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Original article

Evaluating emotional clarity and concordance in ambulatory physiological data and ecological momentary assessments in an adolescent clinical sample

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ABSTRACT

The concordance between physiological and subjective experiences of emotion is viewed as a core aspect of emotion and an important factor underlying psychopathology and well-being. However, there is a lack of research investigating concordance in ecologically valid contexts. Additionally, trait-level risk factors that may moderate concordance have yet to be thoroughly examined. The current study aimed (1) to determine whether concordance for naturally occurring affect is present at the within-person level and (2) to evaluate emotional clarity as a moderator of concordance in ecologically valid settings. The current study used ambulatory measures of autonomic physiological arousal and ecological momentary assessment over a four-week period to examine within-person concordance in everyday life within an adolescent clinical sample. The current study also examined whether between-person differences in trait-level emotional clarity moderate concordance. Significant concordance was found for momentary subjective anxiety and calmness, respectively, in relation to autonomic physiological arousal. In moderator analyses, individuals with greater emotional clarity exhibited greater concordance between physiological arousal and overall negative affect than did individuals with lower emotional clarity. These results extend findings from lab-based, experimental-induction paradigms to concordance in daily life and within clinically acute youth. Our results suggest that targeted interventions to strengthen concordance by improving emotional clarity may be an avenue for enhancing mental health and well-being.

1. Introduction

Physiological and subjective experiences are core aspects of the experience of emotions (Coan, 2010; Levenson, 2014; Siegel et al., 2018). The concordance between physiological and subjective experiences of emotion has been often been viewed as adaptive. The functionalist theory posits that greater concordance allows individuals to better respond to their environment, which may enhance well-being (Brown et al., 2020; Darwin, 1872; Ekman, 1977, 1992; Levenson, 1994, 2014; Mauss et al., 2005; Sommerfeldt et al., 2019). Furthermore, evolutionary emotion theories suggest that concordance is important and beneficial during high-intensity emotions in situations where physical and psychological safety may be threatened (Brown et al., 2020; Levenson, 1994), and in this manner, concordance may be instrumental in individual well-being. Empirical support has been found for associations between greater concordance and greater general well-being, including lower levels of depression, anxiety, and aberrant immunoregulatory activation (i.e., proinflammatory cytokines; Brown et al., 2020; Mauss et al., 2005; Sommerfeldt et al., 2019; Sze et al., 2010). This holds true for mental health outcomes in youth, with one study finding that adolescents demonstrating less concordance between their subjective experience of emotions and physiological arousal had greater internalizing and externalizing problems (Hastings et al., 2009).

Given these findings of between-person differences in concordance

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between physiological and subjective aspects of emotion and their clinical relevance, it is important to understand potential factors that impact concordance in real-world settings. Identifying potential moderators of concordance have important clinical implications, as it may inform the development of interventions that increase concordance. Within this context, a promising potentially modifiable candidate is emotional clarity, an individual's trait-level ability to identify and understand their feelings, which may include individual affective states, as well as broader emotion groupings (Coffey et al., 2003; Erbas et al., 2013; Kashdan et al., 2015). In contrast, concordance reflects the alignment between physiological activity and affective states and one's state-level ability to make this connection (Brown et al., 2020; Lougheed et al., 2021; Mauss et al., 2005). In order to evaluate their physiological activity and relate it to an affective experience, it is likely that individuals first need to have some level of emotional awareness and clarity to attune to and then identify and understand their emotions, respectively. Thus, emotional concordance may tap into a related aspect of emotional knowledge that is the affect-physiological component, with greater knowledge in this component indicating greater concordance (Heine & Dufner, 2025). Related to emotional knowledge, prior emotion literature has demonstrated that better emotion regulation is associated with better mental health outcomes and vice versa (Haliczer et al., 2025; Hu et al., 2014). Concordance, a component of emotional knowledge, allows individuals the ability to accurately identify emotions based on physical sensations and regulate these emotions and their physiological reactivity as well, which in turn supports better mental health outcomes.

Individuals with depression, social anxiety disorder, borderline personality disorder, and autism spectrum disorder tend to have poorer emotional clarity (Demiralp et al., 2012; Erbas et al., 2013; Kashdan & Farmer, 2014). Additionally, exposure to trauma is associated with lower emotional clarity and blunted autonomic responses (Gordis et al., 2010; Heleniak et al., 2016; McLaughlin et al., 2014; Weissman et al., 2020). The transdiagnostic relevance of diminished emotional clarity parallels the aforementioned findings of lower concordance being associated with negative mental health outcomes. Furthermore, studies have shown that individuals with higher alexithymia, a clinical phenomenon characterized by impaired emotional clarity, evidence lower concordance as compared to individuals with lower alexithymia in experimental conditions involving affect and stress inductions using mental imagery tasks and the Trier social stress task (Constantinou et al., 2014; Eastabrook et al., 2013; Peasley-Miklus et al., 2016).

Although these alexithymia studies provide preliminary support for the potential role of emotional clarity in concordance, their reliance on lab-based paradigms for inducing affect and assessing concordance may not generalize to naturally occurring concordance in daily life, including how emotional clarity influences such concordance. Indeed, this limitation characterizes the concordance literature more broadly, with a recent review highlighting the need to conduct concordance studies with ecologically valid assessments in order to assess concordance as affective experiences naturally unfold in response to real-world and idiomatically relevant experiences in daily life (Lougheed et al., 2021). Assessing concordance repeatedly over an extended period of time (e.g., four weeks) allows for greater variability in naturally occurring affective states in terms of type, complexity, intensity, and duration than is possible (or ethical in the case of intensely negative affective states) with lab-based affect induction paradigms. This is important because (1) lab-based affect induction studies typically have focused on a smaller set of high-arousal affective states (e.g., fear, stress), rather than low-arousal ones (e.g., calm); and (2) it has been suggested that pure emotions (i.e., the experience of a single emotion), as are typically the focus of lab-based experimental designs, and mixed emotions (i.e., the experience of multiple emotions simultaneously), such as those often experienced in daily life, differ in both intensity and physiological activity (Kreibig et al., 2013).

To date there have been few studies to investigate concordance in daily life (i.e., utilizing ambulatory measures of physiological activity via smart device and ecological momentary assessment [EMA]). One study found support for concordance between subjective arousal and physiological arousal over a four-week period in a general adult community sample (Van Doren et al., 2021). A second study similarly found support for concordance between valence and arousal of emotion and physiological arousal (Park et al., 2023). Finally, a third study demonstrated that concordance between physiological arousal and specific affective states, including calmness, wakefulness, anger, and mania (Zenker et al., 2021). However, these studies had methodological differences in the investigation of emotional concordance in daily life. Van Doren et al. (2021) focused on self-reported feelings of arousal (e.g., awake, active) rather than affect (e.g., happy, angry). Park et al., (2023) asked participants to select all that apply from four options categorized by valence and arousal of emotion when reporting on how they were feeling (i.e., positive & low, positive & high, negative & low, negative & high), while Zenker et al. (2021) evaluated individual affect states as well as emotional dimensions and psychopathology symptoms. Additionally, the community sample in these studies limits the generalizability of findings to clinical populations in which naturally occurring affective experiences in ecologically valid contexts have been found to differ in prior EMA studies (e.g., as a function of greater anxiety; Schoevers et al., 2021; Seidl et al., 2021).

To expand upon existing findings, the present study examined within-person concordance in an ecologically valid context and explored emotional clarity as a potential moderator in an adolescent clinical sample (i.e., adolescents recently discharged from inpatient psychiatric care due to suicide risk). Given adolescence has been characterized by both an increase in the experience of emotions (Harter & Buddin, 1987; Wintre & Vallance, 1994) and a decrease in the ability to identify emotions, particularly for negative affect states (Barrett et al., 2001; Haas et al., 2019; Kashdan et al., 2010; Nook et al., 2018), this developmental period is particularly relevant to investigate concordance, as well as the relationship between emotional clarity and concordance.

The current study employed EMA to assess subjective affect and wearable physiological data collection to assess electrodermal activity (EDA), an established marker of autonomic arousal (Boucsein, 2012; Venables, 1991), enabling real-time measurement of concordance during a 28-day period. The study aimed 1) to determine whether concordance between physiological activity and individual subjective affective states and composite affect groups, negative affect, positive affect, and high arousal negative affect, respectively, is present at the within-person level in daily life. Based on past findings (Egeren et al., 1971; Grossberg & Wilson, 1968), we hypothesized that concordance will be greater for high arousal affect states compared to low arousal affect states. The study also aimed 2) to examine potential moderation of between-person, trait-level emotional clarity on ecologically assessed concordance between physiological activity and overall composite affect groups. We hypothesized that individuals with greater emotional clarity will have stronger concordance between EDA and affect composite groups.

2. Methods

2.1. Participants

The sample consisted of 31 participants recruited from a pediatric psychiatric inpatient unit. Participants ranged from 13 to 17 years old (M = 15.23, SD = 1.45) and were 67.74 % assigned female at birth. Regarding racial composition, 70.97 % were White, 19.35 % Black, 9.68 % multiracial, and in terms of ethnic composition, 22.58 % were Hispanic. Participants were eligible for participation if they demonstrated English proficiency, had an IQ greater than 69, were not in the custody of Department of Child and Family services, and were not experiencing psychotic symptoms that were severe enough to affect response validity in the study.

2.2. Procedure

This study was approved by the Mass General Brigham Institutional Review Board. At least one parent/guardian provided consent and adolescents also provided assent to participate in the study. Following admission to the pediatric psychiatric inpatient unit, participants completed a baseline assessment that included symptom measures and a trait-level measure of emotional clarity. Upon discharge from the inpatient unit, participants completed a 28-day ambulatory period which included EMA surveys and continuous physiological data collection. Participants completed EMA surveys on smartphones using a HIPAA-compliant application created for EMA research (Catalyst, www.metricwire.com). Signal-contingent EMA surveys were sent five times daily, with the goal of having participants complete at least three of these surveys. The five surveys were to accommodate some participants' limited availability to respond (e.g., if a survey arrived while they were engaged in extracurricular athletic events). Thus, sending five surveys allowed for greater opportunity for participants to meet the goal of three survey completions a day. EMA surveys were sent at random times each day during hours that the participants would typically have access to their phones based on their self-reported sleep time and access to their phone during school. Data from Catalyst were not stored on the participant's device; they were transferred to the research portal via the cloud after survey completion. Data were encrypted during transit and no personal health information or personal identifying information was linked to participant data via the mobile application or research portal. Participants were not able to access or modify their survey responses after completion. EDA data were collected during the 28-day ambulatory period using an Embrace2 wristband that participants were asked to wear whenever possible.

2.3. Measures

2.3.1. Subjective affect

After discharge, participants were prompted five times per day during the 28-day ambulatory assessment period to complete self-report surveys on their smartphones about their subjective affect. Participants completed 15 items adapted from the Positive and Negative Affect Schedule for Children (PANAS-C; Laurent et al., 1999) asking about their momentary affect (e.g., "Right now, how calm do you feel?"; "Right now, how mad do you feel?"). These items were rated on a Likert scale from 0 ("not at all") to 10 ("extremely").

2.3.2. Physiological activity

EDA data were collected continuously during the 28-day ambulatory assessment period using the Empatica Embrace2 wristband (Embrace2 Seizure Monitoring | Smarter Epilepsy Management | Embrace Watch | Empatica, n.d. 2023), an FDA-approved mobile health device. The Embrace2 measures EDA at 4hz using three metal electrodes on the underside of the watch via changes in electrical potential. EDA is characterized by fluctuations in the secretion of sweat from the cutaneous sweat glands which alter the electrical potential on the skin, and which is reflective of activity in the sympathetic nervous system (Horstick et al., 2018). In addition to EDA, the device assesses physical activity (via an accelerometer), geospatial direction (via a gyrometer), and temperature, which collectively help to reduce false positives from EDA signal (e.g., from exercise; Taylor et al., 2015). EDA data from the Embrace2 has been found to predict clinical outcomes, such as suicidal ideation (Kleiman et al., 2021). The Embrace2 employs similar technology and sensors as the E4, a research-grade wearable device also developed by Empatica and which has also been previously validated (Gouverneur et al., 2017; & Milstein and Gordon, 2020; Regalia et al., 2019, 2021). Moreover, the Embrace2 has been recently shown to yield EDA data at a finer resolution than the E4 (Onorati et al., 2021).

2.3.3. Emotional clarity

Emotional clarity was measured using the emotional clarity subscale of the Difficulties in Emotion Regulation Scale (DERS; Gratz, 2001). and consists of five items (e.g., "I have difficulty making sense out of my feelings," "I know exactly how I am feeling"). Each item was rated on a scale of 1 ("almost never") to 5 ("almost always"). Higher scores indicate greater lack of emotional clarity. The DERS clarity subscale had acceptable internal consistency in the sample ($\alpha = .81$).

2.3.4. Mental health symptoms

The PROMIS Depression Pediatric Report, version 2.0. form 8a (Pilkonis et al., 2011, 2014) was used to assess for experiences of depressed mood over the past 7 days and consists of 8 items. Each item was rated on a scale of 1 ("never") to 5 ("almost always"). Total raw scores were converted to T-scores and higher scores indicate greater depressed mood. The PROMIS Depression had acceptable internal consistency in the sample ($\alpha = .92$).

The PROMIS Anxiety Pediatric Report, version 2.0, form 8a (Quinn et al., 2014) was used to assess to symptoms of anxiety over the past 7 days. The PROMIS Anxiety consists of 8 items. Each item was rated on a scale of 1 ("never") to 5 ("almost always"). Total raw scores were converted to T-scores and higher scores indicate greater anxiety. The PROMIS Anxiety had acceptable internal consistency in the sample ($\alpha = .89$).

Suicidal ideation was measured using a modified version of the Suicidal Ideation Questionnaire – Jr. (mSIQ-Jr.; Reynolds, 1987). The mSIQ-Jr. assesses suicidal ideation over the past 30 days. To avoid confounding current with past suicidal ideation, the answer choices "I had this thought before but not in the past month" and "I never had this thought" were replaced with "Not in the past month." Therefore, the mSIQ-Jr. items are scored on a 6-point scale ranging from 0 ("Not in the past month") to 5 ("Almost every day"). Higher scores reflect greater suicidal ideation. The mSIQ-Jr. had acceptable internal consistency in the sample ($\alpha = .95$).

2.4. Analytic strategy

2.4.1. Preparation and feature extraction of skin conductance data

We downloaded data from the Empatica Embrace2 devices and used the following steps to clean the EDA data. First, we removed data that were likely from times when the device was not being worn (i.e., skin temperature was recorded at < 30°C [86°F]). Second, we used the *signal* (Signal developers, 2021) R package to (1) up-sample the data from 4hz to 8hz and (2) reduce noise in the data with a Butterworth filter. In line with other ambulatory monitoring work (Van Doren et al., 2021), we used the filtered EDA data to create an average score of EDA using mean skin conductance level (SCL) in the minute prior to the EMA response.

2.4.2. Affect composite scores

We created composite scores using the affect variables. Specifically, we created composites for negative (anxious, empty, guilty, lonely, mad, sad, scared, and stressed) and positive (calm, excited, happy, hopeful, proud, and excited) affect. We also created a composite consisting of just high-arousal negative affect states (anxious, mad, scared, stressed). We conducted factor analysis in the *lavaan* (Rosseel, 2012) R package to confirm the factor structure of these composites and report the internal consistency at the between- and within-person levels.

2.4.3. Primary analyses

We were interested in two sets of analyses: (1) the main effect between EDA and EMA and (2) the interaction effect between EDA and emotion clarity in predicting EMA ratings of affect. The first set of analyses included individual analyses with each individual affect type as well as composites of negative affect, positive affect, and high arousal negative affect. To reduce the overall number of analyses being considered, the second set of analyses examined cross-level interactions between DERS clarity and the EDA data predicting the emotion composite scores. The emotion composite scores were used in the moderation analyses, given prior literature that broader dimensions are more stable and align best with trait-level moderators, such as emotional clarity (Feldman Barrett & Russell, 1998; Watson & Stanton, 2017; Watson & Tellegen, 1985). All models were multi-level models (responses within people) conducted in the *lme4* r package (Bates et al., 2015). We specified random slopes for all participants to allow for associations to vary across individuals which is recommended for multilevel analyses of within-person dynamic data (Barr, 2013; Bell et al., 2019). All momentary-level variables were person-mean centered prior to analyses.

3. Results

3.1. Descriptive results and factor structure

Descriptive statistics of mental health symptom severity and emotional clarity are shown in Table 1. There was a total of 1,951 EMA responses (M = 63 per participant, SD = 16.83, range = 1 to 73), 556 (28.50 %) of which had EDA data in the 60 seconds prior to the response. Embrace equipment malfunction during the ambulatory period, artifacts in the data leading to exclusion, and participant non-compliance affected the number of EDA observations able to be paired with EMA responses. These are all common challenges in collection of ambulatory psychophysiological data, particularly in adolescents (Boucsein et al., 2012; Healey & Picard, 2005). This rate of 28.50 % for EDA data is reasonably consistent with past research that found a rate of 45.98 % for ambulatory assessments of EDA in adults (i.e., a developmental age group in which a higher rate should be expected), and especially considering this past study evaluated ambulatory EDA data within 60 min (rather than 60 seconds) prior to EMA responses (Kleiman et al., n.d. 2020). The factor structure for the EMA affect composite scores was acceptable for negative affect (α_{within} = .79, $\alpha_{between}$ = .93), positive affect (α_{within} = .82, $\alpha_{between}$ = .96), and high arousal negative affect (α_{within} = .71, $\alpha_{between}$ = .91)

3.2. Main effects

Table 2 shows the results of the main effects analyses. As can be seen from the table, the only significant effects were with "anxious" and "calm" showing the anticipated relationship. EDA was higher when anxiety was higher and lower when calm was higher. Fig. 1 shows the plot of the significant main effect models, which was relatively consistent across participants.

3.3. Interaction effects

Table 3 shows the interaction effects between EDA and emotional clarity in predicting EMA after EDA. There was a significant interaction effect between EDA and emotional clarity in predicting the negative affect composite. When the interaction was decomposed, the relationship between negative affect and EDA was significant for those low (-1 SD) on lack of emotional clarity (*b = 0.03, t* = 2.13, *p* = .034). The simple slopes were not significant for those high on (+1 SD; *b* = −0.02, *t* = −1.39, *p* = .166) or average for (*b* = 0.01, *t* = 0.63, *p* = .531) lack of emotional clarity. In other words, negative affect was significantly (and positively) associated with EDA only when emotional clarity was high. Fig. 2 shows the plot of the significant interaction effect model. There were no significant interaction effects between EDA and emotional clarity in predicting positive affect composite or high arousal negative affect composite.

Table 1
Sample characteristics and descriptive statistics.

	M	SD	Range
Mental Health Symptoms			
PROMIS Depression	67.91	7.80	55.70 – 82.40
PROMIS Anxiety	64.10	10.08	33.50 – 79.30
Modified Suicidal Ideation Questionnaire – Jr.	37.45	20.39	5.00 – 69.00
Emotional Knowledge			
Difficulties in Emotion Regulation Scale – Emotional Clarity	16.97	4.64	7.00 – 25.00

Table 2
Results of regression models examining the relationship between electrodermal activity (EDA) in the minute before an ecological momentary assessment (EMA) prompt and EMA responses.

Dependent variable	Estimate	Std. Error	*P*	*Random Slope Variance* (τ_{11})
Composite models				
Negative affect	0.01	0.01	.61	0.00031
High arousal neg. affect	0.01	0.01	.26	<0.00001
Positive affect	0.01	0.03	.82	0.00396
Negative affect components				
Lonely	-0.03	0.02	.12	0.00007
Anxious	0.04	0.02	.01	0.00001
Scared	-0.01	0.02	.65	0.00055
Mad	0.01	0.01	.69	0.00002
Stressed	0.01	0.02	.42	<0.00001
Guilty	0.02	0.02	.49	0.00356
Sad	0.01	0.02	.77	0.00038
Empty	0.00	0.02	.89	0.00080
Positive affect components				
Calm	-0.03	0.02	.03	0.00004
Excited	0.03	0.02	.09	0.00022
Happy	-0.01	0.03	.71	0.00723
Satisfied	-0.01	0.03	.86	0.00454
Proud	0.01	0.03	.71	0.00328
Hopeful	0.01	0.03	.81	0.00469

Note: Each row corresponds to an individual model with EDA in the minute prior to EMA as the independent variable and the variable in the "dependent variable" column as the dependent variable.

4. Discussion

The current study is one of the first to analyze concordance between momentary individual subjective affect states and physiological arousal via wearable devices in an ecologically valid manner. This study yielded several key findings. First, autonomic arousal as indexed by EDA was positively associated with momentary anxiety and negatively associated with momentary calmness. These findings are consistent with the existing literature on concordance in lab-based, experimental affect induction studies (Brown et al., 2020; Peasley-Miklus et al., 2016; Sommerfeldt et al., 2019), and they expand upon this prior work by finding support for concordance in real-world settings, which capture a broader range of affective experiences as they naturally occur in an individual's daily life (Bolger et al., 2003).

That concordance was found only for the affective states of anxiety and calmness is worth noting. Past studies have predominantly evaluated concordance for broader affect states (e.g., negative affect and positive affect). Although there have been several studies investigating specific affective states within the broader construct of negative affect, the range of these specific affective states investigated is modest. In the limited research that has been done, anxiety is among the negative affect states that has received the most attention. However, findings of concordance for anxiety in lab-based studies have been mixed (Bacow et al., 2010; Ditzen et al., 2007, 2008; Fox et al., 2010; Grace et al., 2022; Jansen et al., 2000; Ringeisen et al., 2019; Uhart et al., 2006). This may be due to the vast majority of studies employing cortisol as their index of

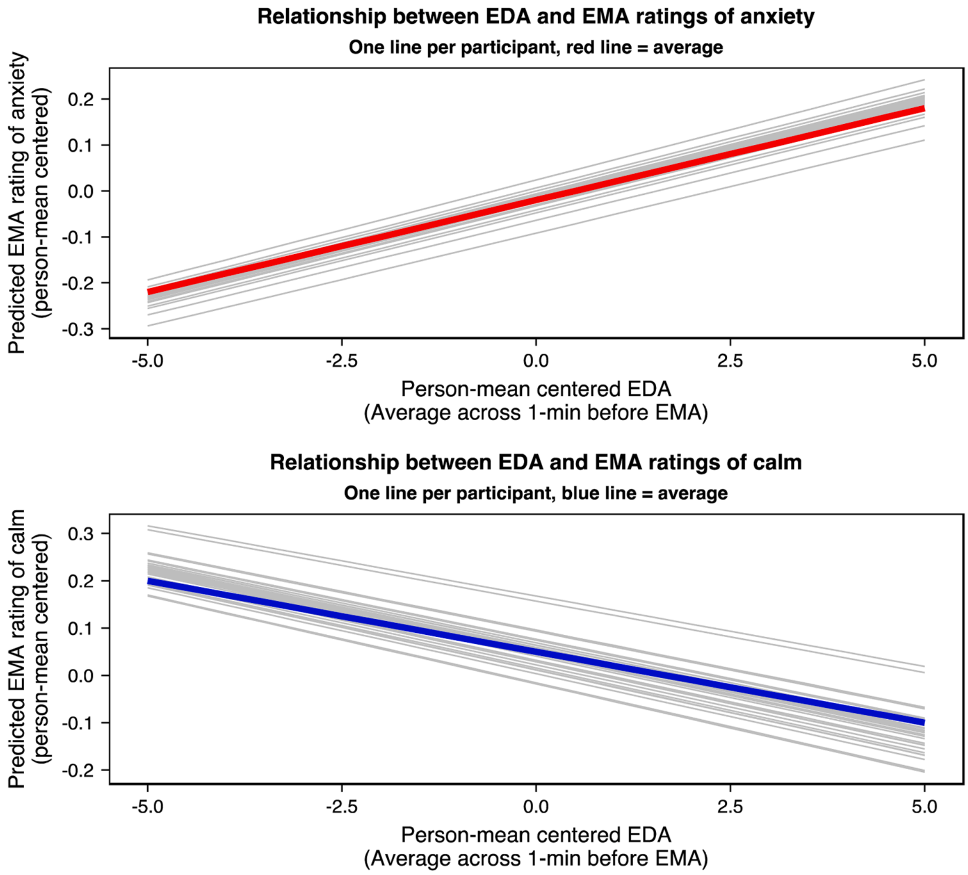

Fig. 1. Plot of significant models of electrodermal activity (EDA) predicting ecological momentary assessment (EMA) responses.

Table 3
Results of the interaction effects between electrodermal activity (EDA) and emotional clarity predicting ecological momentary assessment (EMA) responses.

	DV: All negative affect			DV: High arousal negative affect			DV: Positive Affect		
Predictor	***B***	***95 % CI***	***p***	***B***	***95 % CI***	***p***	***B***	***95 % CI***	***p***
(Intercept)	-0.09	-.52 – .33	.66	-0.13	-.60 – .35	.61	0.21	-.35 – .78	.46
SCL	0.09	.01 – .18	**.03**	0.07	-.02 – .16	.14	-0.08	-.28 – .12	.43
DERS clarity	0.01	-.02 – .03	.68	0	-.02 – .03	.74	-0.01	-.04 – .02	.46
SCL * DERS clarity	-0.01	-.01 – -.00	**.03**	<.001	-.01 – .00	.21	0.01	-.01 – .02	.39
σ^2		1.68			2.27			2.86	
R^2		.01			.01			.01	
$\tau_{00\ ID}$		0.01100			0.00039			0.00456	
$\tau_{11\ ID.filtered\_scale}$		0.00038			0.00002			0.00374	
N_{ID}		31			31			31	
Observations		556			556			556	

physiological arousal, which has been found in the broader psychological literature to yield inconsistent findings, possibly in part a function of the wide variation of methods for sampling cortisol (Incollingo Rodriguez et al., 2015; O'Leary et al., 2016; Slopen et al., 2014; Speer et al., 2019; Zoccola & Dickerson, 2012). Within this context, our focus on EDA as an index of physiological arousal provides unique insight into concordance for anxiety, especially in clinical adolescent samples. Nonetheless, it will be important for future studies to evaluate the replicability of the current finding of concordance before it can be accorded significant weight.

Although relatively little research has been conducted on concordance for specific negative affect states, studies of positive affect states as a general construct are rarer still, and this is particularly the case for specific positive affect states. In the little research that has been done, calm is a positive affect state that has been found to be concordant with physiological arousal (Rimmele et al., 2007). Our findings not only support this prior finding and generalize it to naturalistic settings, but they also demonstrate specificity to feelings of calm among positive affect states, as well as the importance of including more nuanced examinations of specific affect states in addition to broad categories of affect states.

These findings suggest that ambulatory measures of EDA may be more sensitive to moments of affect associated with arousal as opposed to specific affective states (e.g., anger, happiness, sadness). Further examination of concordance across multiple facets of subjective affect (i.e., valence, arousal, and discrete affect states) may help clarify the parameters of how EDA relates to affective experiences, whether autonomic indicators are markers of general activation or emotion-specific experiences. Understanding these nuances may enhance how ambulatory physiological data can be used to characterize affective functioning and emotional knowledge in daily life.

Given the central role of stress in the activation of the autonomic

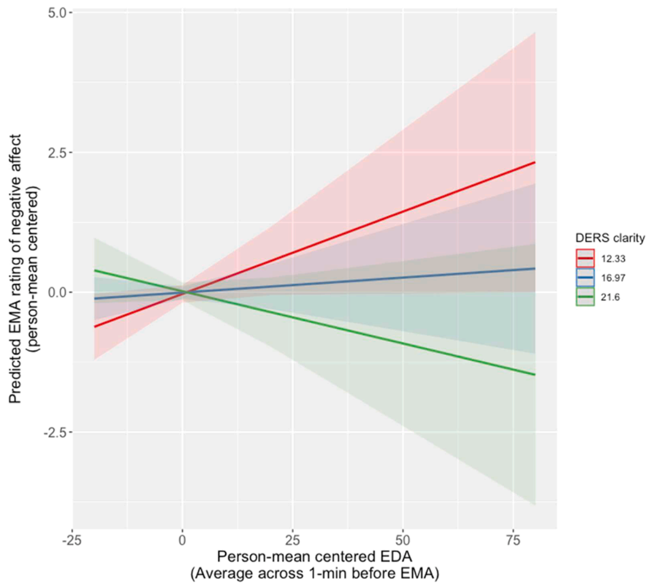

Fig. 2. Plot of electrodermal activity (EDA) and emotional clarity predicting negative affect.

nervous system (Ader et al., 1995), it is particularly interesting to note the lack of concordance between subjective stress and autonomic arousal. Although these findings may initially seem counterintuitive, our findings are consistent with existing literature which largely demonstrated discordance between subjective stress and physiological arousal (Becker et al., 2023; Campbell & Ehlert, 2012; Dalile et al., 2022). Additionally, studies that did find evidence of concordance tend to feature community samples or found concordance to be negatively associated with psychopathology (Dohmen et al., 2023; Sommerfeldt et al., 2019; Wiglesworth et al., 2023). Our focus, in contrast, on a psychiatrically acute sample may therefore account in part for our non-significant finding for subjective stress. One framework that may help to understand these results is the Adaptive Calibration Model of stress responsivity which posits that physiological stress response systems are influenced by life experiences and individual characteristics (Del Giudice et al., 2011). Psychiatrically acute samples, such as ours, may exhibit blunted or exaggerated stress response systems which do not align with subjective stress (Agorastos et al., 2020; Teed et al., 2022; Williamson et al., 2015). This theoretical framework therefore accounts for our findings of a lack of concordance between EDA and stress and highlights the complex and diverse autonomic processes, particularly within clinical populations.

Another key finding of the current study is that difficulties in identifying one's current affect experiences appear to affect the concordance between physiological arousal and momentary affect differently based on the valence of the affect. Specifically, when compared to adolescents with low emotional clarity, those with high emotional clarity had a stronger relationship between overall momentary negative affect and EDA. This moderating effect of emotional clarity appears to be specific to negative affect, as it was not observed for positive affect. This interesting finding regarding emotional clarity may provide unique insight into the pattern seen in prior literature demonstrating greater concordance in community samples and positive associations between concordance and mental well-being. Indeed, mounting evidence suggesting that emotional clarity is a transdiagnostic factor related to multiple forms of psychopathology may account for this pattern of findings (Demiralp et al., 2012; Erbas et al., 2013; Gordis et al., 2010; Heleniak et al., 2016; Kashdan & Farmer, 2014; McLaughlin et al., 2014; Weissman et al., 2020).

The present findings have potential clinical implications. Given findings that individuals with higher emotional clarity demonstrated greater concordance between EDA and overall negative affect, there may be benefit in focusing on emotional clarity in interventions. Although no causal relationships can be inferred from the current study, targeting emotional clarity may have the potential to improve well-being among adolescents through emotional concordance, given prior findings that concordance is associated with greater well-being (Brown et al., 2020; Mauss et al., 2005; Sommerfeldt et al., 2019). A recent systematic review found that mindfulness-based interventions are able to increase emotional clarity across a wide age range, including adolescents, particularly those initially low in emotional clarity, demonstrating that emotional clarity is modifiable during this development period and could be a target of treatments (Cooper et al., 2018). A second clinical implication of our findings is that concordance between ambulatory subjective affect and physiological arousal could serve as an indicator of emotional knowledge in everyday life which may be a useful paradigm for monitoring treatment progress and assessing changes in risk, which is central to evidence-based care (Lewis et al., 2019). This would be particularly relevant if concordance within real-world contexts accurately indexes mental health symptoms or predicts future psychopathology. Given that the current study did not evaluate how concordance relates to current symptoms or prospective outcomes, this implication is based on theoretical information considering current findings of emotional clarity as a moderator of concordance and prior findings that emotional clarity is associated with better mental health outcomes. Further evaluation of how concordance in daily life and the emotional clarity-concordance relationship is related to mental health is needed.

4.1. Limitations and future directions

The current study is not without its limitations. The focus on EDA as our index of physiological arousal was strategic in that autonomic arousal is non-specific with regards to emotional valence and thus is particularly apt for assessing physiological concordance with both positive and negative momentary affect. Nonetheless, it will be important for future studies to complement our findings by evaluating whether other indices of physiological arousal may provide replication or differ in their relation to momentary affect. For example, heart rate, another common index of physiological arousal in the emotion literature, may complement our current findings in providing additional insight in physiological concordance with subjective emotional states, given that heart rate reflects not only the sympathetic nervous system but also the parasympathetic nervous system. Additionally, we focused on adolescents because of the specific relevance of emotional clarity to this age group from a developmental perspective (i.e., emotional clarity decreases during adolescence; Haas et al., 2019; Nook et al., 2018). It would be important, however, to evaluate whether current findings generalize to older age groups (i.e., adults), in which emotional clarity tends to be sharper, and subjective emotional experiences are often more stable and nuanced (Carstensen et al., 2011).. Additionally, although these data are novel in allowing for within-person analyses of concordance in everyday life, the results should be interpreted within the context of the relatively small sample size and limited observations for evaluating concordance. Given these considerations, we were mindful to include information to convey the precision of our estimates. Therefore, it is important for future studies to replicate these analyses with larger samples and more EDA-EMA observations. Finally, although our psychiatric sample heightens clinical relevance of our findings, it will be important for future research to evaluate how clinical and non-clinical populations differ in their emotional concordance during daily life. Further investigation of potential moderators is important to better understand for whom and in what conditions emotional concordance may exist.

Future work in this area should aim to expand on the current findings to further elucidate the experience of subjective affect and physiological concordance in daily life. Future studies should seek to identify additional ideally modifiable trait-level moderators that may impact the strength of concordance. Additionally, future research is needed to evaluate how ecologically valid concordance is associated with mental health outcomes and other aspects of well-being and functioning within longitudinal designs.

Declaration of generative AI and AI-assisted technologies in the writing process

The authors did not use any AI or AI-assisted technologies during the preparation of this work.

Statements and declarations

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CRediT authorship contribution statement

Margarid R. Turnamian: Writing – original draft, Validation, Software, Project administration, Methodology, Investigation, Conceptualization. **Evan M. Kleiman:** Writing – review & editing, Visualization, Supervision, Formal analysis, Conceptualization. **Taylor A. Burke:** Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition. **Richard T. Liu:** Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

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References

Ader, R., Cohen, N., Felten, D., 1995. Psychoneuroimmunology: interactions between the nervous system and the immune system. Lancet (Lond. Engl.) 345 (8942), 99–103. https://doi.org/10.1016/s0140-6736(95)90066-7.

Agorastos, A., Stiedl, O., Heinig, A., Sommer, A., Hager, T., Freundlieb, N., Schruers, K. R., Demiralay, C., 2020. Inverse autonomic stress reactivity in depressed patients with and without prior history of depression. J. Psychiatr. Res. 131, 114–118. https://doi.org/10.1016/j.jpsychires.2020.09.016.

Bacow, T.L., May, J.E., Choate-Summers, M., Pincus, D.B., Mattis, S.G., 2010. Concordance between measures of anxiety and physiological arousal following treatment of panic disorder in adolescence. Child Fam. Behav. Ther. 32 (4), 322–333. https://doi.org/10.1080/07317107.2010.515843.

Barr, D.J., 2013. Random effects structure for testing interactions in linear mixed-effects models. Front. Psychol. 4, 328. https://doi.org/10.3389/fpsyg.2013.00328.

Barrett, L.F., Gross, J., Christensen, T.C., Benvenuto, M., 2001. Knowing what you're feeling and knowing what to do about it: Mapping the relation between emotion differentiation and emotion regulation. Cogn. Emot. 15 (6), 713–724. https://doi.org/10.1080/02699930143000239.

Bates, D., Mächler, M., Bolker, B., Walker, S., 2015. Fitting linear mixed-effects models using lme4. J. Stat. Softw. 67 (1), 1–48. https://doi.org/10.18637/jss.v067.i01.

Becker, S., Spinath, B., Ditzen, B., Dörfler, T., 2023. Psychological stress = physiological stress?: An experimental study with prospective teachers. J. Psychophysiol. 37 (1), 12–24. https://doi.org/10.1027/0269-8803/a000301.

Bell, A., Fairbrother, M., Jones, K., 2019. Fixed and random effects models: making an informed choice. Qual. Quant. 53 (2), 1051–1074. https://doi.org/10.1007/s11135-018-0802-x.

Bolger, N., Davis, A., Rafaeli, E., 2003. Diary methods: capturing life as it is lived. Annu. Rev. Psychol. 54 (1), 579–616. https://doi.org/10.1146/annurev.psych.54.101601.145030.

Boucsein, W., 2012. Electrodermal Activity. Springer US. https://doi.org/10.1007/978-1-4614-1126-0.

Brown, C.L., Van Doren, N., Ford, B.Q., Mauss, I.B., Sze, J.W., Levenson, R.W., 2020. Coherence between subjective experience and physiology in emotion: Individual differences and implications for well-being. Emotion 20 (5), 818–829. https://doi.org/10.1037/emo0000579.

Campbell, J., Ehlert, U., 2012. Acute psychosocial stress: does the emotional stress response correspond with physiological responses? Psychoneuroendocrinology 37 (8), 1111–1134. https://doi.org/10.1016/j.psyneuen.2011.12.010.

Carstensen, L.L., Turan, B., Scheibe, S., Ram, N., Ersner-Hershfield, H., Samanez-Larkin, G.R., Brooks, K.P., Nesselroade, J.R., 2011. Emotional experience improves with age: evidence based on over 10 years of experience sampling. Psychol. Aging 26 (1), 21–33. https://doi.org/10.1037/a0021285.

Coan, J.A., 2010. Emergent ghosts of the emotion machine. Emot. Rev. 2 (3), 274–285. https://doi.org/10.1177/1754073910361978.

Coffey, E., Berenbaum, H., Kerns, J.G., 2003. The dimensions of emotional intelligence, alexithymia, and mood awareness: associations with personality and performance on an emotional stroop task. Cogn. Emot. 17 (4), 671–679. https://doi.org/10.1080/02699930302304.

Constantinou, E., Panayiotou, G., Theodorou, M., 2014. Emotion processing deficits in alexithymia and response to a depth of processing intervention. Biol. Psychol. 103, 212–222. https://doi.org/10.1016/j.biopsycho.2014.09.011.

Cooper, D., Yap, K., Batalha, L., 2018. Mindfulness-based interventions and their effects on emotional clarity: a systematic review and meta-analysis. J. Affect. Disord. 235, 265–276. https://doi.org/10.1016/j.jad.2018.04.018.

Dalile, B., La Torre, D., Verbeke, K., Van Oudenhove, L., Vervliet, B., 2022. When the mind says one thing, but the HPA axis says another: lack of coherence between subjective and neuroendocrine stress response trajectories in healthy men. Psychoneuroendocrinology 139, 105692. https://doi.org/10.1016/j.psyneuen.2022.105692.

Darwin, C., 1872. The descent of man, and selection in relation to sex. D. Appleton & Company. Vol. 2.

Del Giudice, M., Ellis, B.J., Shirtcliff, E.A., 2011. The adaptive calibration model of stress responsivity. Neurosci. Biobehav. Rev. 35 (7), 1562–1592. https://doi.org/10.1016/j.neubiorev.2010.11.007.

Demiralp, E., Thompson, R.J., Mata, J., Jaeggi, S.M., Buschkuehl, M., Barrett, L.F., Ellsworth, P.C., Demiralp, M., Hernandez-Garcia, L., Deldin, P.J., Gotlib, I.H., Jonides, J., 2012. Feeling blue or turquoise? Emotional differentiation in major depressive disorder. Psychol. Sci. 23 (11), 1410–1416. https://doi.org/10.1177/0956797612444903.

Ditzen, B., Neumann, I.D., Bodenmann, G., Von Dawans, B., Turner, R.A., Ehlert, U., Heinrichs, M., 2007. Effects of different kinds of couple interaction on cortisol and heart rate responses to stress in women. Psychoneuroendocrinology 32 (5), 565–574. https://doi.org/10.1016/j.psyneuen.2007.03.011.

Ditzen, B., Schmidt, S., Strauss, B., Nater, U.M., Ehlert, U., Heinrichs, M., 2008. Adult attachment and social support interact to reduce psychological but not cortisol responses to stress. J. Psychosom. Res. 64 (5), 479–486. https://doi.org/10.1016/j.jpsychores.2007.11.011.

Dohmen, T., Rohde, I.M.T., Stolp, T., 2023. Tournament incentives affect perceived stress and hormonal stress responses. Exp. Econ. https://doi.org/10.1007/s10683-023-09801-1.

Eastabrook, J.M., Lanteigne, D.M., Hollenstein, T., 2013. Decoupling between physiological, self-reported, and expressed emotional responses in alexithymia. Personal. Individ. Differ. 55 (8), 978–982. https://doi.org/10.1016/j.paid.2013.08.001.

Egeren, L.F., Feather, B.W., Hein, P.L., 1971. Desensiization of phobias: some psychophysiological propositions. Psychophysiology 8 (2), 213–228. https://doi.org/10.1111/j.1469-8986.1971.tb00452.x.

Ekman, P., 1977. Biological and cultural contribution to body and facial movement. Anthropology of the Body. Academic Press, pp. 39–84, 1st ed., pp.

Ekman, P., 1992. An argument for basic emotions. Cogn. Emot. 6 (3–4), 169–200. https://doi.org/10.1080/02699939208411068.

Embrace2 Seizure Monitoring | Smarter Epilepsy Management | Embrace Watch | Empatica. (n.d.). Retrieved July 18, 2023, from https://www.empatica.com/embrace2/.

Erbas, Y., Ceulemans, E., Boonen, J., Noens, I., Kuppens, P., 2013. Emotion differentiation in autism spectrum disorder. Res. Autism Spectr. Disord. 7 (10), 1221–1227. https://doi.org/10.1016/j.rasd.2013.07.007.

Feldman Barrett, L., Russell, J.A., 1998. Independence and bipolarity in the structure of current affect. J. Personal. Soc. Psychol. 74 (4), 967–984. https://doi.org/10.1037/0022-3514.74.4.967.

Fox, E., Cahill, S., Zougkou, K., 2010. Preconscious processing biases predict emotional reactivity to stress. Biol. Psychiatry 67 (4), 371–377. https://doi.org/10.1016/j.biopsych.2009.11.018.

Gordis, E.B., Feres, N., Olezeski, C.L., Rabkin, A.N., Trickett, P.K., 2010. Skin conductance reactivity and respiratory sinus arrhythmia among maltreated and comparison youth: relations with aggressive behavior. J. Pediatr. Psychol. 35 (5), 547–558. https://doi.org/10.1093/jpepsy/jsp113.

Gouverneur, P., Jaworek-Korjakowska, J., Köping, L., Shirahama, K., Kleczek, P., & Grzegorzek, M. (2017). Classification of physiological data for emotion recognition. In L. Rutkowski, M. Korytkowski, R. Scherer, R. Tadeusiewicz, L. A. Zadeh, & J. M. Zurada (Eds.), Artificial Intelligence and Soft Computing (pp. 619–627). Springer International Publishing. https://doi.org/10.1007/978-3-319-59063-9_55.

Grace, C., Heinrichs, M., Koval, P., Gorelik, A., von Dawans, B., Terrett, G., Rendell, P., Labuschagne, I., 2022. Concordance in salivary cortisol and subjective anxiety to the trier social stress test in social anxiety disorder. Biol. Psychol. 175, 108444. https://doi.org/10.1016/j.biopsycho.2022.108444.
Gratz, K.L., 2001. Measurement of deliberate self-harm: preliminary data on the deliberate self-harm inventory. J. Psychopathol. Behav. Assess. 23 (4), 253–263. https://doi.org/10.1023/A:1012779403943.
Grossberg, J.M., Wilson, H.K., 1968. Physiological changes accompanying the visualization of fearful and neutral situations. J. Personal. Soc. Psychol. 10 (2), 124–133. https://doi.org/10.1037/h0026337.
Haas, L.M., McArthur, B.A., Burke, T.A., Olino, T.M., Abramson, L.Y., Alloy, L.B., 2019. Emotional clarity development and psychosocial outcomes during adolescence. Emot. (Wash. D.C.) 19 (4), 563–572. https://doi.org/10.1037/emo0000452.
Haliczer, L.A., Park, Y., Turnamian, M.R., Cetinkaya, D., DeCaro, S.A., Kleiman, E.M., Burke, T.A., Liu, R.T., 2025. A multi-method evaluation of emotional processing in prospectively predicting suicidal ideation trajectories in adolescents post-psychiatric hospitalization. Psychol. Med. 55. https://doi.org/10.1017/S0033291725101426 e269.
Harter, S., Buddin, B.J., 1987. Children's understanding of the simultaneity of two emotions: a five-stage developmental acquisition sequence. Dev. Psychol. 23 (3), 388–399. https://doi.org/10.1037/0012-1649.23.3.388.
Hastings, P.D., Nuselovici, J.N., Klimes-Dougan, B., Kendziora, K.T., Usher, B.A., Ho, M. R., Zahn-Waxler, C., 2009. Dysregulated coherence of subjective and cardiac emotional activation in adolescents with internalizing and externalizing problems. J. Child Psychol. Psychiatry 50 (11), 1348–1356. https://doi.org/10.1111/j.1469-7610.2009.02159.x.
Healey, J.A., Picard, R.W., 2005. Detecting stress during real-world driving tasks using physiological sensors. IEEE Trans. Intell. Transp. Syst. 6 (2), 156–166. https://doi.org/10.1109/TITS.2005.848368.
Heine, C., Dufner, M., 2025. How aware are people of their current affect? A physiology-based investigation of affective awareness. Emotion 25 (5), 1195–1206. https://doi.org/10.1037/emo0001487.
Heleniak, C., McLaughlin, K.A., Ormel, J., Riese, H., 2016. Cardiovascular reactivity as a mechanism linking child trauma to adolescent psychopathology. Biol. Psychol. 120, 108–119. https://doi.org/10.1016/j.biopsycho.2016.08.007.
Horstick, J., Siebers, S., Backhaus, C., 2018. Examination of the Skin Conductance Level (SCL) as an index of the activity of the sympathetic nervous system for application in the continous blood pressure measurement. Int. J. Biomed. Eng. Sci. 5, 01–11. https://doi.org/10.5121/ijbes.2018.5201.
Hu, T., Zhang, D., Wang, J., Mistry, R., Ran, G., Wang, X., 2014. Relation between emotion regulation and mental health: a meta-analysis review. Psychol. Rep. 114 (2), 341–362. https://doi.org/10.2466/03.20.PR0.114k22w4.
Incollingo Rodriguez, A.C., Epel, E.S., White, M.L., Standen, E.C., Seckl, J.R., Tomiyama, A.J, 2015. Hypothalamic-pituitary-adrenal axis dysregulation and cortisol activity in obesity: a systematic review. Psychoneuroendocrinology 62, 301–318. https://doi.org/10.1016/j.psyneuen.2015.08.014.
Jansen, L.M., Gispen-de Wied, C.C., Kahn, R.S., 2000. Selective impairments in the stress response in schizophrenic patients. Psychopharmacology 149 (3), 319–325. https://doi.org/10.1007/s002130000381.
Kashdan, T.B., Barrett, L.F., McKnight, P.E., 2015. Unpacking emotion differentiation: transforming unpleasant experience by perceiving distinctions in negativity. Curr. Dir. Psychol. Sci. 24 (1), 10–16. https://doi.org/10.1177/0963721414550708.
Kashdan, T.B., Farmer, A.S., 2014. Differentiating emotions across contexts: comparing adults with and without social anxiety disorder using random, social interaction, and daily experience sampling. Emot. (Wash. D.C.) 14 (3), 629–638. https://doi.org/10.1037/a0035796.
Kashdan, T.B., Ferssizidis, P., Collins, R.L., Muraven, M., 2010. Emotion differentiation as resilience against excessive alcohol use: An ecological momentary assessment in underage social drinkers. Psychol. Sci. 21 (9), 1341–1347. https://doi.org/10.1177/0956797610379863.
Kleiman, E.M., Bentley, K.H., Maimone, J.S., Lee, H.-I.S., Kilbury, E.N., Fortgang, R.G., Zuromski, K.L., Huffman, J.C., Nock, M.K., 2021. Can passive measurement of physiological distress help better predict suicidal thinking? Transl. Psychiatry 11 (1), 611. https://doi.org/10.1038/s41398-021-01730-y.
Kleiman, E.M., Zuromski, K.L., Ruork, A., Kelly, F., Bentley, K.H., Nock, M.K., Rizvi, S.L., 2020. Feasibility of collecting wearable data during smartphone-delivered psychological interventions. n.d.. Under Review.
Kreibig, S.D., Samson, A.C., Gross, J.J., 2013. The psychophysiology of mixed emotional states. Psychophysiology 50 (8), 799–811. https://doi.org/10.1111/psyp.12064.
Laurent, J., Catanzaro, S.J., Rudolph, K.D., Joiner, T.E., Potter, K.I., Lambert, S., Osborne, L., Gathright, T., 1999. A measure of positive and negative affect for children: scale development and preliminary validation. Psychol. Assess. 11 (3), 326–338. https://doi.org/10.1037/1040-3590.11.3.326.
Levenson, R.W., 1994. Human emotion: a functional view. The nature of emotion: Fundamental questions. Oxford University Press, pp. 123–126.
Levenson, R.W., 2014. The autonomic nervous system and emotion. Emot. Rev. 6 (2), 100–112. https://doi.org/10.1177/1754073913512003.
Lewis, C.C., Boyd, M., Puspitasari, A., Navarro, E., Howard, J., Kassab, H., Hoffman, M., Scott, K., Lyon, A., Douglas, S., Simon, G., Kroenke, K., 2019. Implementing measurement-based care in behavioral health: a review. JAMA Psychiatry 76 (3), 324. https://doi.org/10.1001/jamapsychiatry.2018.3329.
Lougheed, J.P., Vlisides-Henry, R.D., Crowell, S.E., 2021. Advancing models and methods of emotional concordance. Biol. Psychol. 162, 108112. https://doi.org/10.1016/j.biopsycho.2021.108112.
Mauss, I.B., Levenson, R.W., McCarter, L., Wilhelm, F.H., Gross, J.J., 2005. The tie that binds? Coherence among emotion experience, behavior, and physiology. Emotion 5 (2), 175–190. https://doi.org/10.1037/1528-3542.5.2.175.
McLaughlin, K.A., Sheridan, M.A., Alves, S., Mendes, W.B., 2014. Child maltreatment and autonomic nervous system reactivity: Identifying dysregulated stress reactivity patterns by using the biopsychosocial model of challenge and threat. Psychosom. Med. 76 (7), 538–546. https://doi.org/10.1097/PSY.0000000000000098.
Milstein, N., Gordon, I., 2020. Validating measures of electrodermal activity and heart rate variability derived from the empatica E4 utilized in research settings that involve interactive Dyadic states. Front. Behav. Neurosci. 14. https://www.frontiersin.org/articles/10.3389/fnbeh.2020.00148.
Nook, E.C., Sasse, S.F., Lambert, H.K., McLaughlin, K.A., Somerville, L.H., 2018. The nonlinear development of emotion differentiation: granular emotional experience is low in adolescence. Psychol. Sci. 29 (8), 1346–1357. https://doi.org/10.1177/0956797618773357.
O'Leary, K., O'Neill, S., Dockray, S., 2016. A systematic review of the effects of mindfulness interventions on cortisol. J. Health Psychol. 21 (9), 2108–2121. https://doi.org/10.1177/1359105315569095.
Onorati, F., Regalia, G., Caborni, C., LaFrance, W.C., Blum, A.S., Bidwell, J., De Liso, P., El Atrache, R., Loddenkemper, T., Mohammadpour-Touserkani, F., Sarkis, R.A., Friedman, D., Jeschke, J., Picard, R., 2021. Prospective study of a multimodal convulsive seizure detection wearable system on pediatric and adult patients in the Epilepsy monitoring unit. Front. Neurol. 12, 724904. https://doi.org/10.3389/fneur.2021.724904.
Park, Y., Gordon, A.M., Mendes, W.B., 2023. Age differences in physiological reactivity to daily emotional experiences. Affect. Sci. 4 (3), 487–499. https://doi.org/10.1007/s42761-023-00207-z.
Peasley-Miklus, C.E., Panayiotou, G., Vrana, S.R., 2016. Alexithymia predicts arousal-based processing deficits and discordance between emotion response systems during emotional imagery. Emotion 16 (2), 164–174. https://doi.org/10.1037/emo0000086.
Pilkonis, P.A., Choi, S.W., Reise, S.P., Stover, A.M., Riley, W.T., Cella, D., PROMIS Cooperative Group, 2011. Item banks for measuring emotional distress from the patient-reported outcomes measurement information system (PROMIS®): depression. Anxiety Anger, Assess. 18 (3), 263–283. https://doi.org/10.1177/1073191111411667.
Pilkonis, P.A., Yu, L., Dodds, N.E., Johnston, K.L., Maihoefer, C.C., Lawrence, S.M., 2014. Validation of the depression item bank from the patient-reported outcomes measurement information system (PROMIS®) in a three-month observational study. J. Psychiatr. Res. 56, 112–119. https://doi.org/10.1016/j.jpsychires.2014.05.010.
Quinn, H., Thissen, D., Liu, Y., Magnus, B., Lai, J.-S., Amtmann, D., Varni, J.W., Gross, H. E., DeWalt, D.A., 2014. Using item response theory to enrich and expand the PROMIS® pediatric self report banks. Health Qual. Life Outcomes 12 (1), 160. https://doi.org/10.1186/s12955-014-0160-x.
Regalia, G., Gerboni, G., Migliorini, M., Lai, M., Pham, J., Puri, N., Pavlova, M.K., Picard, R.W., Sarkis, R.A., Onorati, F., 2021. Sleep assessment by means of a wrist actigraphy-based algorithm: Agreement with polysomnography in an ambulatory study on older adults. Chronobiol. Int. 38 (3), 400–414. https://doi.org/10.1080/07420528.2020.1835942.
Regalia, G., Onorati, F., Lai, M., Caborni, C., Picard, R.W., 2019. Multimodal wrist-worn devices for seizure detection and advancing research: focus on the Empatica wristbands. Epilepsy Res. 153, 79–82. https://doi.org/10.1016/j.eplepsyres.2019.02.007.
Reynolds, W.M., 1987. About my Life: SIQ-JR Form HS. Psychological Assessment Resources.
Rimmele, U., Zellweger, B.C., Marti, B., Seiler, R., Mohiyeddini, C., Ehlert, U., Heinrichs, M., 2007. Trained men show lower cortisol, heart rate and psychological responses to psychosocial stress compared with untrained men. Psychoneuroendocrinology 32 (6), 627–635. https://doi.org/10.1016/j.psyneuen.2007.04.005.
Ringeisen, T., Lichtenfeld, S., Becker, S., Minkley, N., 2019. Stress experience and performance during an oral exam: the role of self-efficacy, threat appraisals, anxiety, and cortisol. Anxiety Stress Coping 32 (1), 50–66. https://doi.org/10.1080/10615806.2018.1528528.
Rosseel, Y., 2012. lavaan: an R package for structural equation modeling. J. Stat. Softw. 48 (2), 1–36.
Schoevers, R.A., van Borkulo, C.D., Lamers, F., Servaas, M.N., Bastiaansen, J.A., Beekman, A.T.F., van Hemert, A.M., Smit, J.H., Penninx, B.W.J.H., Riese, H., 2021. Affect fluctuations examined with ecological momentary assessment in patients with current or remitted depression and anxiety disorders. Psychol. Med. 51 (11), 1906–1915. https://doi.org/10.1017/S0033291720000689.
Seidl, E., Venz, J., Ollmann, T.M., Voss, C., Hoyer, J., Pieper, L., Beesdo-Baum, K., 2021. How current and past anxiety disorders affect daily life in adolescents and young adults from the general population-An epidemiological study with ecological momentary assessment. Depress. Anxiety 38 (3), 272–285. https://doi.org/10.1002/da.23133.
Siegel, E.H., Sands, M.K., Van den Noortgate, W., Condon, P., Chang, Y., Dy, J., Quigley, K.S., Barrett, L.F., 2018. Emotion fingerprints or emotion populations? A meta-analytic investigation of autonomic features of emotion categories. Psychol. Bull. 144 (4), 343–393. https://doi.org/10.1037/bul0000128.
Signal developers. (2021). signal: Signal processing (Version 0.7-7) [Computer software]. http://r-forge.r-project.org/projects/signal/.
Slopen, N., McLaughlin, K.A., Shonkoff, J.P., 2014. Interventions to improve cortisol regulation in children: a systematic review. Pediatrics 133 (2), 312–326. https://doi.org/10.1542/peds.2013-1632.

Sommerfeldt, S.L., Schaefer, S.M., Brauer, M., Ryff, C.D., Davidson, R.J., 2019. Individual differences in the association between subjective stress and heart rate are related to psychological and physical well-being. Psychol. Sci. 30 (7), 1016–1029. https://doi.org/10.1177/0956797619849555.

Speer, K.E., Semple, S., Naumovski, N., D'Cunha, N.M., McKune, A.J., 2019. HPA axis function and diurnal cortisol in post-traumatic stress disorder: a systematic review. Neurobiol. Stress 11, 100180. https://doi.org/10.1016/j.ynstr.2019.100180.

Boucsein, W., Fowles, D.C., Grimnes, S., Ben-Shakhar, G., roth, W.T., Dawson, M.E., Filion, D.L., Society for Psychophysiological Research Ad Hoc Committee on Electrodermal Measures, 2012. Publication recommendations for electrodermal measurements. Psychophysiology 49 (8), 1017–1034. https://doi.org/10.1111/j.1469-8986.2012.01384.x.

Sze, J.A., Gyurak, A., Yuan, J.W., Levenson, R.W., 2010. Coherence between emotional experience and physiology: does body awareness training have an impact? Emotion 10 (6), 803–814. https://doi.org/10.1037/a0020146.

Taylor, S., Jaques, N., Chen, W., Fedor, S., Sano, A., Picard, R., 2015. Automatic identification of artifacts in electrodermal activity data. In: Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society, pp. 1934–1937. https://doi.org/10.1109/EMBC.2015.7318762. Annual International Conference, 2015.

Teed, A.R., Feinstein, J.S., Puhl, M., Lapidus, R.C., Upshaw, V., Kuplicki, R.T., Bodurka, J., Ajijola, O.A., Kaye, W.H., Thompson, W.K., Paulus, M.P., Khalsa, S.S., 2022. Association of generalized anxiety disorder with autonomic hypersensitivity and blunted ventromedial prefrontal cortex activity during peripheral adrenergic stimulation: a randomized clinical trial. JAMA Psychiatry 79 (4), 323. https://doi.org/10.1001/jamapsychiatry.2021.4225.

Uhart, M., Oswald, L., McCaul, M.E., Chong, R., Wand, G.S., 2006. Hormonal responses to psychological stress and family history of alcoholism. Neuropsychopharmacol.: Off. Publ. Am. Coll. Neuropsychopharmacol. 31 (10), 2255–2263. https://doi.org/10.1038/sj.npp.1301063.

Van Doren, N., Dickens, C.N., Benson, L., Brick, T.R., Gatzke-Kopp, L., Oravecz, Z., 2021. Capturing emotion coherence in daily life: Using ambulatory physiology measures and ecological momentary assessments to examine within-person associations and individual differences. Biol. Psychol. 162, 108074. https://doi.org/10.1016/j.biopsycho.2021.108074.

Venables, P.H., 1991. Autonomic activity. Ann. N. Y. Acad. Sci. 620, 191–207. https://doi.org/10.1111/j.1749-6632.1991.tb51584.x.

Watson, D., Stanton, K., 2017. Emotion blends and mixed emotions in the hierarchical structure of affect. Emot. Rev. 9 (2), 99–104. https://doi.org/10.1177/1754073916639659.

Watson, D., Tellegen, A., 1985. Toward a consensual structure of mood. Psychol. Bull. 98 (2), 219–235. https://doi.org/10.1037/0033-2909.98.2.219.

Weissman, D.G., Nook, E.C., Dews, A.A., Miller, A.B., Lambert, H.K., Sasse, S.F., Somerville, L.H., McLaughlin, K.A., 2020. Low emotional awareness as a transdiagnostic mechanism underlying psychopathology in adolescence. Clin. Psychol. Sci. 8 (6), 971–988. https://doi.org/10.1177/2167702620923649.

Wiglesworth, A., Butts, J., Carosella, K.A., Mirza, S., Papke, V., Bendezú, J.J., Klimes-Dougan, B., Cullen, K.R., 2023. Stress system concordance as a predictor of longitudinal patterns of resilience in adolescence. Dev. Psychopathol. 1–18. https://doi.org/10.1017/S0954579423000731.

Williamson, J.B., Porges, E.C., Lamb, D.G., Porges, S.W., 2015. Maladaptive autonomic regulation in PTSD accelerates physiological aging. Front. Psychol. 5, 1571. https://doi.org/10.3389/fpsyg.2014.01571.

Wintre, M.G., Vallance, D.D., 1994. A developmental sequence in the comprehension of emotions: Intensity, multiple emotions, and valence. Dev. Psychol. 30 (4), 509–514. https://doi.org/10.1037/0012-1649.30.4.509.

Zenker, M., Venz, J., Koenig, J., Voss, C., Beesdo-Baum, K., Pieper, L., 2021. Evidence for the association between physiological and emotional states in adolescents and young adults without psychopathology under ecologically valid conditions. Psychophysiology 58 (10). https://doi.org/10.1111/psyp.13902.

Zoccola, P.M., Dickerson, S.S., 2012. Assessing the relationship between rumination and cortisol: a review. J. Psychosom. Res. 73 (1), 1–9. https://doi.org/10.1016/j.jpsychores.2012.03.007.