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ARTICLE

The role of physiological and subjective measures of emotion regulation in predicting adolescent wellbeing

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Abstract: Emotion regulation (ER) is a key contributor to psychosocial adjustment in adolescence, while ER deficits contribute to psychological distress and dysfunction. To date, research with adolescents has examined a limited subset of ER processes, often in relation to mental ill-health. This study examined associations between multiple ER measures and wellbeing in a normative sample of 119 adolescents (Mage = 15.73). ER was measured using self-report and physiological (RSA) indices. Multiple measures of positive and negative functioning were examined. After controlling for covariates, hierarchical regression analyses revealed that self-reported ER predicted resilience, perseverance, connectedness, and happiness; and fewer depression and anxiety symptoms. Higher tonic RSA predicted resilience and perseverance. Effect sizes were small to moderate. Theoretical and practical implications are discussed.

Keywords: adolescence, emotion regulation, respiratory sinus arrhythmia, mental health, positive youth development, resilience, wellbeing

1. Introduction

Adolescence is a period marked by vast emotional change, and the capacity for adaptive emotion regulation (ER) contributes to the successful transition into adulthood (Silk, Steinberg, & Morris, 2003). During adolescence, the capacity to successfully regulate emotional experiences facilitates the building and maintenance of social relationships (Halligan et al., 2013), bolsters positive affect (Tugade & Fredrickson, 2007), and promotes academic achievement (Ivcevic & Brackett, 2014). Conversely, the absence of adaptive ER skills and the development of maladaptive ER strategies contribute to psychological distress and dysfunction (see meta-analytic reviews by Aldao, Nolen-Hoeksema, and Schweizer; Graziano & Derefinko, 2013). ER can, therefore, be regarded as a key feature of positive youth development, and of the wellbeing spectrum more broadly (Keyes, 2005).

ER is defined as the ability to manage, modify, and respond to emotional experiences in a contextually appropriate manner (Thompson, 1994). A multidimensional construct, ER involves a variety of physiological, cognitive, and behavioral processes that emerge as particularly relevant during adolescence development (Steinberg, 2016). Mid-adolescence, for example, involves a developmental window characterized by maturational disparity between the prefrontal cortex and limbic system, leading to a period in which emotion- and reward-driven behavior dominates rational decision making (Casey, Jones, & Hare, 2008). ER is

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thought to be a prerequisite to effective impulse control, delayed gratification, and goal-directed behavior, and modulates emotion-driven urges (Davidson, Putnam, & Larson, 2000; Ochsner & Gross, 2005; Steinberg, 2016). Further, ER can buffer against the impact of early childhood experiences, biological and socio-cultural changes associated with puberty, and adverse environmental conditions on adolescent wellbeing (see Beauchaine 2015, for a review).

In contrast to the protective role of adaptive ER processes, ER disruption occurs when an individual's response to emotional arousal loses flexibility or is unresponsive to contextual demands (Cole, Martin, & Dennis, 2004). Once a dysregulatory pattern is established, it becomes maladaptive and may sustain or promote mental ill-health (Berking & Wupperman, 2012). As such, limited access to adaptive ER strategies and use of maladaptive strategies impairs wellbeing and contributes to the development of numerous forms of psychological distress and disorder (see meta-analytic reviews by Aldao et al., 2010; Graziano & Derefinko, 2013). To date, the majority of ER research with young people has focused on its relation to psychological dysfunction. This is certainly warranted, given that adolescence is a period of risk for the onset of mental distress and ill-health, and deficits of ER represent a common feature of numerous mental disorders (Aldao et al., 2010). However, emerging theory suggests that processes of ER also contribute to positive psychological functioning in adolescent (Morrish, Rickard, Chin, & Vella-Brodrick, 2018) and adult samples (Quoidbach, Mikolajczak, & Gross, 2015), and despite these investigative inroads, empirical investigation of the role of ER to a broad range of measures of positive functioning in young people remains under explored. This represents a clear gap in our current understanding and fails to acknowledge the full spectrum of mental health, which includes distinct dimensions of positive and negative functioning (Westerhof & Keyes, 2010).

1.1 Emotion regulation and adolescent wellbeing

Consistent with contemporary definitions of wellbeing as the combination of feeling good and functioning well (Huppert, 2009), wellbeing involves positive functioning across a range of biopsychosocial domains. The PERMA model (Seligman, 2011) identifies five interrelated facets, including Positive emotion, Engagement, positive Relationships, Meaning or purpose in life, and Accomplishment. In principle, the same ER processes that protect against the development of mental ill-health can also be utilized to promote positive psychological functioning, and PERMA specifically, in young people. To elaborate, adaptive ER involves harnessing one's physiological and cognitive resources in order to (i) select an appropriate strategy to influence one's affective experience and actions, and (ii) promote goal-attainment in emotionally charged situations (Gratz & Roemer, 2004). These abilities become particularly important in the face of setbacks, challenges, or competing goals (Ivcevic & Brackett, 2014). By engaging one's adaptive resources, processes of ER likely play a driving role in the realization and maintenance of psychological health (DeSteno, Gross, & Kubzansky, 2013). For example, the use of adaptive cognitive ER strategies, including reappraisal, savoring, and gratitude, have all been found to enhance positive affect, while physiological measures linked to ER capacity (i.e., respiratory sinus arrhthymia) correlate with measures of trait positive affect and greater stability of positive affect in young adult samples (Fredrickson, Tugade, Waugh, & Larkin, 2003; Koval et al., 2013; Oveis et al., 2009; Quoidbach, Berry, Hasenne, & Mikolajczak, 2010; Tugade & Fredrickson, 2007; Wang, Lü, & Qin, 2013). Furthermore, in a sample of 210 undergraduate students (mean age = 21), Gross and John (2003) found that reappraisal strategy use was positively associated six domains of wellbeing (Ryff & Keyes, 1995), including environmental mastery, autonomy, personal growth, self-acceptance, and positive relations with others, as well as measures of optimism, self-esteem, and life satisfaction. Conversely, a putatively maladaptive cognitive ER strategy, expressive suppression, was inversely related to these domains. Such findings demonstrate a link between at least two specific ER strategies and wellbeing, however, there remains a clear need to move beyond "the usual suspects" of reappraisal and suppression, and extend current knowledge by considering the relationship of a more comprehensive range of ER capabilities to positive functioning (Gratz, Weiss, & Tull, 2015).

1.2 Emotion regulation: A mixed-model approach

Given the multidimensional nature of ER, which involves both cognitive and physiological components, comprehensive assessment of its relationship to adolescent wellbeing requires a mixed-method approach (Beauchaine & Thayer, 2015), which, in addition to self-report, includes physiological measures of neural and cardiovascular processes underlying ER (DeSteno, Gross, & Kubzanski, 2013; Thayer, Åhs, Fredrikson, Sollers III, & Wager, 2012). Typically, research with adolescent samples has involved only one method of measuring ER (Adrian, Zeman, & Veits, 2011). This approach is problematic, as it limits cross-study comparisons and provides a partial understanding of the relationship of ER to mental health, and specifically, to positive aspects of psychological functioning that remain largely unexplored in mixed-method designs. Cognitive ER strategies, assessed via self-report, are most often represented in the literature and refer to the ways individuals think about their emotions to make sense of, manage, and respond appropriately to them (Garnefski, Kraaij, & Spinhoven, 2001). However, physiological indices of ER – thought to reflect an individual's capacity to engage in adaptive ER processes (Thayer et al., 2012) – are increasingly examined, and involve changes in neurocognitive and autonomic nervous system functioning associated with emotional experience and regulation.

1.3 Capturing physiological processes of emotion regulation: Respiratory sinus arrhthymia

A number of physiological indices of ER are available to psychological researchers (e.g., electroencephalogram, functional magnetic resonance imaging, cortisol assays), of which respiratory sinus arrhthymia (RSA) is the most commonly cited measure in research with adolescents (Beauchaine, 2015). RSA is a measure of beat-to-beat intervals in heart rate that occur in synchrony with respiration, which reflects changes in the balance between sympathetic and parasympathetic influences on the heart (Thayer et al., 2012). RSA provides an index of autonomic influence on prefrontal cortical activity and executive functioning, and, as such, represents a non-invasive measure of ER capacity (Thayer, Hansen, Saus-Rose, & Johnsen, 2009). More specifically, RSA is thought to represent an individual's physiological capacity to appropriately and flexibly meet environmental demands (Li et al., 2009; Rickard & Vella-Brodrick, 2014). Tonic RSA (i.e., taken at rest) is thought to represent a global measure of ER capacity, with higher values indicating a greater general aptitude for ER (Appelhans & Leucken, 2006). Lower values, conversely, are predictive of mental ill-health (Beauchaine & Thayer, 2015).

As an overall measure of regulatory capacity, tonic RSA may represent, for example, how successfully the body mobilizes cognitive and metabolic resources during times of stress (e.g., during a class presentation) and engages in restorative functions and reducing energy expenditure when environmental demands decrease (e.g., once the presentation is completed). The use of tonic RSA to assess ER capacity, in this regard, can be likened to the measurement of muscle mass as a proxy for overall body strength. Importantly, tonic RSA supports efficient cognitive ER processes, and thus contributes to effective ER above and beyond the use of ER capacities captured via self-report alone (Hildebrandt, McCall, Engen, & Singer, 2016). More specifically, RSA is thought to facilitate effective cognitive processing of emotional experiences by enhancing executive functioning and impulse inhibition (Thayer et al., 2012; Park, Van Bavel, Vasey, & Thayer, 2012). Thus, individual differences in RSA may reflect differences in the capacity to inhibit unhelpful responses to emotional stimuli and engage in more adaptive processes, which, in turn, is likely to promote differentiated and appropriately-matched responses to environmental stressors (Lang, Bradley, & Cuthbert, 1990; Thayer & Lane, 2009. Moreover, assessment of RSA can bypass the reporting biases associated with self-report and is considered an objective measure of ER capacity (Appelhans & Leucken, 2006; Walker, Pfingst, Carnevali, Sgoifo, & Nalivaiko, 2017).

In young adults, measures of RSA are found to be inversely related to self-reported ER difficulties (Williams et al., 2015) and markers of mental ill-health (Beauchaine, 2015). Notably, lower resting RSA is primarily linked to mental distress in young people diagnosed with or at high-risk of developing mental disorders (see review by Beauchaine, 2015). RSA may also protect against the detrimental effects of stress and enhance positive psychological functioning, with research of vulnerable youth finding that individuals with higher tonic RSA displayed greater resilience in the face of stress, and were rated as more popular with peers (Kim & Cicchetti, 2010). Research with adult samples has also linked higher tonic RSA to increased recovery from stress (Souza et al., 2007; Souza et al., 2013). The ability to effectively regulate emotions and inhibit unhelpful impulses also contributes to successful social functioning, and RSA has been linked to social connectedness (Geisler, Kubiak, Siewert, & Weber, 2013) in adults, in children (Patriquin, Lorenzi, Scarpa & Bell, 2014), and in adolescents with autistic spectrum disorders (Patriquin, Scarpa, Friedman, & Porges, 2013). It remains unclear, however, whether the buffering effect of higher tonic RSA against mental ill-health extends to non-clinical and community-based adolescent samples, and how RSA relates to a broader range of markers of positive psychological functioning in adolescent groups, for example, engagement, perseverance, and optimism.

1.4 The current study

The current study aimed to address the aforementioned gaps in the literature by examining the cross-sectional relationship between ER and wellbeing in a healthy adolescent sample. Both positive and negative functioning are central to understanding resilience, wellbeing, and mental health in adolescent samples (Rickard, Chin, & Vella-Brodrick, 2016). Therefore, to reflect the full spectrum of mental health (Keyes, 2005; Westerhoff & Keyes, 2010), the relationship between ER and numerous measures of positive functioning and mental distress was examined. Consistent with best-practice recommendations (Beauchaine, 2015), a multi-method approach was used to measure ER by including both self-reported ER and RSA. The evaluation of self-reported ER provides access to the conscious strategies and unobservable processes typically used by individuals in the face of emotional experiences – that is, "top down" processes linked to ER. The inclusion of RSA, on the other hand, provides an objective, physiological measure marker of ER (Appelhans & Leucken, 20006; Thayer et al., 2012). RSA circumvents a number of potential limitations of self-report (e.g., response biases, limited insight, motivational level), while also capturing "bottom-up" cortical and subcortical processes supporting the flexible, effective regulation of emotion (Park, et al., 2012).

Two empirical studies that have examined the association between RSA and other vagally-mediated measures of heart rate variability and self-reported ER found inverse correlations of small to medium magnitude between RSA and scales of the Difficulties in Emotion Regulation Scale (DERS), suggesting that, although related, each measure captures unique variance of the ER construct (Visted et al., 2017; Williams et al., 2015). It is yet to be determined which components of ER – cognitive appraisals about the ER capabilities or underlying physiological processes – are most relevant to domains of adolescent wellbeing. Thus, the incorporation of both methods extends previous research that has focused primarily on self-reported ER processes in youth, and aims to provide a more comprehensive picture of the relationship of ER processes to adolescent functioning. Understanding the relative contribution of RSA and self-reported ER to adolescent wellbeing may inform the development of targeted ER interventions to enhance specific domains of wellbeing in young people.

It was predicted that ER capacity, as measured by lower self-reported ER difficulties and higher tonic RSA, would be positively related to resilience and domains of wellbeing thought to support optimal psychological functioning (i.e., flourishing) in adulthood, including engagement, perseverance, optimism, connectedness, and happiness (Kern, Benson, Steinberg, & Steinberg, 2016). Second, it was predicted that ER capacity, as measured by lower self-reported difficulties and higher tonic RSA, would be negatively related to symptoms of depression and anxiety.

2. Method

2.1 Participants

Participants were 187 secondary school students enrolled in Years 10 and 11 at one of five Victorian schools (two government, three independent), randomly selected to complete the ER assessments from a larger sample of approximately 600 students participating in a school-based evaluation of adolescent wellbeing. Of the initial sample, 65 did not complete the full assessment (i.e., RSA monitoring, wellbeing and ER questionnaires). Reasons for incomplete data included absence from school on the day of testing, internet dropout while completing online wellbeing surveys, or withdrawing from participation prior to completing all assessments. This resulted in a final sample of 119 students (52% female, 87% Australian, age range 14–18, *M* age = 15.73, *SD* = 0.87).

2.2 Procedure

Informed consent was provided by both students and their guardians prior to participation. Wellbeing data were collected via an online assessment battery, which participants of the larger study completed as part of scheduled wellbeing classes at their respective schools. ER data was collected within a 2-week timeframe of the online assessment, and involved students individually presenting to a low-stimulus experimental room throughout the school day (8.30am–4pm). Participants were provided details of the testing procedure, and verbally provided informed consent. To assess tonic RSA, electrocardiography (ECG) and respiration data were recorded by a trained experimenter using an integrated computer system and software package (Nexxus-10, Mind Media, 2004-2006). Following RSA recording, participants then completed a self-report battery of ER questionnaires. The total duration for data collection was approximately 20 minutes per participant.

2.3 Materials

Respiratory sinus arrhythmia (RSA).

RSA occurs within the frequency of respiration (0.15–0.40 Hz), is considered a relatively stable measure of vagally-mediated heart rate variability (HRV, Li et al, 2009; Thayer & Sternberg, 2010), and is an appropriate HRV measure for short-term recordings of 5 minutes (Task Force of the European Society of Cardiology, 1996).

To monitor RSA, researchers applied disposable electrodes in a standard lead 2 bipolar configuration, approximately 1cm below the clavicle and on the lower ribcage (Berntson, Quigley, & Lozano, 2007). Respiration rate and rhythm were monitored via a sensor positioned around the lower abdomen. A neutral breathing pacer program was used to standardize breathing rate and rhythm, and was set at the recommended rate of 9 (< 10) breaths per minute in order to yield maximum R-R interval power (Brown, Beightol, Koh, & Eckberg, 1993). Given the potential for paced breathing to contribute to stress-related changes in RSA as a result of increased mental effort (Berntson et al., 1997), instructions were provided to participants to "try and breathe along with this pacer, however, if it feels difficult or unnatural, just breathe at a consistent, relaxed pace that feels right to you" (Kobayashi, 2009). Electrocardiography (ECG) and respiration data were then recorded at a sampling rate of 1000Hz by an integrated system and software package (Nexxus-10, Mind Media, 2004-2006). As recommended for RSA assessments of short duration, 5 minutes of continuous recording was obtained while participants remained in a still, seated position (Quintana, Alvares, & Heathers, 2016; Task Force of the European Society of Cardiology, 1996). RSA monitoring software was concealed from the participant during the recording, to avoid potentially confounding effects, including increased sympathetic arousal, distraction, or interference of respiration or heart rate via biofeedback processes.

Self-reported emotion regulation strategies

The Difficulties in Emotion Regulation Scale (DERS; Gratz & Roemer, 2004) includes 36 items and six subscales designed to assess perceived difficulties in ER relating to a) awareness and understanding of emotions, b) acceptance of emotions, c) the ability to engage in goal-directed behavior when experiencing negative emotions, and d) access to effective ER strategies. Items are scored on a five-point Likert scale ranging from 1 (almost never) to 5 (almost always), with higher scores representing greater ER difficulties (example item "*When I'm upset, I have difficulty controlling my behavior*"). The six subscales represent specific problems with ER, including lack of emotional clarity (Clarity; α = .82); lack of emotional awareness (Awareness; α = .81); difficulties controlling impulsive behaviors when distressed (Impulses; α = .89); non-acceptance of emotional responses (Non acceptance; α = .94); and limited access to effective emotion regulation strategies (Strategies; α = .91). These subscales are then summed to calculate a total score (DERS total). The DERS has been validated for use in adolescent samples aged between 12 to 17 years (Neumann, van Lier, Gratz, & Koot, 2010), and the DERS total demonstrated good internal consistency in the current study (α = .85).

Psychological wellbeing.

The EPOCH Measure of Adolescent Well-being (EPOCH; Kern, Benson, Steinberg, & Steinberg, 2016) is a 20-item, multidimensional self-report measure of adolescent wellbeing that assesses five positive psychological characteristics thought to foster flourishing (i.e., optimal psychological functioning) in adulthood (Seligman, 2011). Items are rated on a five-point Likert scale, from 1 (almost never/not at all like me) to 5 (almost always/very much like me), and each scale is computed as the average of its four respective items. These scales measure engagement with valued activities (Engagement; α = .78; e.g., "*I get completely absorbed in what I am doing*"); persistence in the face of challenges or to achieve goals (Perseverance; α = .81; e.g., "*I finish whatever I begin*"); optimism (Optimism; α = .86; e.g., "*I am optimistic about my future*"); connectedness to peers and loved ones (Connectedness; α = .88; e.g., "*There are people in my life who really care about me*"); and subjective feelings of happiness (Happiness; α = .90; e.g., "*I feel happy*"). The EPOCH has been validated for use in adolescents aged between 10 and 18 years in Australia and the United States. Each scale has acceptable psychometric properties, including construct and discriminant validity (Kern, et al., 2016), and had acceptable internal consistency in the current sample (α = .78 - .90).

Resilience

The Connor-Davidson Resilience Scale (CD-RISC; Campbell-Sills & Stein, 2007) is a self-report measure that conceptualizes resilience as positive adaptation following stress or adversity. It comprises 10 items (e.g., "*I believe I can achieve my goals even if there are obstacles*"), each of which is rated on a five-point scale ranging from 0 to 4. Scores range from 0 to 40, with higher scores reflecting greater resilience. The scale demonstrates excellent psychometric properties in late adolescent populations (*M* age = 18.8; Campbell-Sills & Stein, 2007). In the current study, it showed excellent internal consistency (α = .90).

Mental distress

The PHQ-4 (Löwe et al., 2010*)* is a four-item self-report screening tool used to detect the presence of core symptoms of depression and anxiety (e.g., *"In the past two weeks, how often have you been bothered by feeling nervous, anxious, or on edge?"*). Items are measured on a five-point Likert scale ranging from 0 (not at all) to 4 (nearly every day), with higher scores indicating the presence of greater mental distress. Scores on each scale range from 0 to 6, with scores of 3 or above indicating the likely presence of depression or anxiety. The PHQ-4 has been validated for use in the general population aged 11 years and over (Kroenke, Spitzer, Williams & Löwe, 2009). In the current study, the depression subscale demonstrated borderline internal consistency (α = .68), while the anxiety subscale showed good internal consistency (α = .83).

3. Data analyses

RSA data were generated and pre-processed using the Nexus software package (Mind Media, 2004-2006). The first 60 seconds of the 5-minute RSA recording was excluded from analysis, to ensure participants were settled and sufficiently relaxed. A time series of heart rate interbeat intervals (IBIs) were then generated. Raw IBIs were then screened for artifact using the following criteria: (1) IBIs were between 500 and 1500 ms, and 2) IBIs differing by more than 25% from the previous IBI were considered an artifact and removed from analyses and replaced with interpolated data (IBI[n] = (IBI[n-1] + IBI)/2); Mind Media, 2004-2006). The mean percentage of artifact removed from each participant was 3.6 seconds of data (*SD* = 5.90). The remaining 4 minutes of data were then processed in full, and RSA values (i.e., HRV in the high-frequency band of 0.15 -0.40 Hz) were extracted. RSA data was then log transformed to better approximate a normal distribution and meet assumptions of linear regression (Ellis, Sollers III, Edelstein, & Thayer, 2008). RSA and self-report data were entered into SPSS for all statistical analyses (version 23, IBM Chicago, IL, USA).

Four randomly missing items on the DERS and CD-RISC questionnaires were substituted by the item mean score, rounded to a discrete value, before subscale and total scores were calculated for each participant as per scale-developer's instructions (Gratz & Roemer, 2004). Two participants provided DERS scores ± 2 standard deviations from the mean, which were imputed using the Winsor method (item mean + (3 x SD)). No outliers were detected in EPOCH, CD-RISC, PHQ-4 subscales or HRV data.

To identify potential confounds previously documented in the literature, including age, gender, ethnicity, and SES, independent t-tests were conducted with the variables of interest (Currie et al., 2009; Nolen-Hoeksema & Girgus, 1994; Martinez & Dukes, 1997). No significant differences ($p > .05$) were found for gender or ethnicity on any of the examined measures of wellbeing, mental distress, or ER. Therefore, gender was not controlled for in subsequent analyses. As two of the privately funded schools were boarding schools, and two schools (one public, one private) shared a postcode, postcode-generated SES was considered to be an inappropriate measure of social privilege in the current sample. Instead, school funding type (public or private) was used as an index of SES. Significant between-group differences were found for school type on measures of mental distress, including PHQ-4 anxiety (t (117) = 4.64, p <.001), PHQ-4 depression (t (117) = 4.96, p <.001), as well as RSA (t (117) = 2.80, p <.01). Pearson's bivariate correlations showed significant relationships between age and variables including PHQ anxiety (r = -.453, p <.001), PHQ-4 depression (r = -.399, p <.001), and RSA (r = -.259, p <.01). Thus, age and school were statistically controlled for in all analyses.

A series of hierarchical multiple regression analyses were then conducted to assess the relationship between ER (RSA and self-reported DERS total) and each of the wellbeing variables. Step 1 included the covariates of age and school type. Step 2 included the cognitive and physiological ER variables (i.e., DERS total and RSA, respectively). Due to expected multicolinearity, independent regression analyses were run for each EPOCH scale. All performed tests were two-tailed and analysed at a significance level of $p < .05$.

4. Results

Descriptive statistics for ER, wellbeing, and demographic characteristics are presented in Table 1. Results are presented for the total sample, and stratified according to gender.

Table 1.
Descriptive statistics for emotion regulation, wellbeing & mental distress variables, and demographic characteristics

Variable	Total (N = 119) $M \pm SD$	Females (n = 62) $M \pm SD$	Males (n = 57) $M \pm SD$
DERS Total Score	76.08 ± 24.51	79.16 ± 28.94	72.74 ± 18.22
RSA	3.52 ± 0.50	3.54 ± 0.55	3.50 ± 0.45
EPOCH Engagement	17.35 ± 4.32	16.90 ± 4.47	17.84 ± 4.13
EPOCH Perseverance	16.97 ± 4.33	16.76 ± 4.49	17.19 ± 4.18
EPOCH Optimism	17.64 ± 4.87	17.11 ± 5.11	18.23 ± 4.56
EPOCH Connectedness	19.81 ± 4.27	20.26 ± 4.36	19.31 ± 4.15
EPOCH Happiness	19.29 ± 4.80	19.26 ± 5.01	19.33 ± 4.59
CD Resilience	36.85 ± 7.77	36.18 ± 8.03	37.58 ± 7.47
PHQ Depression	2.60 ± 1.87	2.68 ± 2.06	2.51 ± 1.66
PHQ Anxiety	2.69 ± 1.98	2.81 ± 2.25	2.56 ± 1.64
Age (years)	15.73 ± 0.87	15.82 ± 0.95	15.63 ± 0.77

Table 1 depicts the mean and standard deviation values on emotion regulation, wellbeing, and mental distress measures for the full sample, and stratified according to gender. DERS = Difficulties in Emotion Regulation Scale; RSA = log-transformed RSA; EPOCH = EPOCH Measure of Adolescent Wellbeing; CD Resilience = Connor-Davidson Resilience Scale; PHQ = Patient Health Questionnaire 4-item version

Results of bivariate correlations showed a significant positive relationship between RSA and the EPOCH scale Perseverance (r = 0.24, $p < .05$) and CD-RISC Resilience (r = 0.21, $p < .05$). As predicted, significant negative relationships were found between DERS total scores (representing greater ER difficulties) and CD-RISC Resilience (r = -0.36, $p < .01$), and all EPOCH scales. Significant positive relationships were found between DERS total scores and mental distress, as measured by PHQ-4 Depression (r = 0.46, $p < .01$) and PHQ-4 Anxiety (r = 0.40, $p < .01$). A non-significant correlation was found between HRV and DERS total score (r = 0.05, p >.05). A correlation matrix of ER, wellbeing, and mental distress variables is presented in Table 2.

Table 2.
Correlation matrix of emotion regulation, wellbeing, and mental distress variables (N = 119)

Measure	1	2	3	4	5	6	7	8	9
DERS Total Score (1)									
RSA (2)	.05								
EPOCH Engagement (3)	**-.29****	.11							
EPOCH Perseverance (4)	**-.36****	**.24***	.77**						
EPOCH Optimism (5)	**-.40****	.09	.82**	.80**					
EPOCH Connectedness (6)	**-.23***	.13	.55**	.63**	.71**				
EPOCH Happiness (7)	**-.33****	.14	.74**	.68**	.87**	.75**			
CD Resilience (8)	**-.36****	**.21***	.61**	.61**	.68**	.43**	.59**		
PHQ Depression (9)	**.46****	.11	-.35**	-.42**	-.42**	-.38**	-.41**	-.27**	
PHQ Anxiety (10)	**.40****	.10	-.19*	-.28**	-.28**	-.21*	-.29**	-.30**	.75**

* p <.05 ** p <.01

Table 2 shows bivariate (Pearson's r) correlation coefficients between emotion regulation, wellbeing, and mental distress variables. Statistically significant coefficients are presented in bold font. DERS = Difficulties in Emotion Regulation Scale; RSA = log-transformed RSA; EPOCH = EPOCH Measure of Adolescent Well-being; CD Resilience = Connor-Davidson Resilience Scale; PHQ = Patient Health Questionnaire 4-item version.

Multiple hierarchical regression analyses showed that after controlling for age and school type, DERS total scores were significantly and negatively associated with all measures of wellbeing measures, consistent with our hypotheses. In relation to physiological ER, RSA was positively related to both EPOCH Perseverance and CD-RISC Resilience. Semi-partial correlations squared (sr^2) revealed small to medium effect sizes for each significant predictor, which independently accounted for between 5% and 16% of the variance in wellbeing outcomes. A summary of the full hierarchical regression models in which both the DERS total score and RSA predicted wellbeing is presented in Tables 3a and 3b.

Table 3a.
Hierarchical multiple regression models examining emotion regulation variables and wellbeing

Hierarchical regression step	EPOCH Engagement	*B*	β	*t*	*p*	95% CI for Lower	Upper	*r*	*sr*²
Model 1	Age	0.02	0.01	0.04	.97	-1.26	1.31	-.05	.00
	School	-0.66	-0.08	-0.58	.56	-2.89	1.57	-.07	.00
R^2 = .01 (*p* = .73)									
Model 2	Age	0.08	0.02	0.13	.90	-1.16	1.32	-.05	.00
	School	-0.50	-0.06	-0.46	.65	-2.65	1.65	-.07	.00
	DERS Total	-0.05	-0.30	-3.32	**.001**	-0.08	-0.02	-.29	.09
	RSA	1.00	0.12	1.26	.21	-0.57	2.57	.11	.01
R^2 change = .10 (*p* = .003)									

Hierarchical regression step	EPOCH Perseverance	*B*	β	*t*	*p*	95% CI for Lower	Upper	*r*	*sr*²
Model 1	Age	-0.10	-.02	0.15	.88	-1.21	1.19	.06	.00
	School	-0.45	-.05	0.40	.69	-2.69	1.79	.07	.00
R^2 = .01 (*p* =.77)									
Model 2	Age	0.06	.01	0.10	.92	-1.12	1.24	.06	.00
	School	-0.13	-.01	0.12	.90	-2.17	1.92	.07	.00
	DERS Total	-0.07	-.37	4.36	**.000**	-0.95	-0.04	.36	.13
	RSA	2.18	.25	2.88	**.005**	0.68	3.67	.24	.06
R^2 change = .11 (*p* =.000)									

Hierarchical regression step	EPOCH Optimism	*B*	β	*t*	*p*	95% CI for Lower	Upper	*r*	*sr*²
Model 1	Age	0.07	0.01	0.09	.93	-1.37	1.50	-.08	.00
	School	-1.28	-0.13	-1.02	.31	-3.78	1.22	-.12	.01
R^2 = .02 (*p* =.41)									
Model 2	Age	0.09	0.02	0.13	.90	-1.24	1.42	-.08	.00
	School	-1.14	-0.12	-0.98	.33	-3.44	1.17	-.12	.01
	DERS Total	-0.08	-0.41	-4.78	**.000**	-0.11	-0.05	-.40	.16
	RSA	0.80	0.08	0.94	.35	-0.88	2.49	.09	.01
R^2 change = .17 (*p* =.000)									

Hierarchical regression step	EPOCH Connectedness	*B*	β	*t*	*p*	95% CI for Lower	Upper	*r*	*sr*²
Model 1	Age	-0.38	-0.08	-0.60	.53	-1.64	0.88	-.13	.00
	School	-0.68	-0.08	-0.61	.54	-2.86	1.51	-.13	.00
R^2 = .02 (*p* =.30)									
Model 2	Age	-0.32	-0.07	-0.52	.61	-1.56	0.92	-.13	.00
	School	-0.54	-0.06	-0.50	.62	-2.68	1.61	-.13	.00
	DERS Total	-0.04	-0.23	-2.60	**.01**	-0.07	-0.01	-.23	.05
	RSA	0.90	0.11	1.14	.26	-0.67	2.47	.13	.01
R^2 change = .06 (*p* <.02)									

Table 3b.
Hierarchical multiple regression models examining emotion regulation variables and wellbeing

Hierarchical regression step	EPOCH Happiness	B	β	t	p	95% CI for Lower	Upper	r	sr^2
Model 1	Age	0.09	0.02	0.12	.91	-1.33	1.50	-.10	0.00
	School	-1.55	-0.16	-1.25	.21	-4.00	0.90	-.15	0.01
R^2 = .02 (p =.26)									
Model 2	Age	0.16	0.03	0.23	.82	-1.18	1.50	-.10	0.00
	School	-1.36	-0.14	-1.16	.25	-3.68	0.97	-.15	0.01
	DERS Total	-0.07	-0.34	-3.87	**.000**	-0.10	-0.03	-.33	0.11
	RSA	1.24	0.13	1.44	.15	-0.46	2.94	.14	0.02
R^2 change = .12 (p =.000)									

Hierarchical regression step	CD Resilience	B	β	t	p	95% CI for Lower		r	sr^2
Model 1	Age	3.19	0.36	2.83	**.005**	0.96	5.42	.12	.06
	School	-5.13	0.33	2.62	**.01**	-9.00	-1.26	.08	.06
R^2 = .07 (p =.01)									
Model 2	Age	3.48	0.39	3.41	**.001**	1.46	5.50	.12	.08
	School	-4.54	0.29	2.57	**.01**	-8.05	-1.03	.08	.04
	DERS Total	-0.12	-0.37	-4.57	**.000**	-0.17	-0.07	-.36	.14
	RSA	3.97	0.26	3.06	**.003**	1.40	6.53	.21	.06
R^2 change = .19 (p =.001)									

Significant relationships between emotion regulation and measures of wellbeing are presented in bold font. DERS Total = Difficulties in Emotion Regulation Scale total score; RSA = log-transformed RSA; EPOCH = EPOCH Measure of Adolescent Wellbeing; CD Resilience = Connor-Davidson Resilience Scale; PHQ = Patient Health Questionnaire 4-item version.

As predicted, multiple hierarchical regression analyses revealed that after controlling for age and school type, DERS total scores were significantly and positively related to mental distress, as measured by PHQ-4 Depression and Anxiety subscales. Semi-partial correlations squared (sr^2) revealed medium effect sizes for self-reported ER (i.e., DERS total), which independently explained 21% of the variance in depression symptoms, and 15% of the variance in anxiety symptoms. RSA did not significantly predict symptoms of depression or anxiety. A summary of these analyses is presented in Table 4.

Table 4.
Hierarchical multiple regression models examining emotion regulation variables and mental distress

Hierarchical regression step	PHQ Depression	*B*	β	*t*	*p*	95% CI for Lower	Upper	*r*	*sr*^{2}
Block 1	Age	-0.45	-0.21	-1.79	.08	-0.95	0.05	-.40	.02
	School	-1.01	-0.27	-2.30	.02	-1.88	-0.14	-.42	.04
R^2 = .196 (*p* =.000)									
Block 2	Age	-0.439	-0.204	-1.99	.05	-0.88	-0.002	-.40	.02
	School	-1.040	-0.278	-2.72	**.008**	-1.80	-0.28	-.42	.04
	DERS Total	0.035	0.457	6.32	**.000**	0.02	0.05	.46	.21
	RSA	-0.128	-0.034	-0.46	.65	-0.68	0.43	.11	.00
R^2 change = .21 (*p* =.000)									
Hierarchical regression step	**PHQ Anxiety**	***B***	**β**	***t***	***p***	**95% CI for Lower**		***r***	***sr*^{2}**
Block 1	Age	-0.79	-0.35	-3.00	**.003**	-1.31	-0.27	-.45	.06
	School	-0.59	-0.15	-1.30	.20	-1.50	0.31	-.40	.01
R^2 = .22 (*p* =.000)									
Block 2	Age	-0.78	-0.35	-3.27	**.001**	-1.26	-0.31	-.45	.06
	School	-0.63	-0.16	-1.52	.13	-1.46	0.19	-.40	.01
	DERS Total	0.03	0.39	5.26	**.000**	0.02	0.04	.40	.15
	RSA	-0.19	-0.05	-0.05	.54	-0.79	0.42	.10	.00
R^2 change = .15 (*p* =.000)									

Significant relationships between emotion regulation and measures of mental distress are presented in bold font. DERS Total = Difficulties in Emotion Regulation Scale total score, RSA = log-transformed RSA; PHQ = Patient Health Questionnaire

5. Discussion

This study examined the relationship between physiological and self-reported markers of ER and multiple measures of positive psychological functioning and mental distress in a normative adolescent sample. Specifically, we sought to clarify the strength and direction of relationships between ER using subjective and objective indices and dimensions of wellbeing, resilience, and symptoms of depression and anxiety.

5.1 Emotion regulation and positive psychological functioning

It was hypothesized that ER capacity, as measured by lower self-reported ER difficulties and higher tonic RSA, would be positively related to resilience and domains of wellbeing, including engagement, perseverance, optimism, connectedness, and happiness. As predicted, ER capacity significantly predicted numerous measures of wellbeing after controlling for the effects of age and school type, with small to medium effect sizes. Lower scores on the DERS total, indicative of poorer ER capacity, were inversely related to resilience and the wellbeing domains of perseverance, optimism, connectedness, and happiness. In addition, after controlling for the effects of age and school, significant positive relationships were found between RSA and resilience and perseverance. To our knowledge, this is the first study to examine the relationship between multiple measures of ER and wellbeing in a normative, school-based, adolescent sample.

Results of this study indicate that ER is meaningfully related to aspects of positive psychological functioning in young people, with self-reported ER predictive of a broader range of wellbeing domains than RSA and with larger effect sizes. While previous research shows that deficits of ER contribute to mental distress and dysfunction, the current findings indicate that more adaptive ER profiles may also contribute to wellbeing in young people. Indeed, a selection of longitudinal research with adolescent and young adult samples supports this position and shows that ER capacity contributes to improvements in positive affect (i.e., Happiness; Yeung, Wong, & Lok, 2011) and peer acceptance (i.e., Connectedness; Kim & Cicchetti, 2010). Similarly, an adaptive, self-reported ER (positive refocusing) was found to mediate the relationship between optimism and subjective wellbeing (Yeung, Ho, & Mak, 2015), while improvements in life satisfaction were found over a 9-month period in students displaying an adaptive cognitive coping style compared to those displaying less adaptive coping (Vella-Brodrick, Rickard, & Chin, 2014). Further, ER strategies, including positive reappraisal (i.e., thinking about a challenging situation in a more positive manner) and attentional deployment (i.e., attending to non-threatening aspects of a situation) have been found to help individuals cope with a range of stressors across interpersonal and performance domains (Ivcevic & Brackett, 2014; Libbrecht, Lievens, Carette, & Côté, 2014; Troy & Mauss, 2011). The current findings build upon past findings examining limited ER strategies by demonstrating that a broader suite of ER abilities, i.e., the ability to identify, select, and employ cognitive ER strategies, facilitates resilience and wellbeing in the face of stress and setbacks.

In addition to self-reported ER capacity, a novel contribution of this study is its examination of the relationship between an objective ER measure, RSA, and a comprehensive suite of measures of positive psychological functioning in young people. Previous examination of RSA specifically with adolescent samples has focused predominantly on negative aspects of functioning, such as mental ill-health (Beauchaine, 2015), antisocial behaviour (Beauchaine, Gatzke-Kopp, & Mead, 2007), and self-harm (Weilgus, Aldrich, Mezulis, & Crowell, 2016). Although there is increasing support for the role of RSA in social connectedness (Patriquin et al., 2014; Partiquin et al., 2013) and positive affect (Kok & Fredrickson, 2010; Oveis et al., 2009), it has not previously been examined in relation to additional wellbeing domains outlined by the PERMA model. The current research thus contributes to existing literature outlining the relationship between RSA and wellbeing, and supports theory positing that higher tonic RSA can facilitate the flexible engagement of ER processes (Appelhans & Leucken, 2006; Beauchaine & Thayer, 2015).

Our results demonstrate significant positive relationships between resting RSA and self-reported resilience and perseverance. Resilience measures an individual's capacity for adaptive functioning following stress or adversity (Campbell-Sills & Stein, 2007), whereas perseverance is characterized by tenacity in the face of challenges (Kern et al., 2016). Both abilities are supported by efficient cortical-subcortical integration, as reflected by high tonic RSA. To elaborate, RSA is thought to reflect output of the inhibitory cortico-subcortical neurocircuit of the central autonomic nervous system, which includes the brainstem, amygdala, insula, cingulate cortex, and prefrontal cortex (Davidson, Jackson, & Kalin, 2000; Kemp & Quintana, 2013). This neurocircuit is involved in the regulation of visceral responses to emotional stimuli, a process that recruits executive functions such as the selection and implementation of appropriate cognitive ER strategies (Thayer & Lane, 2000, 2009). Resilience and perseverance are similar in that they involve adaptive functioning despite persistent or repeated exposure to emotionally challenging experiences, therefore, a strong capacity to regulate underlying physiological arousal may be particularly important in cultivating these domains of positive functioning. Interventions designed to enhance RSA, such as cultivating mindfulness (Chambers, Gullone, & Allen, 2009), bio-feedback training

(McCraty & Zayas, 2014), and enhancing physical fitness (Routledge, Campbell, McFetridge-Durdle, & Bacon, 2010), may be beneficial in bolstering resilience and perseverance in adolescent groups.

Consistent with this hypothesis, ER capacity can facilitate approach-behaviours in response to environmental stressors, such as persevering on a difficult homework assignment or managing ongoing interpersonal difficulties with teachers, peers, or parents (Troy & Mauss, 2011). In the context of a broader body of positive psychological research, resilience and perseverance appear conceptually similar to the construct of *grit*, defined as perseverance and passion for long-term goals (Duckworth, Peterson, Matthews, & Kelly, 2007). Results of a recent meta-analysis revealed that one facet of grit, perseverance of effort, predicts academic success after controlling for conscientiousness, a personality trait characterised by directedness and a will to achieve (Credé, Tynan, & Harms, 2016; McCrae & Costa, 1987). Further, it has been proposed that ER processes associated with RSA (e.g., the ability to inhibit strong emotional impulses), may share common underlying mechanisms with grit (Duckworth & Gross, 2014). Together, these findings shed light on the role of both physiological and cognitive ER processes in resilience and perseverance in school-age adolescents, and provide a promising direction to bolster resilience in young people, for example, via explicit teaching of cognitive ER strategies or modifying RSA via structured training (e.g., McCraty & Zayas, 2014).

5.2 Emotion regulation and mental distress

In relation to mental distress, we found moderate inverse relationships between self-reported ER capacity and depression and anxiety symptoms, after controlling for age and school type. Mental ill-health broadly involves the experience of one or more unpleasant emotions (e.g., sadness, fear) that is either too intense or endured for too long to be adaptive (Beauchaine et al., 2007). Difficulties identifying emotional distress, the belief that emotions are unchangeable, and the absence of adaptive ER strategies all represent ER difficulties that contribute to mental distress and disorder (De Castella et al., 2013; Hatzenbuehler, McLaughlin, & Nol-Hoeksema, 2008). Unsurprisingly, deficits of ER are regarded as a transdiagnostic risk factor for the development of mental ill-health in both adults and adolescents (Aldao et al., 2010; McLaughlin, Hatzenbuehler, Mennin, & Nolen-Hoeksema, 2011). Results of the current study show that moderate relationships between ER difficulties and mental distress exist even in a healthy, normative sample of young people (see also Garnefski, Kraaij, & van Etten, 2005; Garnefski, Legerstee, Kraaij, Van Den Kommer, & Teerds, 2002; Silk, et al., 2003). Based on these findings, it appears that mental health promotion for young people would benefit from including a greater emphasis on ER skills training, for example, increasing one's ability to acknowledge, identify, and actively modify difficult emotional experiences. These skills can be effectively taught in relatively brief training programs (Berking et al., 2008), and may be built into existing mental health interventions accessible to a broad adolescent population, such as school-based social emotional learning programs (Hamilton & Hamilton, 2009).

5.3 Covariance of self-reported ER and RSA

The experience and regulation of emotion is thought to involve coordinated responses across subjective, cognitive, behavioral, and physiological measures (Marsh, Beauchaine & Williams, 2008). Results of the current study revealed negligible covariance between subjective reports of ER capacity and RSA ($r = .05$), suggesting that each measure captures distinct processes contributing to ER. These findings differ from previous research that reported significant, inverse, small to medium sized correlations between ER difficulties and a tonic measure of RSA in young adult samples in Norway (Visted et al., 2017) and the USA (Williams et al., 2015). Further research is needed to explore differences between the examined samples that may have contributed to these disparate results, such as the age of participants. Broader examination of the literature reveals that low covariance between experiential and physiological measures of emotion and related processes is commonly cited (Bonnano & Keltner, 2004; Evers et al., 2014), leading some researchers to conclude that the correlation between emotional response systems is weak in the absence of intense emotional experiences or very specific contexts (Crowell et al., 2014; Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005). For example, Evers et al. (2014) draw upon the dual process framework, which proposes that psychological responses comprise two largely independent processes – one automatic (e.g., physiological processes) and one reflective (e.g., subjective, experiential processes) – and demonstrate that low coherence exists between automatic (e.g., RSA) and reflective measures (e.g., self-report). Such findings reinforce the importance of adopting a multi-method approach to ER research in order to capture a range of ER processes, while also bringing into question the appropriateness of comparing research that has measured ER with considerably different measures. (For a discussion of this issue, see Cole et al., 2004; Naragon-Gainey et al., 2017.)

As this study involved cross-sectional data taken at a particular point in the school year, it cannot be determined whether the identified associations between ER and wellbeing represent stable relationships or if ER capacity plays a causal role in the development of adolescent wellbeing. This is a notable limitation. Further, longitudinal research is required to clarify whether ER capacity contributes to differences in wellbeing outcomes over time. Due to the small sample, which predominantly comprised Australian-born adolescents from English-speaking backgrounds, the generalizability of our findings to other adolescent groups is restricted. Certain factors thought to influence RSA could not be statistically controlled for in this study. These include variation in the time that RSA was assessed (i.e., at different times throughout the school day), body mass index, and possible caffeine, nicotine, or medication use by participants (Quintana & Heathers, 2014). It is likely that the use of a school sample limited potential variation on a number of these variables (e.g., caffeine and nicotine intake), however, results should be interpreted with these caveats in mind. Finally, the potential influence of common error variance in explaining the relationship between the self-report scales examined in this study, specifically between ER and wellbeing, may have contributed to the current findings and must be considered.

Despite these limitations, results of the current study position ER, and, in particular, self-reported ER strategies, as an important contributor to wellbeing in youth. Cultivating a young person's repertoire of adaptive ER skills and strategies may be a promising target for interventions aiming to enhance wellbeing in adolescent populations, including treatments that seek to reduce symptoms of mental distress (Morrish et al., 2018). Our findings may be of particular relevance to school-based social-emotional literacy platforms, which represent early intervention programs seeking to enhance psychological health within a school cohort of students. Furthermore, the moderate correlations found between self-reported ER and EPOCH wellbeing domains suggest that youth-focused interventions seeking to enhance wellbeing might be further enhanced by including a greater focus on adaptive ER strategies (see also Lü, Wang, & Liu, 2013; Weytens, Luminet, Verhofstadt, & Mikolajczak, 2014). Due to their association with both physiological and self-reported ER, the current findings suggest that cultivating young people's ER capacity – both via physiological markers and self-reported strategy use – may provide a particularly valuable supplement to intervention programs seeking to bolster resilience and perseverance in the face of stress (Souza et al., 2013; Troy & Mauss, 2011). These qualities are key to positive psychological functioning, and foster success across key challenges of adolescence, including academic performance and navigating important life transitions (Zolkoski & Bullock, 2012). Future research should explore the predictive value of specific ER skills and strategies to wellbeing, occurring across the various stages of the emotion-generation cycle (see Ochsner et al., 2009; Ochsner & Gross, 2005). Experimental designs that examine the impact of enhancing student's cognitive and physiological ER capacity on wellbeing outcomes are also recommended.

In sum, the current study provides clear support for the relevance of self-reported, cognitive ER capacity to young people's wellbeing and mental distress. It also adds uniquely to the existing literature by evidencing the contribution of RSA, a physiological marker of ER capacity, to both resilience and perseverance in a healthy youth sample. Recognising the relevance of both self-reported and physiological ER processes to positive psychological functioning in adolescents broadens the scope for ER-oriented interventions, which may be used to complement and enhance existing preventative and early intervention treatment approaches that aim to bolster adolescent wellbeing and encourage flourishing throughout adulthood.

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