e.g., Armstrong et al., 2013; Buckner et al., 2010), dwell time was also calculated for each 500ms epoch interval (i.e., 0-500, 501-1,000, 1,001-1,500, 1,501-2,000, 2,001-2,500, 2,501-3,000ms). Pupil diameter was sampled for the entire 3,000ms trial interval for neutral-threat pairings. Baseline pupil diameter (i.e., while viewing the pre-trial fixation target) was subtracted from (a) pupil diameter during fixation on neutral stimuli and (b) pupil diameter during fixation on threat stimuli. Our pupillary response variable was calculated by subtracting the first score from the second (pupillary response: $M = -.01$ [$SD = .07$], $\alpha = .98$; Duque, Sanchez, & Vazquez, 2014).

Procedure

At a single laboratory session, participants were led to a private room where they completed informed consent, a battery of self-report questionnaires, and an eye-tracking task. Before leaving, participants were debriefed and given credit for the psychology course of their choosing. All study procedures were approved by the University's institutional review board.

Results

Potential Covariates and Descriptive Information

Regarding variables constructed from self-report data, only eight data points that were either missing or univariate outliers (univariate outliers were treated as missing data) were estimated using the multiple imputation procedure recommended by Allison (2002) and Enders (2010). Age, sex, and race/ethnicity (assessed following the National Institute of Health's guidelines for reporting race and ethnicity) were evaluated as covariates for use in our primary analysis via examination of bivariate correlations. Race and ethnicity were collapsed into a single dummy-coded variable (coded as Hispanic and/or non-White [$n = 22$, 12.5%] versus non-Hispanic White [$n = 154$, 87.5%]). Among potential covariates, sex (0 = male, 1 = female) was associated with total dwell time across the 3,000ms stimulus presentation interval ($r = -.15$, $p = .03$). However, this effect appears to be specific to the last three 500ms epochs (from 1,500-3,000ms, ps < .05), indicating that males, compared to females, paid greater attention to threat images at this relatively later stage of information processing. Race/ethnicity and age were not significantly associated with any of the outcome variables. As such, sex served as a covariate in subsequent analyses, while age and race/ethnicity did not.

Regarding the primary variables of interest (ERQ-Expressive Suppression, ERQ-Cognitive Reappraisal, M-DERS Total, pupillary response, total dwell time), ERQ-Expressive Suppression was associated with pupillary response to threat versus neutral stimuli (r = .18, p = .02) and total dwell time across the 3,000ms stimulus presentation interval (r = .25, p <.001). In addition, total dwell time was significantly associated with pupillary response (r = .61, p <.001). ERQ-Cognitive Reappraisal and M-DERS Total were not significantly associated with pupillary response and total dwell time at the bivariate level. For the models described below, the highest variance inflation factor (VIF) was 2.8, a value well below conventional cutoffs (i.e., 10) for indicating problems with multicollinearity (Cohen, Cohen, West, & Aiken, 2003). Moreover, none of the cases exhibited undue influence on the analytic models described below (i.e., multivariate outliers defined as > 1 Cook's D*i*; Cohen et al., 2003).

Primary Analysis (M-DERS Total and ERQ Scales)

Predicting dwell across time. Mixed effects linear modeling with autoregressive variance-covariance structures was used to examine (a) our emotion-regulation related constructs and epoch interval, (b) two-way interactions between each emotion regulation construct and epoch interval, (c) a two-way interaction between ERQ-Cognitive Reappraisal and ERQ-Expressive suppression, and (d) a three-way interaction between ERQ-Cognitive Reappraisal, ERQ-Expressive Suppression, and epoch interval, as predictors of dwell time (see Table 1). In comparison to using repeated measures ANOVA, this approach allows for greater flexibility in modeling interactive time effects and more precisely accounts for within-participant variance in correlated repeated measures. Sex served as covariate in all models.[1] Independent variables were treated as fixed.

In our first model, dwell time served as our outcome variable and M-DERS Total, ERQ-Expressive Suppression, and ERQ-Cognitive Reappraisal served as our emotion-regulation related constructs of interest. From our main effects variables, only epoch interval ($p < .001$) and ERQ-Expressive Suppression ($p = .007$) significantly predicted dwell time (see Table 1). Among our interaction terms, epoch interval x ERQ-Expressive Suppression ($p = .001$) and ERQ-Cognitive Reappraisal x ERQ-Expressive Suppression ($p = .023$) significantly predicted dwell time.

The significant interaction effect between epoch interval x ERQ-Expressive Suppression was examined via conditional mixed linear modeling. Specifically, the relationship between epoch interval and dwell time was tested at both high (+1 SD) and low (-1 SD) levels of ERQ-Expressive Suppression. A positive relation between epoch interval and dwell time was significant at both high (F[5, 797.81] = 70.90, $p < .001$) and low (F[5, 798.04] = 62.98, $p < .001$) levels of ERQ-Expressive Suppression (see Figure 1). Importantly, an examination of conditional means of dwell time and 95% confidence intervals at each epoch interval by level of ERQ-Expressive Suppression (i.e., ± 1 SD) revealed that the mean difference in dwell time, based on ERQ-Expressive Suppression, was significant at three of the six epoch intervals (i.e., 1,500-2,000, 2,000-2,500, 2,500-3,000ms). Non-overlapping confidence intervals at these epoch intervals suggests that individuals with greater expression suppression exhibited significantly greater attention to threat in comparison to those with relatively lower expressive suppression at these later stages of information processing.

Because the significant interaction of ERQ-Cognitive Reappraisal x ERQ-Expressive Suppression was not influenced by time (i.e., epoch interval), we removed epoch interval from the analytic model and examined this interaction effect using regression analysis. Consistent with the original model, sex served as a covariate and M-DERS Total, ERQ-Expressive Suppression and ERQ-Cognitive Reappraisal, as well as the two-way interaction effect (ERQ-Cognitive Reappraisal x ERQ-Expressive Suppression) served as predictor variables. Total dwell time across the 3,000ms stimulus presentation interval served as the outcome variable. Of the main effects predictors for this model (R^2 = .11; *p* = .02), only ERQ-Expressive Suppression (*β* = .24, *p* =.003), but not sex (*β* = -.13, *p* =.08), ERQ-Cognitive Reappraisal (*β* = -.02, *p* =.84), or M-DERS Total (*β* = .01, *p* =.89), significantly predicted total dwell time. The interaction term (ERQ-Expressive Suppression x ERQ-Cognitive Reappraisal) significantly predicted total dwell time (*β* = -.17, *p* = .02; see Figure 2).

The significant interaction effect was further explored using simple slopes analysis (Aiken & West, 1991). Simple slopes analysis consists of constructing two simple regression equations in which the relationship between the predictor variable and the outcome variable is tested at both high (+1 SD) and low (-1 SD) levels of the moderating variable (i.e., ERQ-Cognitive Reappraisal). Simple slopes analysis revealed a significant positive association between ERQ-Expressive Suppression and total dwell time at low (*β* = .40, *p* < .001), but not high (*β* = .06, *p* = .56), levels of ERQ-Cognitive Reappraisal.

Predicting pupillary response to threat. Pupillary response served as the outcome variable in a hierarchical regression model (see Table 2). Predictor variables were consistent with those above. Specifically, except for epoch interval, all of the variables described above (i.e., sex, ERQ-Cognitive Reappraisal, ERQ-Expressive Suppression, M-DERS Total) served as predictor variables. In this model (R^2 = .05; *p* = .07), ERQ-Expressive Suppression significantly predicted pupillary response (*p* =.02). The nature of this relation was such that, as ERQ-Expressive Suppression increased, so too did pupillary response. The remaining variables did not predict pupillary response (i.e., sex [p =.13], ERQ-Cognitive Reappraisal [p =.96], M-DERS Total [p =.33], and ERQ-Cognitive Reappraisal x ERQ-Expressive Suppression [p =.96]).

Exploratory Analysis (M-DERS Subscales and ERQ Scales)

Predicting dwell across time. We conducted a more fine-grained analysis of emotion regulation difficulties in relation to dwell across time by including each of the five dimensions of emotion regulation difficulties assessed by the M-DERS in a second mixed effects linear model. As seen in Table 3, the only difference between this model and the first mixed model is that each M-DERS subscale, as well as the interaction between each subscale and epoch interval, served as predictor variables in place of M-DERS Total. Consistent with the primary model, epoch interval ($p < .001$) and ERQ-Expressive Suppression ($p = .02$) significantly predicted dwell time. In addition, M-DERS Strategies significantly predicted dwell time ($p = .03$). This effect did not change as a function of time. Among our interaction terms, epoch interval x ERQ-Expressive Suppression ($p = .006$), ERQ-Cognitive Reappraisal x ERQ-Expressive Suppression ($p = .02$), and epoch interval x M-DERS Goals ($p = .02$) interacted to predict dwell time. The nature of the interaction between epoch interval x ERQ-Expressive Suppression is consistent with Figure 1 and the nature of the interaction between ERQ-Cognitive Reappraisal x ERQ-Expressive Suppression is consistent with Figure 2.

Conditional mixed linear modeling was used to further examine the significant interaction between epoch interval x M-DERS Goals. The relationship between epoch interval and dwell time was tested at both high (+1 SD) and low (-1 SD) levels of M-DERS Goals. A positive relation between epoch interval and dwell time was significant at both high (F[5, 779.13] = 62.81, $p < .001$) and low (F[5, 779.31] = 38.63, $p < .001$) levels of M-DERS Goals. However, an examination of conditional means of dwell time and 95% confidence intervals at each epoch interval by level of M-DERS Goals (i.e., ± 1 SD) revealed that the mean difference in dwell time, based on M-DERS Goals, was not significant at any of the epoch intervals. Overlapping confidence intervals at all epoch intervals indicates that, even though the interaction effect is statistically significant as assessed via the *p*-value, the actual effect, as displayed in Figure 3, lacks substantive value.

Predicting pupillary response to threat. Pupillary response served as the outcome variable in a hierarchical regression model (see Table 4). Predictor variables were consistent with those in the exploratory mixed model. Specifically, except for epoch interval, all of the variables described above (i.e., sex, ERQ-Cognitive Reappraisal, ERQ-Expressive Suppression, the five M-DERS subscales) served as predictor variables. In this model (R^2 = .08; p = .08), sex (p =.16), ERQ-Cognitive Reappraisal (p =.72), ERQ-Expressive Suppression (p =.13), M-DERS Nonacceptance (p =.90), M-DERS Goals (p =.41), M-DERS Impulse (p =.65), M-DERS Strategies (p =.38), M-DERS Identification (p = .07), and ERQ-Cognitive Reappraisal x ERQ-Expressive Suppression (p = .93) did not significantly predict pupillary response.

Discussion

Recently, there has been a groundswell of support for identifying the biobehavioral processes underlying transdiagnostic vulnerability factors for psychopathology. In support of this goal, the purpose of the present study was to examine constructs of emotion dysregulation, based on two widely used models of emotion regulation, in relation to threat-related (a) attentional bias and (b) sympathetic nervous system arousal. Of our constructs of emotion dysregulation, the most robust effects were observed for expressive suppression. When accounting for cognitive reappraisal and emotion regulation difficulties, expressive suppression was significantly associated with both ABT and pupillary response to threat. This effect appears to be due to sustained attention, rather than faster orienting, toward threat among those with higher levels of habitual expressive suppression. The significant association between expressive suppression and ABT was stronger among those with relatively lower levels of cognitive reappraisal.

Those who reported higher habitual expressive suppression exhibited greater pupil dilation to threat versus neutral stimuli. This finding is consistent with experimental research showing that participants instructed to suppress emotional behavior, compared to those given no regulatory instructions, exhibit significantly greater sympathetic nervous system reactivity in response to watching negatively-valenced film clips (e.g., skin conductance, respiratory and cardiovascular activation; Gross & Levenson, 1993; 1997). Heightened sympathetic activation, in and of itself, is associated with decrements in sensory processing and sensorimotor integration and deficits in attention regulation (Lacey & Lacey, 1980). These decrements, in combination with the propensity to use expressive suppression as a regulatory strategy, may result in particularly high levels of attention to threat. That is, sympathetic activation may decrease one's ability to (a) effectively disengage and shift attention from threat stimuli, and (b) choose a more effective regulatory strategy, thus resulting in the tendency to use that which has become automatic through habitual use (e.g., expressive suppression). A tendency toward expressive suppression, rather than other more adaptive emotion regulation strategies, is likely to further exacerbate disengagement difficulties. As described, attempts to suppress behavioral indicators of emotional distress requires monitoring in such a way as to constantly turn one's attention to that which is producing the behaviors and associated stimuli of concern, thus maintaining attentional engagement with threat, heightened physiological arousal, and subsequent emotional distress (Wenzlaff & Wegner, 2000).

Importantly, the effect of expressive suppression on ABT (i.e., total dwell time) was only significant at lower levels of cognitive reappraisal. This effect was medium to large in size, suggesting that those who use expressive suppression to the exclusion of other regulatory strategies may be at particularly high risk for ABT and associated maladaptive outcomes. This finding is consistent with research suggesting that it is important to consider one's emotion regulation strategy repertoire rather than focusing solely on basic associations between strategies and outcomes (Chesney & Gordon, 2017; Dixon-Gordon et al., 2014; Levi-Gigi et al., 2016; Sheppes et al., 2011). As described by Cisler and Koster (2010), the use of suppression in the context of distressing stimuli may be adaptive, but not when used chronically and inflexibly. Our findings suggest that the use of cognitive reappraisal may allow those who tend to use expressive suppression as a regulatory strategy to flexibly disengage attention from threat information, thus increasing one's ability to attend to goal-relevant pursuits.

Global emotion regulation difficulties (i.e., M-DERS Total score) did not predict ABT. On the surface, this finding appears to contradict those of Bardeen et al. (2017) who found that higher emotion regulation difficulties (i.e., DERS-Total score) were associated with greater attention bias variability. However, a number of caveats may help to make sense of this surface discrepancy. First, whereas eye-tracking technology was used in the present study to assess overt ABT over the course of 3,000ms, Bardeen et al. (2017) used a stimulus-response paradigm (i.e., dot-probe) to assess covert attention bias variability across four presentation durations (15, 85, 150, and 500ms). This suggests the possibility that global emotion regulation difficulties may be associated with a form of threat-related attention dysregulation best represented by rapid continual shifts between vigilance and avoidance. In contrast, the present results suggest that people are generally prone to attend to threat stimuli in earlier stages of information processing (i.e., 0-1,000ms), but those with relatively higher expressive suppression and lower cognitive reappraisal appear to exhibit a pattern of attention maintenance in which they continue to attend to threat to a higher degree than those with lower expressive suppression who shift from threat to neutral stimuli. The use of tasks in future research that allow for the simultaneous assessment of threat-related attention bias variability and overt ABT (e.g., Amir, Zvielli, & Bernstein, 2016) may help to further clarify the nature of threat-related attentional processing in the context of emotion regulation.

Also of note, the effects observed by Bardeen et al. (2017) were small in magnitude and emotion regulation strategies (e.g., expressive suppression and cognitive reappraisal) were not accounted for. Accounting for specific strategies in multivariate analyses may attenuate the associations observed by Bardeen et al. (2017). However, it may also be the case that specific DERS subscales were driving the associations between the DERS-Total score and indices of ABT observed by Bardeen et al. (2017), especially given the small magnitude of the effects. This hypothesis is supported by the results of the present study in which two dimensions of emotion regulation difficulties (i.e., M-DERS Nonacceptance, M-DERS Identification) were positively associated with at least one of the dwell time epochs at the bivariate level. However, after accounting for cognitive reappraisal and expressive suppression, the only subscale of the M-DERS to significantly predict dwell time was M-DERS Strategies. As perceived ability to effectively regulate emotional distress decreased, attentional bias to threat increased, whereas those who were more confident in their ability to regulate negative emotions spent less time attending to threat.

The present results highlight the distinctiveness of the constructs assessed by the ERQ and M-DERS. Whereas the M-DERS assesses five dimensions of emotion regulation difficulties, which may impact emotional experience, expression, reactivity, etc., none of the five dimensions assess specific strategies that may be used to influence emotional experience. In contrast, the ERQ assesses two specific emotion regulation strategies. The distinct pattern of relations of the scales of the M-DERS and ERQ with ABT and pupillary reactivity speak to the importance of clearly defining what exactly one is trying to assess with these measures, rather than using any one measure as a measure of "emotion regulation." This is especially important given the countless number of cognitive and behavioral techniques that can be used to regulate emotional experience and expression.

The present study is not without limitations; foremost among these might be our use of a sample of unselected undergraduate students. Given that emotion dysregulation is often examined in relation to psychopathology, it will be important to ensure that the results of the present study generalize to clinical samples and across forms of pathology. As mentioned, our cross-sectional study design precludes causal inferences regarding the nature of relations among study variables. In contrast to conceptualizations of ABT that presuppose automaticity of threat processing, some have suggested a bidirectional relationship between emotion regulation and the cognitive mechanisms associated with biased information processing (Hoorelbeke, Marchetti, De Schryver, & Koster, 2016). It will be important in future research to use longitudinal and experimental methods to clarify the temporal nature of these relations, as well as to make inferences regarding causality. Given the paucity of empirical research examining associations among constructs of emotion dysregulation and ABT, we believe that the assessment of two specific emotion regulation strategies in relation to ABT and pupillary reactivity meaningfully contributes to the extant literature. However, as noted, there are a host of other well documented emotion regulation strategies that should be examined in relation to ABT in future research to further improve our understanding of the degree to which ABT may be more or less important to specific types of strategies. Moreover, although evidence that pupillary response to IAPS images is indicative of emotional arousal (Bradley et al., 2008), and our free-viewing task required relatively little cognitive effort, we cannot rule out the possibility that changes in pupil diameter in the present study reflected increased cognitive load. As discussed, suppression efforts can be extremely cognitively taxing, and as such, the expressive suppression-pupillary response relationship observed in the present study may be related to increases in both emotional arousal and cognitive demand. It will be important in future research to combine eye tracking with additional measures of autonomic nervous activity (e.g., skin conductance, heart rate) to ensure that that the observed effect is specific to emotional arousal. Finally, the risk of Type I error may be higher due to the large number of predictors in our analytic models. Therefore, findings that are less robust (e.g., the ERQ-Cognitive Reappraisal x ERQ-Expressive Suppression interaction) should be considered preliminary until replicated.

The present study is the first to our knowledge to simultaneously examine emotion regulation difficulties, expressive suppression, and cognitive reappraisal in the context of ABT. These findings suggest a link between the habitual use of expressive suppression to regulate emotional distress and ABT. Furthermore, they highlight the need to think about emotion regulation flexibility when considering associations among strategies and ABT. Specifically, study findings are in line with theoretical accounts and some recent empirical evidence that suggests that effective emotion regulation may be contingent on being able to use a variety of emotion regulation strategies in a flexible manner, based on contextual demands. As such, individuals who have a tendency toward expressive suppression may benefit from emotion regulation skills training, with an emphasis on strategy selection based on context. For example, Sheppes et al. (2011) found that cognitive reappraisal may be used effectively in low-intensity emotional situations, whereas distraction may be better suited for use in high-intensity emotional situations. Thus, development of a skills training package that includes training in the use of a variety of strategies, with an emphasis on flexibly shifting between strategies based on the demands of a given situation, may decrease the likelihood that one will experience ABT and subsequent negative outcomes.

References

Aiken, L. S., & West, S. G. (1991). Multiple Regression: Testing and interpreting interactions. Newbury Park, CA: Sage.

Aldao, A., Nolen-Hoeksema, S., & Schweizer, S. (2010). Emotion-regulation strategies across psychopathology: A meta-analytic review. *Clinical Psychology Review, 30,* 217–237.

Allison, P. D. (2002). *Missing data.* Thousand Oaks. CA: Sage.

Amir, I., Zvielli, A., & Bernstein, A. (2016). (De)coupling of our eye and our minds eye: A dynamic process perspective on attentional bias. Emotion, 16, 978-986.

Armstrong, T., Blisky, S. A., Zhao, M., & Olatunji, B. O. (2013). Dwelling on potential threat cues: An eye movement marker for combat-related PTSD. *Depression and Anxiety, 30,* 497-502.

Armstrong, T., Olatunji, B. O., Sarawgi, S., & Simmons, C. (2010). Orienting and maintenance of gaze in contamination fear: biases for disgust and fear cues. *Behavior Research and Therapy,* 48, 402–408.

Bardeen, J. R. (2015). Short-term pain for long-term gain: The role of experiential avoidance in the relation between anxiety sensitivity and emotional distress. *Journal of Anxiety Disorders, 30*, 113-119.

Bardeen, J. R., Daniel, T. A., Hinnant, J. B., & Orcutt, H. K. (2017). Emotion dysregulation and threat-related attention bias variability. *Motivation & Emotion*, *41,* 402-409.

Bardeen, J. R., Fergus, T. A., Hannan, S. M., & Orcutt, H. K. (2016). Addressing psychometric limitations of the Difficulties in Emotion Regulation Scale through item modification. *Journal of Personality Assessment, 98,* 298-309.

Bardeen, J. R., Fergus, T. A., & Orcutt, H. K. (2012). An examination of the latent structure of the Difficulties in Emotion Regulation Scale. *Journal of Psychopathology and Behavioral Assessment, 34,* 382-392.

Bardeen, J. R., Tull, M. T., Daniel, T. A., Evenden, J., & Stevens, E. N. (2016). A preliminary investigation of the time course of attention bias variability in posttraumatic stress disorder: The moderating role of attentional control. *Behaviour Change, 33,* 94-111.

Bradley, M. M., Miccoli, L., Escrig, M. A., & Lang, P. J. (2008). The pupil as a measure of emotional arousal and autonomic activation. *Psychophysiology, 45,* 602-607.

Bradley, B. P., Mogg, K., Millar, N., Bonham-Carter, C., Fergusson, E., … & Parr, M. (1997). Attentional biases for emotional faces. *Cognition and Emotion, 11,* 25-42.

Buckner, J. D., Maner, J. K., & Schmidt, N. B. (2010). Difficulty disengaging attention from social threat in social anxiety. *Cognitive Therapy and Research, 34,* 99–105.

Catanzaro, S. J., & Greenwood, G. (1994). Expectancies for negative mood regulation, coping, and dysphoria among college students. *Journal of Counseling Psychology, 41*, 34-44.

Cisler, J. M., & Koster, E. H. W. (2010). Mechanisms of attentional biases towards threat in in anxiety disorders. *Clinical Psychology Review, 30,* 203-216.

Chesney, S. A., & Gordon, N. S. (2017). Profiles of emotion regulation: Understanding regulatory patterns and the implications for posttraumatic stress. *Cognition and Emotion, 31,* 598-606.

Cohen, J., Cohen, P., West, S. G., & Aiken, L. A. (2003). *Applied multiple regression/correlation analysis for the behavioral sciences* (3rd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Compton, J. R. (2000). Ability to disengage attention predicts negative affect. *Cognition and*

Emotion, 14, 401-415.

Denny, B. T., Inhoff, M. C., Zerubavel, N., Davachi, L., & Ochsner, K. N. (2015). Getting over it: Long-lasting effects of emotion regulation on amygdala response. *Psychological Science, 26*, 1377-1388.

Dixon-Gordon, K. L., Aldao, A., & De Los Reyes, A. (2014). Repertoires of emotion regulation: A person-centered approach to assessing emotion regulation strategies and links to psychopathology. *Cognition and Emotion*, *29*, 1314–1325.

Duque, A., Sanchez, A., & Vazquez, C. (2014). Gaze-fixation and pupil dilation in the processing of emotional faces: The role of rumination. *Cognition and Emotion, 28,* 1347-1366.

Ehring, T., & Quack, D. (2010). Emotion regulation difficulties in trauma survivors: The role of trauma type and PTSD symptom severity. *Behavior Therapy*, *41*, 587-598.

Ellenbogen, M. A., Schwartzman, A. E., Stewart, J., Walker, C. D. (2006). Automatic and effortful emotional information processing regulates different aspects of the stress response. *Psychoneuroendocrinology, 31,* 373-387.

Enders, C. K. (2010). *Applied Missing Data Analysis*. New York: Guilford Press.

Erk, S., Kiefer, M., Grothe, J., Wunderlich, A. P., Spitzer, M., & Walter, H. (2003). Emotional context modulates subsequent memory effect. *NeuroImage*, *18*, 439–447.

Granholm, E., Asarnow, R. F., Sarkin, A. J., Dykes, K. L. (1996). Pupillary responses index cognitive resource limitations. *Psychophysiology, 33,* 457–461.

Gratz, K. L. & Roemer, L. (2004). Multidimensional assessment of emotion regulation and dysregulation: Development, factor structure, and initial validation of the Difficulties in Emotion Regulation Scale. *Journal of Psychopathology and Behavioral Assessment, 26,* 41-54.

Gross, J. J. (1998). The emerging field of emotion regulation: An integrative review. *Review of General Psychology, 2*, 271-299.

Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology, 85*, 348–362.

Gross, J. J., & Levenson, R. W. (1993). Emotional suppression: Physiology, self–report, and expressive behavior. *Journal of Personality and Social Psychology, 64*, 970–986.

Gross, J. J., & Levenson, R. W. (1997). Hiding feelings: The acute effects of inhibiting positive and negative emotions. *Journal of Abnormal Psychology, 106,* 95–103.

Holmqvist, K., Nyström, N., Andersson, R., Dewhurst, R., Jarodzka, H., & Van de Weijer, J. (Eds.) (2011). *Eye tracking: a comprehensive guide to methods and measures,* Oxford, UK: Oxford University Press.

Hoorelbeke, K., Marchetti, I., De Schryver, M., & Koster, E. H. W. (2016). The interplay between cognitive risk and resilience factors in remitted depression: A network analysis. *Journal of Affective Disorders, 195,* 96-104.

John, O. P., & Gross, J. J. (2004). Healthy and unhealthy emotion regulation: Personality processes, individual differences, and life span development. *Journal of Personality, 72,* 1301–1334.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1999). International affective picture system (IAPS): Technical Manual and Affective Ratings. Gainesville, FL: The Center for Research in Psychophysiology, University of Florida.

Lacey, J. I., & Lacey, B. C. (1980). The specific role of heart rate in sensorimotor integration. In R. F. Thompson, L. H. Hicks, & V. B. Shvyrkov (Eds.), Neural mechanisms of goal-directed behavior. New York: Academic Press.

Lee, H. J., & Telch, M. J. (2008). Attentional biases in social anxiety: an investigation using the inattentional blindness paradigm. *Behaviour Research and Therapy, 46*, 819-835.

Lee, D. J., Witte, T. K., Bardeen, J. R., Davis, M. T., & Weathers, F. W. (2016). A factor analytic evaluation of the Difficulties in Emotion Regulation Scale. *Journal of Clinical Psychology, 72,* 933-946.

Levy-Gigi, E., Bonanno, G. A., Shapiro, A.R., Richter-Levin, G., Keri, S., & Sheppes, G. (2016). Emotion regulatory flexibility sheds light on the elusive relationship between repeated traumatic exposure and posttraumatic stress disorder symptoms. *Clinical Psychological Science, 4,* 28-39.

Manera, V., Samson, A. C., Pehrs, C., Lee, I. A., & Gross, J. J. (2014). The eyes have it: The role of attention in cognitive reappraisal of social stimuli. *Emotion, 14,* 833–839.

McNally, R. J., Riemann, B. C., & Kim, E. (1990). Selective processing of threat cues in panic disorder. *Behaviour Research and Therapy, 28,* 407-412.

Nixon, R.D., & Rackebrandt, J. (2016). Cognitive load undermines thought suppression in acute stress disorder. *Behavior Therapy, 47,* 388-403.

Partala, T., & Surakka, V. (2003). Pupil size variation as an indication of affective processing. *International Journal of Human-Computer Studies, 59,* 185-198.

Pineles, S. L., Shipherd, J. C., Mostoufi, S. M., Abramovitz, S. M., & Yovel, I. (2009). Attentional biases in PTSD: More evidence for interference. *Behaviour Research and Therapy, 47,* 1050-1057.

Pretz, J. E., Totz, K. S., & Kaufman, S. B. (2010). The effects of mood, cognitive style, and cognitive ability on implicit learning. *Learning and Individual Differences, 3,* 215-219.

Sanchez, A., Vazquez, C., Gomez, D., & Joormann, J. (2014). Gaze-fixation to happy faces predicts mood repair after a negative mood induction. *Emotion, 14,* 85-94.

Sanchez, A., Vazquez, C., Marker, C., LeMoult, J., & Joormann, J. (2013). Attentional disengagement predicts stress recovery in depression: An eye-tracking study. *Journal of Abnormal Psychology, 122*, 303-313.

Schmukle, S. C. (2005). Unreliability of the dot probe task. *European Journal of Personality*, *19,* 595–605.

Scult, M. A., Knodt, A. R., Swartz, J. R., Brigidi, B. D., & Hariri, A. R. (2017). Thinking and feeling: Inidividual differences in habitual emotion regulation and stress-related mood are associated with prefrontal executive control. *Clinical Psychological Science, 5,* 150-157.

Seligowski, A. V., Lee, D. J., Bardeen, J. R., & Orcutt, H. K. (2015). Emotion Regulation and Posttraumatic Stress Symptoms: A Meta-Analysis. *Cognitive Behaviour Therapy, 44,* 87-102.

Sheppes, G., Scheibe, S., Suri, G., & Gross, J. J. (2011). Emotion-regulation choice. *Psychological Science, 11*, 1391-1396.

Strauss, G. P., Ossenfort, K. L., & Whearty, K. M. (2016). Reappraisal and distraction emotion regulation strategies are associated with distinct patterns of visual attention and differing levels of cognitive demand. *PLoS ONE 11*(11): e0162290.

Vanderhasselt, M.A., Baeken, C., Van Schuerbeek, P., Luypaert, R., & De Raedt, R. (2013). Inter-individual differences in the habitual use of cognitive reappraisal and expressive suppression are associate with variations in prefrontal cognitive control for emotional information: An event related fMRI study. *Biological Psychology, 92*, 433-439.

van Reekum, C. M., Johnstone, T., Urry, H. L., Thurow, M. E., Schaefer, H. S., Alexander, A. L., & Davidson, R. J. (2007). Gaze fixations predict brain activation during the voluntary regulation of picture-induced negative affect. *NeuroImage, 36,* 1041–1055.

Vogt, J., & De Houwer, J. (2014). Emotion regulation meets emotional attention: The influence of emotion suppression on emotional attention depends on the nature of the distracters. *Emotion, 14,* 840-845.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54,* 1063-1070.

Wenzlaff, R. M. & Wegner, D. M. (2000). Thought suppression. *Annual Review of Psychology, 51,* 59-91.

Zvielli, A., Bernstein, A., & Koster, E. H. W. (2015). Temporal dynamics of attentional bias. *Clinical Psychological Science, 5,* 772-788.

Footnote

[1]To increase confidence that the observed associations between emotion regulation-related constructs and ABT and pupillary reactivity were not a function of the relations of these variables with emotional distress, or affect more generally, we repeated our primary analyses and included measures of positive and negative affect as covariates (i.e., Positive and Negative Affect Schedule: Watson, Clark, & Tellegen, 1988). Results were consistent with our initial analysis; statistically significant findings remained significant and nonsignificant findings were unchanged.

Conflict of Interest

The authors declare no conflicts of interest regarding this submission. Additionally, the results of the submitted manuscript have not been presented elsewhere.

Informed Consent

This study was approved by the Office of Research Compliance at Auburn University. All participants provided informed consent prior to the completion of any study measures.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

Table 1

Primary test of fixed effects for dwell time

	F	*df*	*p*
Sex	3.71	(1, 185.84)	.056
M-DERS-T	0.01	(1, 192.94)	.946
ERQ-CR	0.48	(1, 192.14)	.489
ERQ-ES	7.57	(1, 193.14)	.007
Epoch (Time)	136.391	(5, 791.93)	< .001
M-DERS-T x Epoch (Time)	0.48	(5, 791.81)	.789
ERQ-CR x Epoch (Time)	0.75	(5, 791.25)	.584
ERQ-ES x Epoch (Time)	4.00	(5, 792.05)	.001
ERQ-ES x ERQ-CR	5.22	(1, 191.86)	.023
ERQ-ES x ERQ-CR x Epoch (Time)	1.09	(5, 791.05)	.367

Note. *N* = 176. Sex = (0 = male, 1 = female); M-DERS-T = Modified Difficulties in Emotion Regulation Scale total score; ERQ Emotion Regulation Questionnaire (CR = Cognitive Reappraisal score, ES = Expressive Suppression score); Epoch (Time) = Dwell time on threat stimuli over six intervals (1 = 0-500, 2 = 500-1,000, 3 = 1,000-1,500, 4 = 1,500-2,000, 5 = 2,000-2,500, 6 = 2,500-3,000 ms).

Table 2

Regression analysis: Predicting pupillary response

	ΔR^2	Step 1 β	Step 2 β
Step 1	.05		
Sex		-.12	-.12
M-DERS-T		-.08	-.08
ERQ-CR		.01	.01
ERQ-ES		.18*	.18*
Step 2	.00		
ERQ-ES x ERQ-CR			-.01

Note. N = 176. Sex = (0 = male, 1 = female); M-DERS-T = Modified Difficulties in Emotion Regulation Scale total score; ERQ Emotion Regulation Questionnaire (CR = Cognitive Reappraisal score, ES = Expressive Suppression score).

* $p < .05$.

Table 3

Test of fixed effects for dwell time with DERS subscale scores as predictor variables

	F	*df*	*p*
Sex	3.05	(1, 180.48)	.082
ERQ-CR	1.62	(1, 186.56)	.205
ERQ-ES	5.15	(1, 187.70)	.024
M-DERS-N	0.89	(1, 187.58)	.346
M-DERS-G	0.68	(1, 188.33)	.412
M-DERS-Im	0.02	(1, 187.34)	.880
M-DERS-S	4.77	(1, 190.65)	.030
M-DERS-Id	0.73	(1, 188.25)	.394
Epoch (Time)	138.86	(5, 772.92)	< .001
ERQ-CR x Epoch (Time)	0.83	(5, 772.15)	.530
ERQ-ES x Epoch (Time)	3.27	(5, 773.06)	.006
M-DERS-N x Epoch (Time)	0.10	(5, 773.28)	.418
M-DERS-G x Epoch (Time)	2.83	(5, 773.44)	.015
M-DERS-Im x Epoch (Time)	1.06	(5, 772.45)	.383
M-DERS-S x Epoch (Time)	1.28	(5, 774.35)	.273
M-DERS-Id x Epoch (Time)	1.99	(5, 773.53)	.079
ERQ-ES x ERQ-CR	5.53	(1, 186.52)	.020
ERQ-ES x ERQ-CR x Epoch (Time)	1.10	(5, 772.07)	.359

Note. *N* = 176. Sex = (0 = male, 1 = female); ERQ Emotion Regulation Questionnaire (CR = Cognitive Reappraisal score, ES = Expressive Suppression score); M-DERS = Modified Difficulties in Emotion Regulation Scale (N = Nonacceptance subscale score, G = Goals subscale score, Im = Impulse subscale score, S = Strategies subscale score, Id = Identification subscale score); Epoch (Time) = Dwell time on threat stimuli over six intervals (1 = 0-500, 2 = 500-1,000, 3 = 1,000-1,500, 4 = 1,500-2,000, 5 = 2,000-2,500, 6 = 2,500-3,000 ms).

Table 4

Regression analysis with DERS subscale scores

Predicting pupillary response

	ΔR^2	Step 1 β	Step 2 β
Step 1	.08		
Sex		-.11	-.11
ERQ-CR		-.03	-.03
ERQ-ES		.13	.13
M-DERS-N		-.01	-.01
M-DERS-G		-.08	-.08
M-DERS-Im		-.05	-.06
M-DERS-S		-.11	-.11
M-DERS-Id		.20	.20
Step 2	.00		
ERQ-ES x ERQ-CR			-.01

Note. N = 176. Sex = (0 = male, 1 = female); ERQ Emotion Regulation Questionnaire (CR = Cognitive Reappraisal score, ES = Expressive Suppression score); M-DERS = Modified Difficulties in Emotion Regulation Scale (N = Nonacceptance subscale score, G = Goals subscale score, Im = Impulse subscale score, S = Strategies subscale score, Id = Identification subscale score).

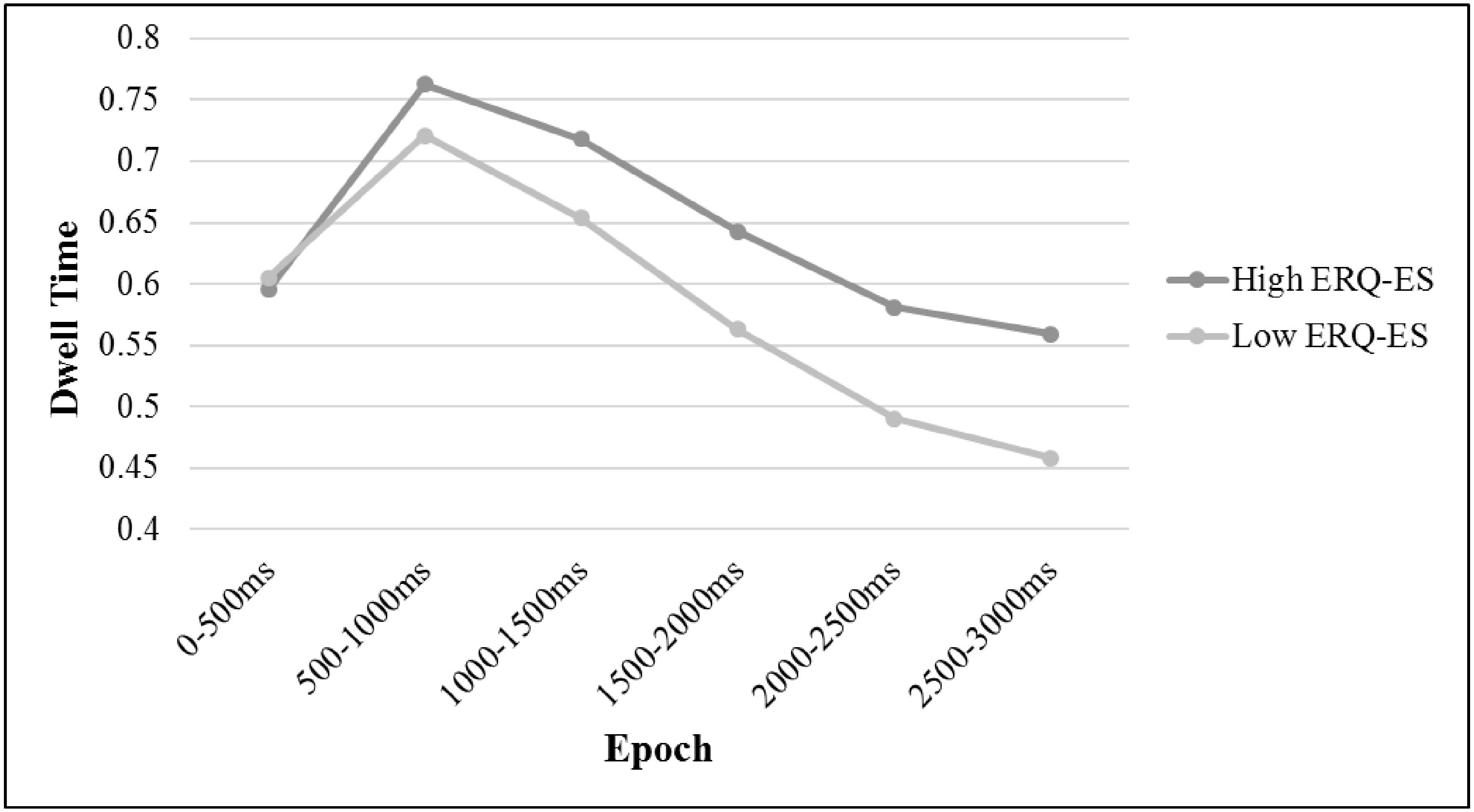

Figure 1. Conditional means of dwell time at each epoch interval plotted at ± 1 SD of ERQ-Expressive Suppression.

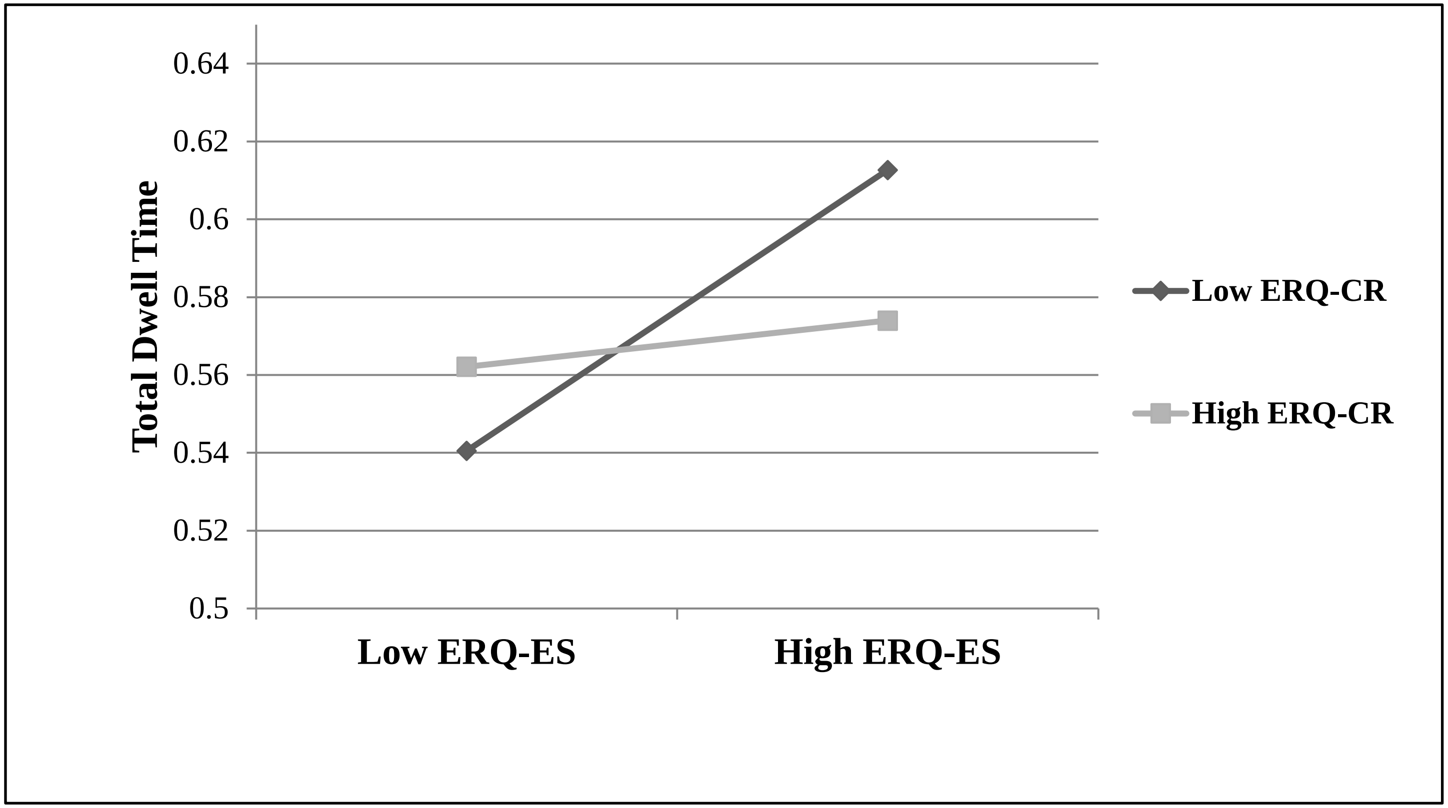

Figure 2. The relation between ERQ-Expressive Suppression and total dwell time plotted at ± 1 SD of ERQ-Cognitive Reappraisal.

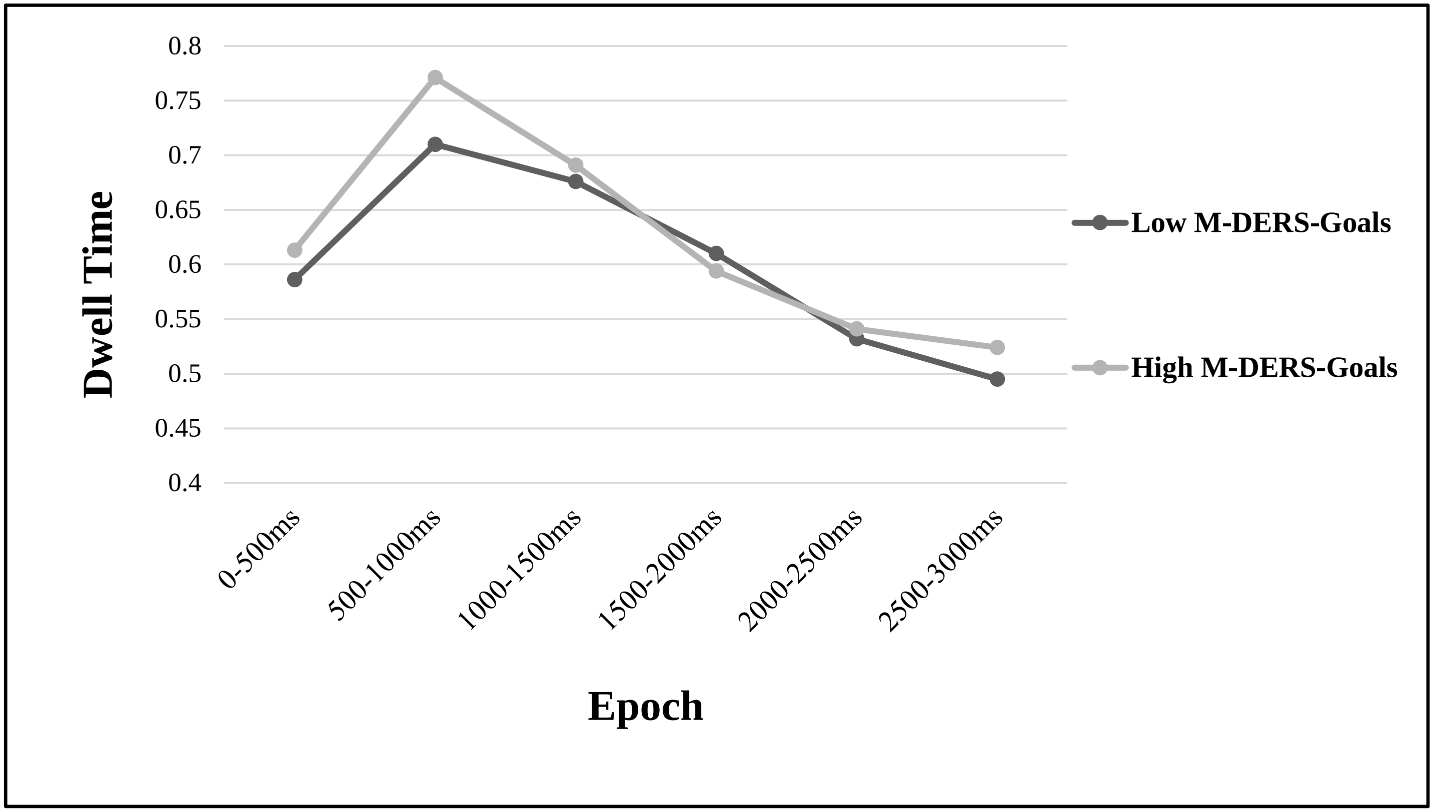

Figure 3. Conditional means of dwell time at each epoch interval plotted at ± 1 SD of M-DERS-Goals.