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How Aware Are People of Their Current Affect? A Physiology-Based Investigation of Affective Awareness

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The assumption that people differ in *affective awareness* (i.e., the extent to which a person's subjective affective experience matches their affective bodily state) is central to emotional competence. To test this assumption empirically, we used a physiology-based approach to investigate individual differences in affective awareness. Participants (N = 255) viewed 76 pictures with affective content and rated their experienced affect. Facial muscle activity during picture presentation was assessed via electromyography (EMG) as a direct physiological measure of affective reactions. We used a multilevel model to quantify affective awareness as the strength of the intraindividual relationship between a person's EMG reactions and affect ratings. This relationship was positive on average and differed significantly between participants. These individual differences in affective awareness were reliable and stable over time. Affective awareness was higher for women than for men and went along with generally strong affective EMG reactivity and better socioemotional abilities.

Keywords: emotional awareness, alexithymia, emotional abilities, facial expressions, electromyography

Consider a couple having an argument. In the heat of the debate, the husband's voice grows louder. His wife tells him to calm down, whereupon he yells at the top of his lungs "I'm perfectly calm!" However, his booming voice, threatening posture, and strained face tell a very different story. Apparently, he is not aware of how upset he got. This example illustrates that people may not always be aware of their own affective reactions, and research suggests that people systematically differ in this regard in the sense with some people being more attuned to their bodily signals than others (Lane & Smith, 2021).

The ability to accurately perceive, identify, and interpret emotions and their meanings is referred to as emotional awareness (Lane & Smith, 2021). In the framework of socioemotional abilities, emotional awareness is considered an important skill (Hoemann et al., 2021). In the clinical context, alexithymia—which is characterized by difficulties in identifying and describing one's emotions and therefore represents a lack of emotional awareness—has been considered a vulnerability factor for psychological maladjustment (Honkalampi et al., 2000; New et al., 2012).

Being emotionally aware involves higher level processes such as labeling and interpreting emotions. Yet, the introductory example illustrates that also at a more basic level, individuals can differ in the degree to which they are aware of their feelings. An affective reaction, which typically starts with a valenced neurophysiological state, is accompanied by specific physiological and behavioral elements (loud voice, threatening posture, strained face) and can be perceived more or less accurately by the person. We refer to this concept as *affective awareness*. Affective awareness can thus be seen as a prerequisite of emotional awareness in the sense that recognizing one's affective reactions is essential for adequately labeling and interpreting one's emotions. But do people differ systematically in affective awareness, that is, in the extent to which their subjective affective experience and objectively assessed indicators of a given affective state converge? If so, what might the correlates of affective awareness be?

Contingencies of Automated Facial Expressions and Experienced Affect

Central to the understanding of affective awareness is the concept of core affect. Core affect is defined as a neurophysiological state that is consciously accessible as a simple, nonreflective feeling on the dimensions of valence and arousal (Russell, 2003; Russell & Barrett, 1999). As shown in Figure 1, the affect-generating process

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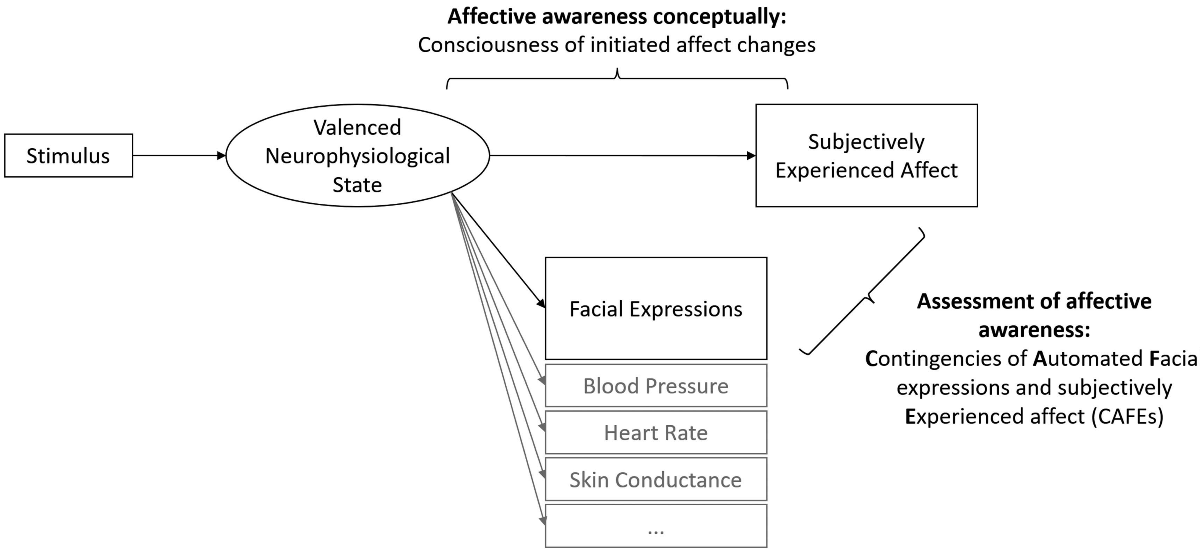
Figure 1
Simplified Conceptualization and Assessment of Affective Awareness in the Current Research



begins with an affective stimulus that leads to changes at the neurophysiological level, which then leads to changes in people's subjective affective experience (Smith et al., 2018). The early stages of changes in this process are thought to be fast and automatic (Kahneman, 2011), and it has been demonstrated that they entail physiological reactions, such as changes in facial expressions, muscle tension, or heart rate (Scherer & Moors, 2019; Smith et al., 2018).

However, there are reasons why people's subjectively experienced affect may not necessarily align with the changes elicited by an affective stimulus. Research on unconscious and implicit affect, for example, suggests that people's behavior can be influenced by affective stimuli without changes in their subjective affective experience (Lane, 2008, Smith & Lane, 2016, Winkielman & Berridge, 2004, Zemack-Rugar et al., 2007). This phenomenon indicates that people lack direct access to the complexities of the affect generation process, which can lead to divergences between (neuro)physiological changes and subjective affective experience (see Smith et al., 2018)—suggesting a relative (un)awareness of one's affective reactions. Furthermore, recent research indicates that people differ in the processing of affective information (Fiori et al., 2022). Those who comprehensively process such information should be more likely to make deliberate affective judgments, again suggesting individual differences in affective awareness.

Given the conceptualization, a measure of affective awareness should directly rely on people's subjective affective experience that can be compared to a physiological indicator of affective reactions. But what could such an indicator be? A physiological approach that previous research has successfully used to assess the valence dimension of core affect is facial electromyography (EMG; Dimberg, 1988). A positive affective experience is typically paired with increased zygomaticus major activity (the muscle that raises the corners of the mouth) and decreased corrugator supercilii activity (the muscle that draws the eyebrow downward and medially). Recording the activity of these two muscles via EMG can thus provide a physiological indicator of changes in affect valence (Lang et al., 1993; J. T. Larsen et al., 2003).

We used this approach to investigate individual differences in affective awareness as *contingencies of automated facial expressions and subjectively experienced affect* (*CAFEs*). To gain an indicator of CAFEs, we showed participants stimuli with affective content and assessed the extent to which their facial reactions to these stimuli (measured via EMG) corresponded with their self-reported affective experience. We reasoned that the higher this within-person correspondence would be, the more people are aware of their affective states. If the core assumption underlying concepts of socioemotional abilities is true, people should differ systematically in their CAFEs.

Correlates of CAFEs

Who can be characterized by relatively strong CAFEs? Research on non-criterion-based measures of emotional awareness and alexithymia (i.e., self-reports, informant-reports, situational judgment tests) might provide hints about potential correlates of CAFEs. For example, emotional awareness was found to be higher (Barrett et al., 2000) and alexithymia lower (Levant et al., 2009) in women than in men, a pattern that has been explained by different socialization processes such that emotional attention is more strongly valued for girls than for boys. Accordingly, this would suggest that CAFEs might be stronger in women than in men.

General affective reactivity is another potential correlate of CAFEs. People who are generally reactive to affective stimuli should be better at distinguishing between cases when an affective reaction was triggered versus when it was not. People differ in the typical strength of their affective reactivity (R. J. Larsen & Diener, 1987), and when presented with images of positive versus negative emotional facial expressions, some people consistently show stronger facial reactions than others (Hess & Fischer, 2014). This tendency, which is referred to as valence-based emotional mimicry, is attenuated in people with alexithymia (Franz et al., 2021). The finding indicates that a lack of affective reactivity might be detrimental to a person's awareness of changes in their own affect.

Finally, affective awareness is considered a key socioemotional ability (Hoemann et al., 2021), and research indicates that different kinds of socioemotional abilities are positively interrelated (Salovey & Mayer, 1990). Accurately perceiving one's own emotions and accurately detecting the emotions expressed by others are even sometimes considered part of the same overarching construct (Lane & Smith, 2021). Empirically, it has been shown that emotional awareness is positively and alexithymia is negatively linked to the ability to detect the emotions expressed by others (Lane et al., 1996; Prkachin et al., 2009). From this background, CAFEs should be positively linked to measures of socioemotional abilities, especially the ability to accurately detect others' emotions.

The Current Research

We investigated affective awareness as CAFEs in response to affective picture stimuli. We hypothesized that CAFEs would be generally positive in the sense that the more indicative facial muscular activity is of positive affect, the more positive affect is experienced. The focus of our investigation was on individual differences in CAFEs. If some people are better than others at recognizing changes in their affect, the magnitude of the relationship between facial reactions and subjective affect experience should differ systematically between individuals. We also investigated potential correlates of individual differences in CAFEs. We expected CAFEs to be higher in women than in men and to be positively related to general affective EMG reactivity and socioemotional abilities.

Method

Sample

Data were collected as part of a comprehensive study on personality and social behavior called the Leipzig Context Study (LeiCo-Study). The sample originally included $N = 256$ participants (198 women) between the ages of 18 and 35 ($M = 24.60$, $SD = 4.38$), of which the majority (79%) were university students. Of the 256 participants, five did not attend the laboratory session, and EMG recording failed for another seven (e.g., the experimenter forgot to press the record button). Out of 244 participants with available EMG data, we excluded all cases with less than 60% valid data points as technical difficulties (e.g., too high impedances) led to a large amount of missing data for some participants. In the current research, we thus analyzed data of 236 participants.

When planning the LeiCo-Study, we aimed for a sample size that was sufficient to detect correlations of $r = .20$ (which corresponds to a medium effect size in personality research; Funder & Ozer, 2019) with a power of at least 80% and an α level of .05. A minimum sample size of $N = 191$ was necessary for attaining this goal. With the actual sample size of $N = 236$, the power for finding such effects was .89.

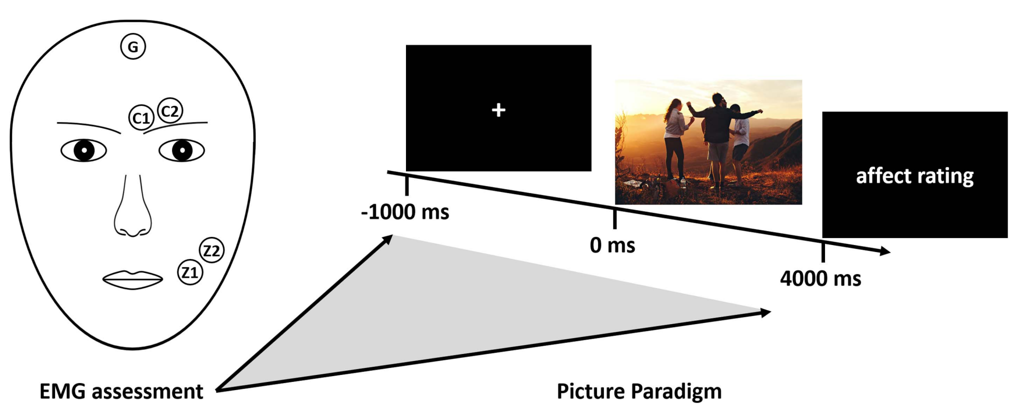
This value can be used as a proxy for the analyses pertaining to the correlates of CAFEs we performed in the current research (see below) because the relationships between CAFEs and individual difference variables (gender, general affective reactivity, socio-emotional abilities) are located at the person level. These analyses were the critical ones in terms of statistical power. Under the assumption that individual differences in CAFEs can be measured reliably, power was most likely high enough to detect medium-sized relationships with individual difference variables.

Procedure

We will only describe the parts of the study and the measures that are relevant to the current research question (a detailed description is available on the Open Science Framework at https://osf.io/yhjve/ in the study codebook). The study contained an online self-report questionnaire that was completed at home and a subsequent laboratory session. The laboratory session took place at the University of Leipzig and involved assessments of socioemotional abilities. Moreover, participants viewed a paradigm that included 76 picture stimuli (see Figure 2). Each picture was displayed on a

Figure 2

Presentation of Picture Stimuli Including Assessments of EMG and Affect Ratings



Note. The displayed stimulus is obtained from a repository that allows free use of images without requiring permission. EMG assessment during the entire presentation of the 76 picture stimuli. C1, C2 = corrugator electrodes; Z1, Z2 = zygomaticus electrodes; G = ground electrode; EMG = electromyography. See the online article for the color version of this figure.

computer screen for 4,000 ms and was preceded by a fixation cross of 1,000 ms. Most pictures ($n = 64$) contained affective content related to motive dispositions (e.g., groups of friends, romantic couples, or status symbols). Previous research has shown that motive-related pictures elicit positive affective responses with strong individual differences (Dufner et al., 2015). The remaining control pictures ($n = 12$) displayed neutral content (e.g., a chair or a stone). Facial muscle activity was measured via EMG during the whole paradigm, and participants provided affect ratings after each stimulus was presented.

A randomly selected subset of participants ($n = 101$, 75 women, $M_{age} = 24.74$, $SD = 4.69$) completed these assessments (EMG recordings, affect ratings) again approximately 15 weeks after the initial session ($M = 103.20$ days, $SD = 19.96$), which allowed us to examine the stability of CAFEs. (Excluding all cases with less than 60% valid EMG responses led to 95 analyzable participants at the retest.) After participants had completed all parts of the study, they were thanked, debriefed, and given a monetary compensation of 70 Euros.

Measures

CAFEs

EMG Responses. We recorded the activity of the zygomaticus and corrugator muscles with bipolar, 4-mm standard nonpolarizing silver/silver chloride surface electrodes. In line with Fridlund and Cacioppo's (1986) guidelines, four electrodes were placed on the corresponding muscle sites on the left side of the face with an approximate center-to-center distance of 1 cm, and one electrode was placed on the forehead as a common reference. We assessed the signal with a digital *PsychLab* amplifier (Contact Precision Instruments, Boston, MA) at a sampling frequency of 1,000 Hz. Offline, the fEMG raw signal was filtered with a 30-Hz high-pass cutoff filter and a 300-Hz low-pass cutoff filter as well as a notch filter at 50 Hz to remove the power line hum.

Facial EMG reactions to motive-relevant emotional picture cues typically come with a delay of 1 s (Dufner et al., 2015). Therefore, we aggregated muscular activity for each muscle from 1,001 to 4,000 ms after stimulus onset. We regressed each picture's aggregated activity on the activity during its preceding fixation cross in a multilevel model to control for baseline activity. The resulting person-centered residuals represent the strength of a participant's muscle response toward a picture compared to the strength of his or her reactions toward the other pictures. From the residual scores, we set extreme values (>3 and <−3) to missing as they were likely caused by artifacts (e.g., head movements, sneezing).

We then subtracted the baseline-controlled corrugator activity from the baseline-controlled zygomaticus activity to gain a general indicator of affective EMG responses for each of the 76 pictures. Combining the activity of the muscles utilizes the aggregation principle, according to which aggregation of multiple indicators always leads to more reliable assessments (Epstein, 1983). The same approach was also taken in previous research (see, e.g., Drimalla et al., 2019; Dufner et al., 2015; Schliebener et al., 2023). The resulting scores indicated how positively or negatively participants responded to a given picture in relation to their personal average.

Affect Ratings. After each picture was presented, participants indicated the feelings the image triggered in them on an item that ranged from 1 (*very negative*) to 5 (*very positive*). To obtain a measure of individual CAFEs, we predicted the affect ratings from the EMG responses in a multilevel model with random slope estimates for each participant (see below).

Correlates of CAFEs

Gender. Participants' gender was measured with the online questionnaire. Of the 236 participants, 182 were women and 49 were men.[1] Five participants classified themselves as neither female nor male and were thus excluded from the analyses pertaining to gender effects.

General Affective EMG Reactivity. To obtain an indicator of general affective EMG reactivity, we used the same approach to compute EMG responses as before (see above) with the only difference that we separately regressed the activities toward each picture on the baseline activity of that picture (in a between-person model). By this, the resulting residuals represent the strength of an affective reaction toward a picture compared to the strength of the other participants' reactions toward that picture (between person).

We then averaged the absolute values of the EMG responses for each participant across all 64 pictures that displayed affective content. The resulting score was indicative of individuals' general tendency to respond to the affective stimuli with increased EMG activity. The reliability of the general affective EMG reactivity was very high ($\alpha = .97$). However, a problem with this score was that it was potentially confounded by measurement-related aspects (e.g., electrode placement, skin thickness; Castroflorio et al., 2005). To control for such measurement-related aspects, we calculated the average EMG activity to the 12 nonaffective control pictures and residualized the activity to the affective pictures by activity to the control pictures. The EMG reactivity to control pictures was indeed strongly related to the EMG reactivity to the 64 affective pictures ($\beta = .70$, 95% CI [.60, .79]), $t(234) = 14.86$, $p < .001$. The resulting residuals were thus a measure of individual differences in affective EMG reactivity that is not confounded with measurement-related aspects.

Socioemotional Abilities. We assessed socioemotional abilities via a self-report and two performance-based measures. We used a short form (Mota et al., 2019) of the emotional competence questionnaire (ECQ; Rindermann, 2009) as the self-report measure. The short scale consists of six items (e.g., "I am good at describing my friends' varying emotional states") that are answered on a scale ranging from 1 (*not at all like me*) to 5 (*very much like me*). The reliability of the short scale was high ($\alpha = .86$).

As a first performance-based measure, we used a test battery developed by Wilhelm et al. (2014) that tapped into the ability to accurately perceive and recognize emotions from facial expressions (emotion perception abilities). We implemented three tasks from the battery. Task 1 consisted of 72 composite faces, where the upper and lower halves of the face showed different expressions of emotions. Participants were asked to correctly identify the expressed emotion on either the upper or the lower half of the face. Task 2 asked

[1] As the number of men and women was unevenly distributed in the final sample, we reestimated the actual power for the effect given the previously assumed effect size. With 182 women and 49 men, the power to detect a standardized mean difference of $d = .41$ in CAFEs (which corresponds to $r = .20$, the effect sizes that guided our power considerations) was .72 for a two-sided and .82 for a one-sided test and thus still high.

participants to identify emotional expressions on 72 dynamically developing emotional expressions in upright and inverted faces displaying emotions of differing intensity. Task 3 consisted of 40 grids with nine faces, of which a majority always displayed the same emotion. The task involved a visual search for all faces that differed from the target emotion. The reliabilities were good for Tasks 1 ($\alpha = .79$) and 3 ($\alpha = .80$) but were barely acceptable for Task 2 ($\alpha = .56$). Thus, we excluded items with negative scale correlations (one item in Task 1, 28 items in Task 2, and eight items in Task 3), which led to an acceptable reliability for Task 2 ($\alpha = .68$). The reliability of the composite scale for emotion perception was high ($\alpha = .87$).

As the second performance-based measure, we applied the Movie for the Assessment of Social Cognition (MASC; Dziobek et al., 2006). The MASC is a broader measure than Wilhelm et al.'s (2014) test in the sense that it assesses not only people's capacity for recognizing others' emotions but also their thoughts and intentions. The test consists of a 15-min movie about a group of people who spend an evening together. Following the standard procedure, the movie was paused 45 times, and each time participants answered a question about the people in the movie. The questions referred to the people's feelings, intentions, or motivations and offered four response options. Participants were asked to identify the correct option. The reliability of the MASC was only acceptable ($\alpha = .50$), so we again excluded four items with negative scale correlations. However, this did not substantially improve the reliability of the MASC ($\alpha = .53$).[2]

Analytic Approach

We used a multilevel modeling approach with picture stimuli as Level 1 nested in participants as Level 2. Affect ratings of pictures as the dependent variable were predicted by affective EMG responses as the independent variable. As we were mainly interested in the within-person effect, we used person mean centering of affective EMG responses. Furthermore, individuals differed in the variability of EMG responses, which was largely influenced by measurement-related aspects (see above). To eliminate these and obtain a comparable scale for each participant, we used the within-person standard deviation to standardize the EMG responses (Wang et al., 2019). Individual differences in CAFEs were then modeled as random slopes of affective EMG responses as can be seen in the basic model:

$$\text{Affect rating}_{ij} = B_0 + u_{0j} + (B_1 + u_{1j}) \cdot \text{EMG response}_{ij} + \varepsilon_{ij}. \quad (1)$$

The affect rating of person j for picture i is predicted by the corresponding affective EMG response. The intercept B_0 denotes the overall average affect rating, and the random intercept u_{0j} denotes the person-specific deviation from the average affect rating, with variance σ_{B0}^2. The fixed-effect B_1 of the affective EMG response corresponds to the average relationship between facial reactions and affect ratings. The random slope of the affective EMG response u_{1i} corresponds to individual differences in CAFEs with variance σ_{B1}^2. The residuals are denoted by ε_{ij} with variance σ_ε^2. All random effects and the error term are assumed to be normally distributed (for their empirical distribution, see additional online material Section 1 at https://osf.io/yhjve/), and the random intercept and slope are correlated.

The analyses included five steps. First, we estimated a fixed-effects model for the overall relationship between affective EMG responses and affect ratings. Second, we quantified individual differences in CAFEs as the standard deviation of random slope estimates from the predictive effect of affective EMG responses. We compared the two models with and without random slopes by using a likelihood ratio test to test for whether the estimation of individual differences in the CAFEs led to a significant improvement in model fit. Third, we investigated the reliability of the CAFEs, which we describe below. Fourth, we investigated the temporal stability of individual differences in CAFEs in order to explore whether affective awareness is indeed a stable person characteristic. Fifth and last, we included the expected correlates of CAFEs as Level 2 predictors and investigated their cross-level interactions. All analyses were conducted in *R* (R Core Team, 2020), and multilevel models were fit with the *lme4* package (Bates et al., 2015).

Transparency and Openness

The study was not preregistered, and parts of the data were analyzed in previous publications that dealt with unrelated research topics (Dufner et al., 2024; Grosz et al., 2020; Heine et al., 2024; Rau et al., 2022; Schliebener et al., 2023). The study was approved by the ethics commission of the German Psychological Society (DGPs). The study codebook, data, analysis code, and the additional online material are provided on the Open Science Framework (https://osf.io/yhjve/; Heine, 2024).

Results

CAFEs

In Step 1, we estimated the fixed-effects model predicting the standardized affect ratings from the affective EMG responses. The EMG reactions positively and significantly predicted the affect ratings ($B_1 = .25$, 95% CI [.23, .26]), $t(17105) = 35.223$, $p < .001$. This means that, on average, participants reported experiencing the most positive affect for the stimuli that elicited the most positive EMG responses, which is in line with our assumption that CAFEs are generally positive.

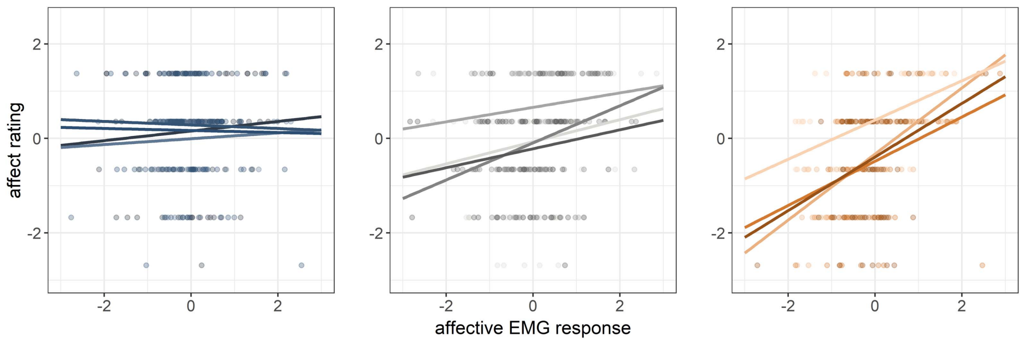
In Step 2, we added the random slope for the EMG effect to allow for individual differences in CAFEs. Individual slopes differed with a standard deviation of $\sigma_{B1} = .19$, 95% CI [.17, .22], and including random slopes significantly improved model fit, $\chi^2(2) = 432.46$, $p < .001$. This finding means that the association between affective EMG responses and affect ratings varied between participants, and there were indeed systematic individual differences in the magnitude of this association. Figure 3 presents exemplary plots of individual CAFEs and the additional online material Section 1 at https://osf.io/yhjve/ presents distributions and descriptive statistics of the basic model's random effects.

In Step 3, we investigated the reliability of these individual differences in CAFEs by computing two reliability indices. First, we used Neubauer et al.'s (2020) formula, which defines the reliability

[2] For the sake of transparency, we present all results for emotion perception abilities and the MASC without any item exclusions in the additional online material Section 2 at https://osf.io/yhjve/. These results are very similar to the original ones in terms of both effect sizes and statistical significance.

Figure 3

Plots of Participants With Low, Average, and High CAFEs



Note. Each line represents the contingencies for one participant. Randomly selected participants (four participants each) with low CAFEs (left plot, average $B_1 = .09$), average CAFEs (middle plot, average $B_1 = .24$), and high CAFEs (right plot, average $B_1 = .44$) are shown. CAFEs = contingencies of automated facial expressions and subjectively experienced affect; EGM = electromyography. See the online article for the color version of this figure.

as the proportion of variance in individual contingency estimates that can be attributed to true individual differences (rather than measurement error). An estimate of .77 indicated that our CAFE measurements were highly reliable. Second, as an indicator of split-half reliability, we divided the item set into two random halves, estimated separate multilevel models for each set, and examined the correlations of random effects across the two halves. Random slope estimates for the two halves were substantially correlated with each other, $r = .67$, 95% CI [.59, .73], $t(234) = 13.72$, $p < .001$. We applied the Spearman–Brown correction, which resulted in an estimate of .80 and again indicated good reliability of individual differences in CAFEs.

In Step 4, we investigated the stability of individual differences in CAFEs. We estimated the correlation between random slope estimates and their retest estimates 15 weeks later. This correlation indicated that individual differences in CAFEs were indeed stable and thus reflect an attribute of a person, $r = .51$, 95% CI [.34, .65], $t(85) = 5.47$, $p < .001$.

In sum, the results indicated that interindividual differences in CAFEs could be reliably captured with the current paradigm and that individual differences were stable over time. Thus, we could move on to investigate the expected correlates of CAFEs.

Correlates of CAFEs

Step 5 involved the analyses involved in the potential correlates of CAFEs. Table 1 presents descriptive statistics, internal consistencies, and intercorrelations of the expected correlates. As can be seen in the table, women scored significantly higher on all measures of socio-emotional abilities and showed stronger general affective EMG reactivity than men. Furthermore, the two performance-based measures of socioemotional abilities were positively correlated, which fits with past research and indicates that they tap into the same overarching class of abilities. Both measures were also positively but weakly linked to the self-report measure, which indicates that participants who were good at judging others' emotions and intentions also considered themselves somewhat capable in emotional matters.

To investigate the relationships with CAFEs, we included the expected correlates as Level 2 predictors in the basic model and examined cross-level interactions of these Level 2 predictors with the effect of EMG reactions. If a Level 2 predictor was related to individual differences in CAFEs, it would moderate the relationship between affective EMG responses and affect ratings. A separate model was fit for each correlate, and all variables in the interaction analyses were *z*-standardized, except for gender, which was effect-

Table 1

Descriptive Statistics, Reliabilities, and Intercorrelations of Level 2 Moderator Variables

Level 2 moderator	*M*	*SD*	α	ω	1	2	3	4	4a	4b	4c	5
1. Gender					—							
2. General affective EMG reactivity	0.00	1.02	.86	.87	.09	—						
3. ECQ	3.89	0.59	.97	.97	.23**	.11	—					
4. Emotion perception	0.74	0.07	.87	.89	.25**	.03	.15*	—				
a. Composite faces	0.66	0.11	.79	.80	.22**	.06	.18**	—	—			
b. Dynamic upright and inverted faces	0.64	0.11	.68	.68	.24**	−.01	.10	—	.38**	—		
c. Corresponding emotion search	0.89	0.07	.80	.84	.14*	−.00	.04	—	.43**	.41**	—	
5. MASC	0.81	0.08	.53	.55	.28**	.06	.18**	.29**	.23**	.19**	.24**	—

Note. Biserial correlations with effect-coded gender (−1 = men, 1 = women). EMG = electromyography; ECQ = Emotional Competence Questionnaire; MASC = Movie for the Assessment of Social Cognition.
* $p < .05$. ** $p < .01$.

coded (−1 = men, 1 = women). Table 2 summarizes the results of the moderator analyses.

Gender

A significant cross-level interaction between gender and affective EMG responses indicated that gender was a significant moderator of the slope estimates (B_3 = .05, 95% CI [.01, .08]), t(230.84) = 2.66, p = .009. The slopes for women (B_{1f} = .26) were steeper than those for men (B_{1m} = .17), indicating that CAFEs were stronger in women than in men.

General Affective EMG Reactivity

Given that EMG reactions should capture positive affect and that the affective pictures were positive in valence, one would expect individuals with an overall stronger general affective EMG reactivity to also provide more positive affect ratings in general. This was indeed the case, as evident in a significant main effect, B_2 = .06, 95% CI [.01, .10], t(296.45) = 2.48, p = .014. Furthermore, a significant cross-level interaction between general affective EMG reactivity and affective EMG responses indicated that general affective EMG reactivity was a moderator of the slope estimates: Higher EMG reactivity was associated with steeper slopes of affective EMG responses (B_3 = .04, 95% CI [.00, .07]), t(340.78) = 2.18, p = .030.[3] This finding means that individuals with stronger general affective EMG reactivity also had stronger CAFEs.

Socioemotional Abilities

We administered the ECQ as a self-report measure of socioemotional abilities. A significant main effect implied more positive affect ratings overall among participants who rated themselves high in socioemotional abilities, B_2 = .07, 95% CI [.03, .11], t(230.91) = 3.22, p = .002. However, the ECQ did not moderate the slopes of affective EMG responses, as the cross-level interaction was not significant, B_3 = −.01, 95% CI [−.03, .02], t(234.28) = −.42, p = .676. Thus, the self-report measure of socioemotional abilities was unrelated to CAFEs.

In contrast, a significant cross-level interaction indicated that emotion perception abilities moderated individual slope estimates. Better emotion perception abilities were associated with steeper slopes of affective EMG responses, B_3 = .05, 95% CI [.02, .07], t(233.70) = 3.29, p = .001. This effect could be found consistently across all three tasks, as the scores for the composite faces task, the upright and inverted dynamic faces task, and the corresponding emotion search task all moderated the steepness of affective EMG response slopes in a comparable fashion (see Table 2).

For the MASC, there was a positive main effect in the direction that higher MASC scores predicted more positive overall affect ratings, B_2 = .05, 95% CI [.01, .09], t(230.96) = 2.22, p = .027. Although higher MASC scores were descriptively associated with steeper slopes for affective EMG responses, the cross-level interaction was not significant, B_3 = .03, 95% CI [−.00, .05], t(233.92) = 1.67, p = .096. Thus, only the emotion perception measure of socioemotional abilities was positively related to the strength of CAFEs.

Understanding the magnitude of effects is paramount in psychological research. But how strong are the cross-level interaction effects we found? To clarify this, we extracted the individual slope estimates from the basic multilevel model, which was feasible given their high reliability. We then estimated Pearson correlations between these individual slope estimates and the Level 2 variables (see Table 2). In terms of their typical range, the correlations with gender, general affective EMG reactivity, and emotion perception were medium-sized (see, e.g., Funder & Ozer, 2019).

Controlling for Expressivity

A prerequisite for CAFEs to correspond with our conceptualization of affective awareness (see Figure 1) is that changes in affect manifest in facial expressions comparably for all individuals. However, past research on emotional expressivity indicates that individuals also vary in the extent to which the affect changes manifest in facial expressions (Gross & John, 1997). From this background, it is conceivable that individual differences in expressivity underlie CAFE scores rather than (or in addition to) individual differences in affective awareness. For example, two individuals could be equally aware of changes in their own affect, but affective change consistently goes along with the respective facial expression for only one of them. This person will consequentially have a higher CAFE score.

If this alternative explanation held, the score we used as an indicator of general affective EMG reactivity would in fact be a measure of emotional expressivity, and once this score was controlled for, individual differences in CAFEs and their relationships to personality correlates should vanish. However, when we controlled for general affective EMG reactivity, CAFEs were still positive and significant on average, B_1 = .25, 95% CI [.23, .26], t(17106.26) = 35.47, p < .001, and individual differences were still significant, σ_{B1} = .19, 95% CI [.17, .21], $\chi^2(2)$ = 417.40, p < .001, reliable (formula by Neubauer et al., 2020: .77; split-half: .80), and stable (test–retest: r = .50, 95% CI [.33, .65]), t(85) = 5.38, p < .001. Moreover, as Table 2 shows, the results on the correlates of CAFEs were very similar when expressivity was controlled for. Thus, the alternative explanation could be excluded; CAFEs reflect individual differences in affective awareness.

Comparing Different Baseline Control Approaches

To control for EMG baseline activity, we predicted picture from baseline activity and used the residual scores from this prediction as indicators for activity, ensuring that picture activity was no longer influenced by baseline levels. In EMG research, however, baseline activity is typically controlled by calculating difference scores (i.e., subtracting average baseline from average picture activity; e.g., Drimalla et al., 2019) or percentage scores (i.e., dividing picture activity by baseline activity; e.g., van Boxtel & van der Graaff, 2024). Among these, percentage scores have been considered superior to difference scores because the EMG signal recorded from

[3] We also tested the effect of affective EMG reactivity that was not residualized by control picture reactivity. Results were very similar to the ones from our original analysis (for details, see additional online material Section 2 at https://osf.io/yhjve/). By contrast, individual differences in EMG reactivity to control pictures were neither related directly to affect ratings, B_2 = −.02, 95% CI [−.06, .03], t(252.06) = −.76, p = .448, nor were they related to CAFEs, B_3 = .01, 95% CI [−.02, .04], t(277.84) = .92, p = .360. These results indicate that effects of EMG reactivity are based on affect-related and not measurement-related individual differences.

Table 2
Standardized Fixed Effects in Models With Cross-Level Interactions

Level 2 moderator	B_1 EMG	B_2 moderator	B_3 interaction	r
1. Gender	.216*** (.219***)	.049 (.043)	.046** (.043*)	.20**
2. General affective EMG reactivity	.247***	.057*	.035*	.13*
3. ECQ	.246*** (.247***)	.069** (.064**)	−.006 (−.010)	−.02
4. Emotion perception	.247*** (.248***)	.014 (.012)	.046** (.044**)	.21**
a. Composite faces	.248*** (.249***)	.006 (.003)	.034* (.032*)	.16*
b. Dynamic upright and inverted faces	.247*** (.248***)	.020 (.020)	.043** (.042**)	.19**
c. Corresponding emotion search	.246*** (.247***)	.007 (.006)	.035* (.034*)	.16*
5. MASC	.246*** (.247***)	.047* (.044*)	.023† (.021)	.11

Note. Coefficients in parentheses were controlled for expressivity (i.e., general affective EMG reactivity). Significant B_1 = overall relationship between affective EMG responses and affect ratings; EMG = electromyography; B_2 = relationship between the moderator and affect ratings; B_3 = relationship between contingencies of automated facial expressions and subjectively experienced affect (CAFEs) and the moderator (these effects were of main interest); r = correlations between CAFEs and the moderator calculated from the basic multilevel model's individual slope estimates (the correlations serve to illustrate the strength of the relationship; for adequate tests of the hypotheses, refer to the cross-level interactions); ECQ = Emotional Competence Questionnaire; MASC = Movie for the Assessment of Social Cognition.
$^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

facial muscles is measured on a ratio scale (van Boxtel & van der Graaff, 2024). To ensure our findings were not driven by the choice of baseline correction method, we reanalyzed all results using both difference and percentage scores. For both approaches, we again set extreme values (>$M + 3$ *SD* or <$M - 3$ *SD*) to missing, as they were likely caused by artifacts.

Table 3 compares the results across the three baseline control approaches. CAFEs were slightly weaker when using difference and percentage scores. Similarly, reliability estimates were marginally lower, though still good. In contrast, CAFEs' stability was slightly higher with these methods compared to residual scores. Importantly, the pattern of relationships to gender, general affective EMG reactivity, and socioemotional abilities closely mirrored the results obtained using residual scores.

Discussion

The assumption that individuals differ in affective awareness is central to prominent conceptualizations and theories of emotional competencies. In a physiology-based approach, we put this assumption to an empirical test. On average, the CAFEs were positive in the sense that stronger smile reactions, as measured via EMG, were linked to

Table 3
Results of the Current Research Compared for the Three Baseline Control Approaches

Result	Difference score	Percentage score	Residual score
Distribution of CAFEs			
Overall CAFEs	B_1 = .226***	B_1 = .221***	B_1 = .247***
Individual differences in CAFEs	σ_{B1} = .17***	σ_{B1} = .17***	σ_{B1} = .19***
Reliability of individual differences in CAFEs			
1. Neubauer et al.'s (2020) formula for within-person contingencies	.73	.72	.77
2. Split-half (picture set divided into random halves)	.76	.73	.80
Stability of individual differences in CAFEs			
Correlation of CAFEs at T_1 and T_2	r = .57	r = .59	r = .51
Correlates of CAFEs			
1. Gender	B_3 = .050**	B_3 = .050**	B_3 = .046**
2. General affective EMG reactivity	B_3 = .072**	B_3 = .068**	B_3 = .035*
3. ECQ	B_3 = −.010	B_3 = −.012	B_3 = −.006
4. Emotion perception	B_3 = .036**	B_3 = .028*	B_3 = .046**
a. Composite faces	B_3 = .026†	B_3 = .019	B_3 = .034*
b. Dynamic upright and inverted faces	B_3 = .030*	B_3 = .029*	B_3 = .042**
c. Corresponding emotion search	B_3 = .031*	B_3 = .022†	B_3 = .035*
5. MASC	B_3 = .029*	B_3 = .025*	B_3 = .023†

Note. CAFEs = contingencies of automated facial expressions and subjectively experienced affect; B_1 = Level-1 fixed effect of EMG responses in the basic multilevel model; σ_{B1} = standard deviation of random slopes in the basic multilevel model; T = time; B_3 = cross-level interactions indicate a relationship between CAFEs and the Level-2 predictors; EMG = electromyography; ECQ = Emotional Competence Questionnaire; MASC = Movie for the Assessment of Social Cognition.
$^{\dagger}p < .1$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

more experienced positive affect. More important, we found systematic individual differences in the overall strength of CAFEs. The CAFEs were assessed with fairly high reliability, and they were relatively stable across 15 weeks. This latter finding highlights not only that people differ systematically in their affective awareness but that these individual differences are indeed a trait-like characteristic of a person.

Regarding the expected correlates of CAFEs, the findings fit the general pattern that women outperform men in emotion-related tasks and match previous results on gender differences in emotional awareness and alexithymia (Barrett et al., 2000; Levant et al., 2009). Future research needs to clarify whether these differences actually arise from socialization.

The results were also in line with our expectation about general affective EMG reactivity. They match the proposal that if a person is generally more reactive to affective stimuli, generated affect more frequently exceeds a threshold of consciousness, and thus, it is easier for this person to evaluate generated affect compared with a person who is less affectively reactive. Several psychological disorders are characterized by blunted affect (e.g., Schizophrenia; Andreasen & Olsen, 1982). The present findings could explain why low levels of emotional awareness often co-occur in patients suffering from these disorders (Kimhy et al., 2012). Future research should address this possibility.

We also found the expected relationship between CAFEs and socioemotional abilities in terms of emotion perception abilities. This finding underlines the proposal that people who can accurately perceive their own affective states are also good at estimating others' emotional expressions and intentions. However, the relationship was found only for the emotion perception tasks and not self-reported socioemotional abilities. This pattern may be explained by the fact that self-reports are usually an imperfect measure of socioemotional abilities (Petrides, 2011). Furthermore, the MASC was unreliable in the present study, which may explain that the relation to CAFEs was smaller and did not reach significance (although it did for the alternative baseline control approaches). It might also be that the association was weaker because the MASC assesses theory of mind skills more generally, whereas the emotion perception tasks focused—just like our measure of affective awareness—on emotions. A future study might revisit the association between the MASC and affective awareness using a larger sample, in which also associations with moderately reliable measures can be detected with high power. In any case, the present study provides strong performance-based empirical evidence for the proposal that accurately perceiving one's own and others' affective states is related.

But why are individuals with high affective awareness actually better at judging the emotional expressions of other people? A potential explanation is that the emotional expressions of others represent a class of affective stimuli that cause an embodied simulation of the displayed affect (Hess & Fischer, 2013). Consider, for example, a happy target person who smiles and another person who observes that smile. The smiling face causes an observer to imitate the smiling person's positive affect so that the observer also experiences joy. This experience serves as a cue for the observer to recognize the target's emotional expression. This cue should be especially available for individuals with high affective awareness because they will more accurately perceive this simulated affective reaction. With this information source in hand, individuals high in affective awareness will consequentially make more accurate judgments of others' emotional expressions than individuals low in affective awareness.

Next to providing answers with regard to a long-standing theoretical issue, the current research also introduced a paradigm that could be used in future studies. By conducting EMG assessments during the presentation of around 70 stimuli, we could measure individual differences in affective awareness in a criterion-based fashion with a level of reliability that is unusually high for physiological approaches. Future research might use the same or a slightly adapted procedure as a standard paradigm to study affective awareness.

Limitations and Future Directions

A limitation of the current approach is that there is an alternative explanation for the occurrence of individual differences in CAFEs. That is, they might emerge from some people having a stronger tendency to express changes in affect with corresponding facial movements than others (see Figure 1). This could, for example, be because, during their socialization, they were consistently encouraged to associate positive affect with a smile, in order to communicate this feeling with others. If such socialization processes were stronger for women than for men, it would explain the gender difference in CAFEs. Likewise, culture might be a relevant factor. It is less normative for Easterners than for Westerners to openly show positive feelings (Matsumoto, 1990), and therefore, Easterners may be inclined to inhibit smiling when feeling positive. In this case, weaker CAFEs might not reflect lower awareness but rather cultural differences in the expression of affective reactions. Such stereotypical (e.g., culture-related) facial expressions of affect may also account for better performance in interpreting emotional states from others' faces. For instance, a person who has internalized the association between smiling and positive affect might not only smile when feeling positive but also use smiles as indicators of happiness when assessing others' emotions, leading to better performance in typical emotion-recognition tasks.

There are three arguments why the alternative interpretation is unlikely to be the exclusive factor causing individual differences in CAFEs. First, controlling for expressivity did not change the results, which makes it unlikely that individual differences in CAFEs occur because some people have a stronger tendency to express affect changes with corresponding facial movements. Second, our design with people being alone in front of the computer makes the explanation that individual differences in affect expression account for the present results rather unlikely. Although it is not possible to completely eliminate social context (Hess & Fischer, 2013), it seems most likely that facial movements were not used to communicating feelings in our isolated setting, at least not intentionally. Third, we investigated a highly homogeneous Western sample (Henrich et al., 2010), which means that in our case individual differences in CAFEs cannot be accounted for by cultural background.

Nevertheless, future research should systematically test by which extent CAFEs are driven by awareness and expressivity. For example, one could extend the generalizability of the current findings in a cross-cultural study. If the affect-related tendency to smile and the strength of CAFEs are weaker in Eastern cultures, this would indicate that it is not only the awareness of affect that influences the strength of CAFEs. More broadly, one could assess whether there are individual differences in the association between subjective affective experience and other physiological indicators that—unlike facial expressions—do not serve a communicative function and that are typically largely outside conscious control, such as, for example, heart rate, skin conductance, or blood pressure. If systematic and reliably assessable individual differences in how strongly these parameters are linked to subjective experience can be found again, individual differences in affect expression could be ruled out as an alternative explanation.

Assessing such additional physiological indicators would also allow one to examine affective awareness with regard to arousal, which is next to valence, the second dimension of core affect (Russell, 2003; Thayer, 1989). An investigation into arousal-related awareness could also test associations to valence-related awareness (as assessed in the present study) and how they both relate to other physiology-based measures of self-awareness (e.g., Ring & Brener, 2018). This could valuably complement the criterion-based research into self-awareness.

As a more distal but highly relevant practical implication, the physiology-based approach to affective awareness could also contribute to a better understanding of psychological disorders. For example, patients with different psychological disorders often have trouble managing their emotionality (e.g., borderline personality disorder; Levine et al., 1997), an issue that is potentially related to an impairment in affective awareness. Likewise, eating disorders are often motivated by a desire to escape from self-awareness (Heatherton & Baumeister, 1991), another issue that could be reflected in impaired affective awareness. It is also conceivable that individuals with certain psychological disorders (e.g., depression) might be relatively unaware of their positive affective reactions but highly aware of their negative affective reactions (Pyszczynski & Greenberg, 1987). Whereas we primarily used social stimuli with positive affective content, awareness of negatively valanced affective states could be studied separately by using stimuli that elicit generally negatively valanced affective states (e.g., pictures from the international affective picture system; Lang et al., 2005).

Conclusion

With our physiology-based approach, we found systematic individual differences in CAFEs that could be reliably assessed, were stable across time, and exhibited a pattern of correlated constructs, which was in line with theoretical assumptions. Hence, individuals indeed differ in their affective awareness, and these individual differences are psychologically meaningful. Future studies can build on this approach to gain a deeper and empirically supported understanding of the functioning and relevance of self-awareness.

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