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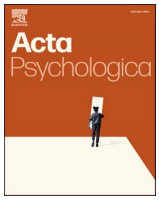

An EMG-based approach toward the assessment of implicit self-esteem

Melanie Schliebener [a,*], Livia Kraft [b], Michael Dufner [a]

[a] Department of Psychology and Psychotherapy, Witten/Herdecke University, Alfred-Herrhausen-Str. 44, 58455 Witten, Germany
[b] Department of Psychology, University of Leipzig, Neumarkt 9, 04109 Leipzig, Germany

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ABSTRACT

An important aspect of implicit self-esteem is the positivity of peoples spontaneous affective reactions to the self. In this study, we developed and validated a physiology-based measure that captures such positive reactions. We presented participants ($N = 256$) self-related stimuli (i.e., pictures of themselves) and used electromyography (EMG) to record changes in facial muscular activity that are indicative of subtle smiling. EMG responses were on average positive, which matches with previous research findings on positively biased self-evaluations. Individual differences in EMG responses were moderately reliable and positively associated with explicit self-esteem and self- and peer-rated likability (but not consistently with measures of well-being and agentic behavior). The relations between the EMG responses and likability indicators largely held when we controlled for explicit self-esteem, indicating that the novel measure possessed incremental validity over self-reports. The results thus indicated that the EMG approach might be fruitful for the assessment of implicit self-esteem.

1. Introduction

The idea that aspects of personality are implicit is almost as old as academic psychology itself (see for example Freud, 1955; Murray, 1938). Researchers have aimed at assessing implicit aspects of motive dispositions (McClelland, 1987), relationship satisfaction (Krause & Dufner, 2020), attitudes (Vanman et al., 1997) and many other constructs, and they did so mainly by relying on projective tests or reaction-time based measures. The current investigation stands in this tradition and presents a novel measure of implicit self-esteem that is physiology-based and that focuses on mimic reactions to self-related cues. To validate the measure, we examined the overall positivity of responses, the measures' reliability and its associations with socio-emotional correlates.

1.1. Implicit self-esteem

Self-esteem refers to the positivity (versus negativity) of people's attitudes toward themselves (Rosenberg, 1965) and in the case of explicit self-esteem (ESE) the evaluation of the self is conscious and declarative. But then, what is implicit self-esteem (ISE)? In the literature, different definitions of the terms implicit in general (see Corneille & Hütter, 2020) and of implicit self-esteem in particular (see Buhrmester et al., 2011; Greenwald et al., 2002) exist. Classical dual process models (e.g., Fazio & Olson, 2003; Greenwald & Banaji, 1995) would argue that implicit constructs are unconscious and exclusively predict automatic and uncontrolled behavior, less radical perspectives (e.g., Mann et al., 2020) would argue that the label "implicit" primarily indicates that a construct is being assessed indirectly, without the usage of self-reports, and still other approaches (e.g. Gawronski & Bodenhausen, 2006; Lee et al., 2018) define implicit constructs as ones that are comprised of spontaneous, physiological-based, affective reactions to attitude objects.

This latter definition was highly relevant for the current work. The core idea is that as emotional reactions start with physiological processes (Barrett, 2006; Schachter & Singer, 1962), people who encounter a specific attitude object first have a spontaneous physiological, or visceral, reaction to it. This reaction can be noticed by the conscious self (which would then translate into conscious attitude-related affect), but it does not have to, and regardless of whether or not it does, it can influence subsequent attitude-relevant behavior. With regard to self-esteem, affect clearly plays a central role (Brown & Mankowski, 1993) and the point has been made repeatedly that the spontaneous tendency to associate the self with positive affect is a core aspect of implicit self-esteem (Conner & Barrett, 2005; Epstein, 2006; Pelham & Hetts, 1999). From this perspective, spontaneous physiological reactions indicative of positive affect to self-related stimuli should be highly informative about implicit aspects of self-esteem. As we will argue in the following, such reactions can be measured using electromyography (EMG).

* Corresponding author.
E-mail addresses: melanie.schliebener@uni-wh.de (M. Schliebener), livia.kraft@uni-leipzig.de (L. Kraft), michael.dufner@uni-wh.de (M. Dufner).

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1.2. An EMG-based measure of spontaneous self-related affect

The human face provides valuable information about people's affective states (Van Boxtel, 2010). In general, positive and negative affective states can be reliably distinguished based on corrugator and zygomaticus responses. Specifically, positive emotional experience is typically paired with increased activity of the zygomaticus major (the muscle that raises the corners of the mouth) and decreased activity of the corrugator supercilii (the muscle that draws the eyebrow downward and medially) as assessed via EMG (Cacioppo et al., 1986; Larsen et al., 2003).

In recent years, research from different content domains has accumulated indicating that people reliably differ in their mimic responses to a specific class of stimuli (Hess et al., 2017), and that the respective EMG scores can be used as proxies for implicit personality aspects. For example, Dufner et al. (2015) have recorded EMG reactions to affiliation-related cues as a proxy for the affiliation motive and found that these reactions were internally consistent, correlated with affiliation self- and peer-reports, and predicted affiliative outcomes above and beyond the self-reports. In a follow-up investigation (Dufner et al., 2018), the same approach was taken to measure EMG reactions to achievement- and power-related cues. Furthermore, Vanman et al. (1997) used EMG reactions to pictures of black and white faces as a measure of implicit attitudes. Finally, Krause and Dufner (2020) used facial EMG responses to pictures of one's partner as a measure of implicit relationship satisfaction.

Taken together, these findings indicate that EMG recordings can be used to reliably capture individual differences in affective reactivity toward picture cues. We applied this approach to the measurement of ISE and recorded EMG responses to pictures of oneself, which have been shown to reliably produce affective reactions in past research (Back et al., 2009; Krause et al., 2012). Our rationale was that the stronger people's ISE (defined as the tendency to spontaneously associate the self with positive affect) is, the more they should respond with increases in the activity of the zygomaticus muscle and with decreases in the activity of the corrugator muscle to self-related cues.

1.3. General positivity toward oneself

But how can one tell that the EMG-based approach is valid? One possibility is to investigate the overall positivity of EMG reactions. It is well documented that, at least in Western societies, people on average hold a flattering view about themselves (Paulhus, 1993; Sedikides & Gregg, 2008; Taylor & Brown, 1988). This is true not only for explicit self-evaluations, but also for implicit ones. Several findings indicate that most people have positively based attitudes toward self-related objects such as the letters contained in their names or the numbers contained in their birth dates (Bosson et al., 2000, 2003; Kitayama & Karasawa, 1997; Koole et al., 2001). Moreover, studies using IAT or APT approaches indicate that people's implicit self-evaluations are, on average, positive (see, e.g., Krause et al., 2011). In fact, some findings indicate that measures of ISE are positively biased not only in Western cultures, but also in Eastern cultures, such as China and Japan (Yamaguchi et al., 2007).

Given that across operationalizations, implicit self-evaluations tend to be positively biased, EMG responses to self-related stimuli should be generally positive. That is, on average, people should respond with increased zygomaticus activity and decreased corrugator activity, in comparison to baseline, while viewing self-related stimuli.

1.4. Socio-emotional correlates

Another way of testing the validity of the EMG measure is to investigate how EMG scores are related to a number of key correlates of self-esteem. Research has often found that the same outcomes are determined by both explicit and implicit components of a construct (Perugini, 2005), and as we will point out in the following, also in the self-esteem literature, the same correlates have often been linked to measures of both ESE and ISE. We focused on three classes of such correlates, namely subjective well-being, likability, and agentic behavior.

1.4.1. Self-esteem and subjective well-being

Subjective well-being is characterized by high levels of life satisfaction and positive affect, paired with low levels of negative affect (Diener, 1994). ESE has been positively linked to indicators of subjective well-being (DeNeve & Cooper, 1998; Diener, 1994), even though the causality underlying these links has not been clearly established yet (Baumeister et al., 2003; but see Orth & Robins, 2022).

Less research has investigated the relation between ISE and subjective well-being. Previous studies found that ISE, as measured via the Name-Letter Task, was significantly positively correlated with positive affect, but it was not significantly correlated with life satisfaction or negative affect (Bosson et al., 2000; Lin, 2019; Schimmack & Diener, 2003). However, the Name-Letter Task has been the target of critique (Buhrmester et al., 2011) and showed only modest reliability in some studies (Bosson et al., 2000; Jusepeitis & Rothermund, 2022; Schimmack & Diener, 2003). Accordingly, the question whether ISE goes along with high subjective well-being is still not fully answered.

1.4.2. Self-esteem and likability

Self-esteem is robustly linked to social feedback. Sociometer theory (Leary & Baumeister, 2000) postulates that due to the evolutionary importance of social inclusion, humans constantly seek to maintain positive interpersonal relationships and monitor cues indicating their relational value. In this context, self-esteem is thought to function as a "sociometer" that monitors the quality of one's interpersonal relationships and social inclusion (Leary & Baumeister, 2000). The higher people perceive their relational value to be, the higher their self-esteem should be. In support of this proposal, research linked both actual, other-rated liking (Srivastava & Beer, 2005) and self-rated perceptions of being liked by others (Reitz et al., 2016) to high ESE.

We are only aware of one study investigating the relation between ISE and likability, and this study focused exclusively on self-perceived likability. Back et al. (2009) investigated how ISE, as assessed via IAT and APT, as well as ESE, assessed via self-report, are related to the perception of being liked. Both ESE and ISE independently predicted the perception of being liked.

1.4.3. Self-esteem and agentic behavior

Social behavior can be described on two basic dimensions, labeled agency (e.g., ambitious, competitive, outgoing) and communion (e.g., caring, honest, understanding; Wiggins, 1979). With regard to the agency dimension, it has been proposed that (social) status, self-esteem, and behavioral assertiveness are all part of an evolutionarily adaptive system (Mahadevan et al., 2016). Self-esteem is thought to serve as a mediator between perceived social status and agentic behavior. If people feel they have high social status, this makes their self-esteem rise, and high self-esteem will, in turn, lead to displays of agentic behaviors, such as assertiveness and dominance. Thus, a positive association between self-esteem and agentic behavior should emerge.

Empirically, ESE has indeed been positively linked to both self-reports (Leary et al., 2001) and actual observations (De Waal-Andrews & Van Beest, 2012) of agentic behavior. There is also some evidence linking ISE to self-confident behavior, which belongs to the class of agentic behaviors (Wiggins, 1979). Krause et al. (2016) assessed self-confident behavior with observer-ratings based on video recordings of participants' behavior in the laboratory. Across different social situations, ISE, as assessed via an APT, was positively associated with self-confident behavior.

1.5. The current research

To evaluate the psychometric quality of the novel EMG-based measure of spontaneous self-related affect, we focused on three main questions. First, we examined the general positivity of EMG responses to self-related stimuli. Given that people's implicit self-evaluations are generally positive (Greenwald & Banaji, 1995), we expected that people would on average show increases in zygomaticus activity paired with decreases in corrugator activity (in comparison to baseline activity) when viewing pictures of themselves.

Second, we tested the reliability of the novel EMG measure. We did so by considering both its internal consistency and test-retest correlation. Krause et al. (2012) compared the reliabilities of five different measures of ISE both in terms of their Spearman-Brown corrected split-half reliability and in terms of their test re-test reliability across a 4-week time interval. Across measures (scores were calculated using the respective standard procedure), the median split-half reliability was Rel = 0.61 and the median test-retest correlation was $r = 0.34$. Any reliability scores above these values would indicate that the novel EMG measure is rather reliable in comparison to alternative approaches.

Third, we examined several socio-emotional correlates of the EMG measure. In particular, we investigated how the EMG measure relates to subjective well-being, likability and agentic behavior and expected positive relations. We investigated associations with likability in a detailed fashion. That is, we considered both self-perceived (i.e., people's subjective perceptions of their own likability) and other-perceived likability (i.e., people's likability in the eyes of other persons). For each of these indicators, we considered likability in general (i.e., how likable people themselves and other persons find them in general) and likability in specific group contexts (i.e., how likable people themselves and other persons find them in a specific group context).

During the EMG task, we did not only present participants images of themselves, but also of other persons. We used EMG reactions to these other-related cues as control stimuli. That is, to consider the alternative explanation that individual differences in EMG reactions might not be specific to self-related cues, but might refer to social stimuli in general, we also explored the associations between these other-related EMG reactions and the socio-emotional correlates. If an outcome should be correlated to both the self-related and the other-related EMG reactions, other-related EMG reactions would qualify as a potential confounder and should be statistically controlled when association with the socio-emotional correlated are examined.

Finally, we also examined the relation between the novel EMG measure and ESE. Previous findings on the relation between measures of ISE and measures of ESE are inconsistent. Whereas some studies report a null correlation (Back et al., 2009; Krause et al., 2016), others report small positive correlations (e.g., Jusepeitis & Rothermund, 2022; Koole et al., 2001). We therefore investigated the issue in an explorative fashion.

2. Materials and methods

2.1. Open science statement

The analyses have not been pre-registered. The analysis code and the data can be found online (https://osf.io/68thb/).

2.2. Participants and design

Data assessment took part within a larger study called the Leipzig Context (LeiCo)-Study, which took place between February and October 2019 in Leipzig, Germany. The ethics commission of the German Psychological Society (DGPs) approved the study. Data from the LeiCo-Study have also been analyzed in three other publications that dealt with research topics unrelated to ISE (Dufner et al., 2022; Grosz et al., 2020; Rau et al., 2021). The study included an online self-report survey, and online acquaintance-report survey, an EMG laboratory session, in which participants were tested individually, and two laboratory group sessions. The complete design with a detailed description of all procedures, measures and materials can be found in the study codebook (https://osf.io/3f9dq/). In the following section, we will only describe the parts of the study that are relevant for the current research.

For recruitment, online social networks, notice boards flyers and a study homepage were employed. Participants were required to be between 18 and 35 years old; psychology students were excluded, as they might have been familiar with many of the measures. For complete attendance, participants received 70 euros.

A total of 256 persons participated (199 female, 53 male, 4 diverse) with a mean age of 24.57 years ($SD = 4.38$). Most of them were students (79%), 9.80 % were employees, 5.49 % unemployed, 3.53 % freelancers and the rest were pupils or trainees.

There were some missing cases in each of the relevant sub datasets. The EMG data consisted of 251 valid cases, five cases were missing either due to technical problems or because participants did not attend the laboratory session. Self-report questionnaire data was available for 255 cases, as one participant did not complete the online questionnaire. The acquaintance-report data set included 238 valid cases. For the remaining cases, no acquaintances had been recruited or the acquaintance IDs could not be matched to the target ID. Concerning the group session data, 253 participants attended at least one of the sessions. In 22 cases, the minimum group size of $n = 4$ was not attainted, which would have been necessary for the computation of the group-based likability indicators (see below; Schönbrodt et al., 2012). Hence, data for these indicators was available for 231 cases.

Before participants attended the laboratory sessions, they completed an online survey, in which ESE, subjective well-being as well as self-perceived likability in general were assessed. To prevent fatigue, the self-reports survey, which included many additional scales, was split in two halves, each of which took approximately 45 min to complete. Participants invited at least three persons ($M = 3.23$, $SD = 1.13$) to complete the acquaintance-report online questionnaire in which other-perceived likability in general was assessed. Most of the acquaintances were friends (60 %), 14 % were romantic partners, 10 % were siblings and the rest (16 %) classified their relationship with “other.” Acquaintances were not allowed to participate in the study themselves.

Subsequently, participants attended the two laboratory group sessions, which were seven days apart from each other. During these group sessions, photographs for the EMG task were taken, context-specific assessments of self-perceived and other-perceived likability were gathered and participants' interaction behavior was videotaped, so that agentic behavior could be rated by external observers later on. Participants were assigned to 50 same-sex groups of four to six participants each (resulting in 12 groups of four, 20 groups of five, 18 groups of six). It was ensured that group members did not know each other. In the beginning of the first session, a portrait photograph was taken of each participant. To standardize the content of the pictures, a white plain wall was used as background and participants were instructed to display a neutral facial expression. These pictures were later used as self-related stimuli in the EMG task. The pictures of participants' group members were used as other-related stimuli. Afterwards, group members briefly introduced themselves and then engaged in a number of interactive group tasks. Some of these tasks were more competitive and others were more cooperative in nature (for a detailed description, see the study codebook). In the beginning and at the end of each group session, other-perceived likability was assessed (for details, see below).

The EMG assessments took place during a third laboratory session, in which participants were tested individually and in which the photographs from the group sessions were used. A randomly selected sub-set of participants ($n = 101$, 74 % females, 25 % males, 1 % diverse; $M_{age} = 24.74$, $SD = 4.69$) re-visited the laboratory approximately 15 weeks later ($M = 103.20$ days, $SD = 19.96$) and completed the assessments again, so that test-retest correlation could be examined.

2.3. Measures

2.3.1. EMG task

In the EMG task, participants first saw their own picture five times, resulting into five self-related pictures. Afterwards, they saw pictures of each of their group members five times, which were used to assess other-related EMG reactions. Depending on the group size, participants saw between 15 and 25 other-related pictures in randomized order. Both self- and other-related picture cues were preceded by a fixation cross which was shown for 1000 ms and remained on the screen for 4000 ms. Two electrodes were placed on the corresponding muscle sites of the zygomaticus and the corrugator in line with Fridlund and Cacioppo's (1986) guidelines and one electrode on the forehead as a common reference. We used bipolar, 4 mm standard nonpolarizing silver/silver chloride surface electrodes and assessed the signal with a digital Psychlab amplifier (Contact Precision Instruments, Boston, MA) at a sampling frequency of 1000 Hz. Offline, the EMG raw signal was filtered with a 30-Hz low cutoff filter and a 300-Hz high cutoff filter as well as a notch filter at 50 Hz to remove the power line hum.

We followed the same approach as in previous studies on EMG assessments of implicit constructs (Dufner et al., 2015, 2018, 2022; Krause & Dufner, 2020) to obtain an individual differences score of ISE. We first aggregated activity across ms 1001 to ms 4000 following picture presentation for each muscle (we excluded the first second of picture presentation, because EMG reactions to picture stimuli usually occur with a delay of approximately 1 s; Tassinary et al., 2012). To control for baseline muscular activity, we partialled out activity during fixation cross presentation for each picture. To gain general activity for corrugator and zygomaticus activity, we averaged these residuals across all self-related pictures, separately for each muscle, which resulted in baseline-controlled composite corrugator ($SELF_C$) and zygomaticus ($SELF_Z$) activity scores. Finally, to gain an index of the overall positivity of EMG reactions, we subtracted the $SELF_C$ from $SELF_z$ because positive affective experience is accompanied by both decreases in corrugator and increases in zygomaticus activity (Cacioppo et al., 1986) which resulted in our overall ISE EMG composite score ($SELF_{diff}$).[1] We used the same procedure to obtain an other-related EMG score ($OTHER_{diff}$).

2.3.2. Socio-emotional correlates

2.3.2.1. ESE. The German version (von Collani & Herzberg, 2003) of the Rosenberg Self-Esteem Scale (RSES; Rosenberg, 1965) was employed to assess ESE. The scale consists of 10 items (1 = *strongly disagree* to 4 = *strongly agree*).

2.3.2.2. Satisfaction with life. To assess satisfaction with life, the German version (Janke & Glöckner-Rist, 2012) of the Satisfaction with Life Scale (SWL; Diener et al., 1985) was used, which consists of five items (1 = *strongly disagree* to 7 = *strongly agree)*.

2.3.2.3. Positive and negative affect. The German version (Krohne et al., 1996) of the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988) was employed to assess positive and negative affect. The schedule consists of 20 items (1 = *not at all* to 5 = *extremely*).

2.3.2.4. Likability. As the general measure of self-perceived likability, we used an eight-item self-developed scale, which asked to what extent people perceive that they are generally liked by others (sample items: "Most people like me,", "When I like a person, it's mostly mutual;" 1 = *not agree at all* to 6 = *agree completely*). In a pilot validation study (N = 90) the internal consistency was high (α = 0.82) and the scale score correlated with self-reports of the affiliation motive, extraversion, and the quality of one's with relationships with close peers, which speaks for the validity of the scale. We employed an informant-report version of the scale to assess other-perceived likability in general. The mean agreement across acquaintances was ICC(1,k) = 0.57.

To measure self-perceived likability in the specific group context of the study, participants rated separately for each their group members how much they believed the respective member liked them (1 = *strongly disagree* to 6 = *strongly agree*). We then averaged these ratings to compute a group-specific self-perceived likability score. To measure other-perceived likability in the group context, group members indicated to what extent they actually liked the respective participant via three items (sample item: "I like this person"; response format: 1 = *strongly disagree* to 6 = *strongly agree*). These ratings were then aggregated using Kenny's (1994) social relation model (SRM). The SRM is a framework that allows the decomposition of variance in interpersonal perception. When in a group of individuals everyone rates everyone else in terms of liking, variance in these ratings stems from three sources, namely differences in perceiver effects (i.e., in the extent to which the different group members generally like others), in target effects (i.e., in the extent to which particular group members are generally liked by the others), and in relationship effects (i.e., specific idiosyncrasies in terms of liking that exist in different dyads independently of any perceiver and target effects). Of interest in our case were the target effects, which are conceptually and empirically similar to the average liking rating a person has received from the group members. We used the R package Triple R (Schönbrodt et al., 2012) to compute the target effects. The package returns group-mean centered scores, meaning that a value of zero indicates that a person was average in terms of likability within the group. To maximize the reliability of the obtained scores, we aggregated across the ratings provided within each group session and across the two group sessions.

2.3.2.5. Agentic behavior. To assess agentic behavior, eight external observers (research assistants or undergraduate students who were unfamiliar with the target persons) watched the video recordings of the group interactions (four of them watched the interactions of the first group session and the remaining four watched the interactions of the second group session). The observers were supposed to watch the video for at least 6 min and to focus on a single person. Agentic behavior was rated with six adjectives from the German version (Jacobs & Scholl, 2005) of the Interpersonal Adjectives List (IAS; Wiggins et al., 1988) on a 6-point Likert scale from 1 = do *not agree at all* to 6 = *agree completely*, an approach has already been successfully taken in previous research (Dufner et al., 2015). Agentic behavior was coded via two items from the high-agency octant of the Circumplex (e.g., "self-assured") and two reverse-scored items from the low-agency octant (e.g., "shy"). The mean interrater agreement was ICC(3,k) = 0.80. Again, scores were aggregated across the two sessions.

2.4. Power analysis

Using the software G*Power (version 3.1.9.4; Faul et al., 2007), we computed the statistical power of our main statistical tests (i.e., Pearson correlations between the EMG measure and the socio-emotional correlates). An N of 256 would suffice to detect effects of r = 0.17 or larger with 80 % power (alpha = 0.05, two-tailed). In light of the missing values, we calculated a second, more conservative power analysis. An N of 235 would suffice to detect effects of r = 0.18 or larger with 80 % power (alpha = 0.05, two-tailed). Thus, statistical power was large enough to detect effects sizes that are considered "medium" in social-personality psychology (Funder & Ozer, 2019).

[1] Because in physiological data, it is possible that results are strongly driven by outlier values (Hastings et al., 1947), we re-computed the ISE EMG index based on winsorized EMG scores. That is, we replaced all values with a z score of < -3 to the value of -3 and the ones with a z score of $> +3$ with the value of $+3$. As shown in Tables S3 and S4, the results were highly similar to the ones of our original analyses, which indicates that outlier values were not a major issue.

3. Results

Our analyses focused on the three major questions raised in the Introduction. First, we examined whether on average, participants responded positively (i.e., with smile responses) to the self-related stimuli. Second, we analyzed the reliability of EMG based measure of ISE. Third, we investigated the associations between the EMG measure and the socio-emotional correlates. Further analyses marked by an S can be found in the Supplemental Material.

3.1. The general positivity of EMG responses to self-related stimuli

To examine the average EMG responses to self-related pictures, we first ran a two-factor repeated measures analysis of variance with muscle as the first factor (corrugator versus zygomaticus) and time as the second factor (ms −1000-0000, 0001–1000, 1001–2000, 2001–3000, 3001–4000 after stimulus presentation) and used the filtered raw muscle activity as the outcome variable. To correct for violations of sphericity, we used the Greenhouse-Geisser adjustment. There was a significant main effect of muscle, $F(1, 235) = 31.48$, $p < .001$, indicating higher corrugator activity than zygomaticus activity. There was no significant effect of time, Greenhouse-Geisser $F(1.94, 455.14) = 0.72$, $p = .481$. Most importantly, there was a significant interaction of muscle and time, Greenhouse-Geisser $F(1.75, 410.66) = 7.16$, $p = .002$. After stimulus presentation, corrugator activity decreased whereas zygomaticus increased over time (see Fig. 1). Thus, participants indeed showed a (subtle) smile response when viewing their own pictures. The figure also shows that, as expected, the responses took place with a delay of 1000 ms after stimulus presentation.

We then checked whether the descriptive increase in zygomaticus activity and the decrease in corrugator activity were both significant. To do so, we ran a separate one-factor ANOVA for each muscle with time as a single repeatedly measured factor. We again used the Greenhouse-Geisser adjustment to correct for violations of sphericity. The effect of time was significant for both the corrugator muscle, Greenhouse-Geisser $F(1.93, 454.18) = 3.34$, $p = .038$, and the zygomaticus muscle, Greenhouse-Geisser $F(1.78, 418.68) = 3.74$, $p = .029$, indicating that the activity of both muscles changed.

And third, we also explored whether EMG responses to self-related stimuli might be more positive than responses to the other-related stimuli. For this purpose, we ran the same analysis of variance as before with muscle as the first factor (corrugator versus zygomaticus), time as the second factor (ms −1000-0000, 0001–1000, 1001–2000, 2001–3000, 3001–4000 after stimulus presentation), but included target as third within-person factor (self versus other). The three-way interaction between muscle, time and target was not significant, Greenhouse-Geisser $F(1.84, 432.73) = 0.20$, $p = .805$ (for detailed results, see Table S1), which indicated that changes in facial muscular activity across time were similar for self- and other related pictures. Indeed, as can be seen in Fig. 1, also participants' reactions to the other-related stimuli were, on average, positive.

3.2. Reliability of the self-related EMG reactions

So far, results showed that on average participants tended to display facial muscular activity indicative of joy when viewing pictures of themselves. Next, we investigated whether participants reliably differed in their affective reactions to the self-related stimuli. Therefore, we examined the internal consistencies of the EMG reactions to each picture (with baseline activity being partialled out). Table 1 shows the Cronbach's Alpha and McDonald's Omega scores separately for each muscle and for the difference zygomaticus-corrugator. Internal consistencies were in the medium range (Rel =0.60–0.70). The internal consistency of

Table 1
Descriptive statistics and reliabilities for EMG measures and socio-emotional correlates.

Variable	*M*	*SD*	α	ω
$SELF_C$	0.00	0.63	0.60	0.67
$SELF_Z$	0.01	0.77	0.66	0.70
$SELF_{diff}$	0.01	0.97	0.63	0.69
$OTHER_{diff}$	0.02	0.61	0.68	0.49
ESE	3.01	0.61	0.89	0.89
Satisfaction with Life	4.57	1.23	0.87	0.87
Positive Affect	3.31	0.64	0.87	0.87
Negative Affect	1.86	0.60	0.86	0.87
Self-perceived $Likability_{general}$	4.28	0.83	0.86	0.89
Other-perceived $Likability_{general}$	4.81	0.54	0.80	0.79
Self-perceived $Likability_{group}$	4.23	0.52	–	–
Other-perceived $Likability_{group}$	0.00	0.41	0.94	0.95
Agentic behavior	4.27	0.71	0.89	0.89

Note. α = Cronbach's Alpha; ω = McDonald's Omega; SELF = reactivity to self-related stimuli; C = Corrugator supercilii; Z = Zygomaticus major; diff = difference score; OTHER = reactivity to other-related stimuli; ESE = Explicit Self-Esteem; general = in general; group = in group sessions; for Other-perceived $Likability_{general}$, we computed internal consistencies separately for acquaintance 1 to 3 and reported the median values; we did not report internal consistencies for Self-perceived $Likability_{group}$, as it was assessed with a single item measure; for Other-perceived $Likability_{group}$, we computed the internal consistencies separately for each time point within each session and reported the median values; for Agentic behavior, we computed internal consistencies separately for each of the eight observers and reported the median values.

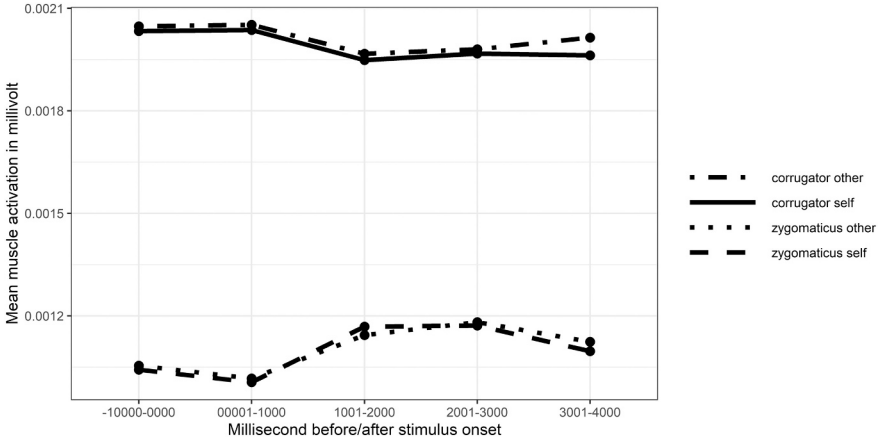

Fig. 1. Mean corrugator and zygomaticus activity during the presentation of self-related and other-related stimuli.
Note. Scores are averaged across all trials. Standard errors are represented by the error bars. MS -1000-0000 refers to the time interval during which the fixation cross was presented (baseline).

the other-related EMG reactions was similar in magnitude (α = 0.68, ω = 0.49). We explored the correlations between the self- and other-related EMG reactions and found that the two were weakly, but significantly correlated ($r = 0.21$, $p = .003$).

We then examined the test-retest correlations of the EMG measures. (We refrained from comparing the mean values across the two waves, as the EMG indices were based on residualized scores, which by definition had a mean value of zero.) As shown in Table 2, the correlations were significantly positive for all EMG indicators. In all cases, the t1 assessments of the self-related EMG measures correlated descriptively most strongly with the t2 assessment of the same measure and test-retest correlations were moderate to high ($r \geq 0.65$). For other-related EMG measures, the pattern was less consistent and the test-retest correlation was descriptively lower ($r = 0.42$).

3.3. Relations to socio-emotional correlates

We went on to investigate links between the self-related EMG measure and the socio-emotional correlates. (The reliabilities of the correlates are shown in Table 1 and Table S2 shows correlations between all variables.)

Concerning subjective well-being, $SELF_C$ was significantly linked to all three indicators. Precisely, the less participants frowned in response to self-related stimuli (as indicated by low $SELF_C$ scores), the higher their life satisfaction and positive affect were and the lower their negative affect was. $SELF_Z$ as well as $SELF_{diff}$ – which is arguably the most valid indicator, as it is based on the highest level of aggregation – were not significantly linked to any of these indicators.

Concerning likability, $SELF_C$ was significantly linked to three out of four indicators, $SELF_Z$ was linked to one these indicators and $SELF_{diff}$ was significantly linked to the same three indicators as $SELF_C$. The only likability indicator that was unrelated to all EMG measures was other-perceived likability in the specific group context.

Concerning behavioral observations, there were no significant links between the EMG measures and agentic behavior. Thus, the results did not support the notion that ISE, as measured via self-related EMG responses, went along with agentic behavior.

We next considered the possibility that associations between self-related EMG reactions and socio-emotional correlates might not be driven specifically by reactivity to the self, but by reactivity to social cues in general. To do so, we examined the links between the other-related EMG reactions and the correlates. As shown in Table 3, there were no significant links between other-related EMG reactions and any of the socio-emotional correlates. Thus, the alternative explanation did not hold.

Finally, we addressed the association between the self-related EMG reactions and ESE. As shown in Table 3, there was a rather weak, but significant, correlation between these two. Furthermore, ESE was significantly correlated with all outcomes except two (see Table S2). In light of these overlaps, the question came up whether or not the associations between the self-related EMG score and the socio-emotional correlates would persist once the effect of ESE was controlled. We thus ran a series of regressions models, in which we simultaneously predicted each correlate that had originally shown an at least significant zero-order correlation with the $SELF_{diff}$ score (see Table 3) by both the $SELF_{diff}$ score and ESE. As Table 4 shows, except for self-perceived likability in general, the effects remained significant. These findings indicate that when it comes to predicting likability, the EMG measure possessed some incremental validity beyond ESE self-reports.

Table 2
Intercorrelations between the EMG measures at both waves of assessment.

	t2 assessment			
t1 assessment	$SELF_C$	$SELF_Z$	$SELF_{diff}$	$OTHER_{diff}$
$SELF_C$	**0.76**** **[0.66, 0.84]**	−0.17	−0.55**	−0.21*
$SELF_Z$	−0.08	**0.65**** **[0.51, 0.76]**	51**	0.39**
$SELF_{diff}$	−0.58**	0.59**	**0.74**** **[0.63, 0.82]**	0.43**
$OTHER_{diff}$	0.15	0.10	−0.01	**0.42**** **[0.23, 0.57]**

Note. Retest correlations are printed in bold, values in square brackets indicate 95 % confidence intervals.
SELF = reactivity to self-related stimuli; C = Corrugator supercilii; Z = Zygomaticus major; diff = difference score; OTHER = reactivity to other-related stimuli.
* Indicates $p < .05$.
** Indicates $p < .01$.

4. Discussion

This research introduced a novel EMG-based measure of ISE. It did so by recording the activity of the corrugator and the zygomaticus muscles during the presentation of self-related pictures. To validate the measure, we examined the overall positivity of EMG reactions, their reliabilities and their relations to socio-emotional correlates.

4.1. The general positivity of EMG responses to self-related stimuli

On average, participants displayed facial muscular activity indicative of joy in response to their own pictures. That is, the activity of the zygomaticus increased whereas the activity of the corrugator decreased in comparison to baseline. This finding fits well with previous research indicating that on average people hold positively implicit evaluations of themselves (Greenwald & Banaji, 1995; Koole et al., 2001; Paulhus, 1993; Swann et al., 1990) and thus provides first evidence for the validity of the EMG measure.

It might seem surprisingly that EMG reactions for other-related stimuli were also on average positive and that reactions to self-related stimuli were not more positive than the ones to other-related stimuli. How can this pattern be explained? One aspect of the current study that distinguishes it from previous research using other-related cues as control stimuli (e.g., Krause et al., 2012) is that faces of *acquainted* others were used, namely of participants' group members. Research on the mere-exposure effect (Zajonc, 1968) has shown that stimuli are often evaluated positively just because they have been encountered before. In the current case, participants have not only briefly encountered their group members, but actually interacted with them repeatedly in getting-acquainted tasks. From this background, it seems understandable that also EMG reactions to other-related cues were on average positive. Future research should compare EMG reactions to self-related stimuli to reactions to photographs of unacquainted other and ideally also to other kinds of positive, neutral and negative picture cues.

4.2. Reliability of the self-related EMG reactions

With regard to internal consistency, the results indicated that the reliability of the self-related EMG measure was moderate in absolute terms, comparable to the value reported by Krause and Dufner (2020) for their EMG measure of implicit relationship satisfaction and slightly higher than the median reliabilities of alternative ISE measures, as reported in Krause et al. (2011). The test-retest reliability of the EMG measure was fairly high in absolute terms ($r = 0.74$ for the $SELF_{diff}$ score) and substantially higher than the median test-retest reliability of the alternative ISE measures (Krause et al., 2011). Taken together, the findings indicate that the EMG measure performed well in terms of reliability, if compared to alternative ISE measures.

4.3. Relations to socio-emotional correlates

Regarding subjective well-being, only recordings of the corrugator

Table 3
Intercorrelations between EMG measures, ESE and socio-emotional correlates.

	ESE	Subjective well-being			Likability				Agentic behavior
		Satisfaction with Life	Positive Affect	Negative Affect	Self-perceived $Likability_{general}$	Other-perceived $Likability_{general}$	Self-perceived $Likability_{group}$	Other-perceived $Likability_{group}$	
$SELF_C$	−0.18**	−0.17*	−0.15**	0.14**	−0.22**	−0.14**	−0.16**	−0.05	−0.02
$SELF_Z$	0.08	0.00	0.04	−0.02	0.04	0.15*	0.10	0.00	0.01
$SELF_{diff}$	0.18**	0.11	0.13	−0.11	0.18**	0.21**	0.19**	0.04	0.02
$OTHER_{diff}$	0.03	−0.03	−0.02	0.03	−0.01	0.07	0.08	−0.06	0.03

Note. SELF = reactivity to self-related stimuli; C = Corrugator supercilii; Z = Zygomaticus major; diff = difference score; OTHER = reactivity to other-related stimuli; ESE = Explicit Self-Esteem; general = in general; group = in group sessions.
* Indicates $p < .05$,
** Indicates $p < .01$.

Table 4
Regression analyses predicting each socio-emotional correlate simultaneously by $SELF_{diff}$ and ESE.

Predictors	Likability		
	Self-perceived $Likability_{general}$	Other-perceived $Likability_{general}$	Self-perceived $Likability_{group}$
$SELF_{diff}$	0.10	0.17**	0.13*
ESE	0.45**	0.20**	0.31**

Note. The displayed coefficients are standardized beta weights at each step. SELF = reactivity to self-related stimuli; diff = difference score; ESE = Explicit Self-Esteem; general = in general; group = in group sessions.
* Indicates $p < .05$.
** Indicates $p < .01$.

muscle passed the threshold to statistical significance for all subjective well-being indicators, whereas associations were non-significant for the zygomaticus and for the $SELF_{diff}$ score. The results were thus inconsistent and did not uniformly supported the notion that ISE, as measured via self-related EMG responses, goes along with high levels of subjective well-being.

In contrast, the EMG measure was positively linked to both indicators of self-perceived likability, which is in line with sociometer theory (Leary & Baumeister, 2000). With values approaching $r = 0.20$, the effect sizes can be considered "medium" according to modern standards (Funder & Ozer, 2019) and approximates the average effect sizes in social-personality psychology (Richard et al., 2003). With regard to other-perceived likability, results were mixed. When likability was rated by closely acquainted informants, it was positively linked to the EMG measure, but not when it was rated by group members during the laboratory session. How can this latter null effect be explained? First of all, one should note that also ESE was not significantly linked to other-perceived likability in group, see Table S2, which raises the question whether actual likability during the group sessions was indeed relevant for self-esteem. The low correlation between self- and other-perceived likability in the group setting ($r = 0.23$; see Table S2) indicates that participants hardly noticed how much they were liked by their group members and therefore it seems quite plausible that other-perceived likability in a specific group session might not have been salient and noticeable enough to affect either ISE or ESE.

Contrary to our expectations, EMG scores were not significantly linked to agentic behavior. These null effects might be explained by methodological differences between the current study and the one by Krause et al. (2016) that reported a positive link between ISE and observer-ratings of self-confident behavior. First, Krause and colleagues did not focus on agentic behavior in general, but specifically on self-confident behavior, as assessed via several clearly defined behavioral indicators. Second, Krause et al. (2016) created experimental contexts that were specifically chosen to make individual differences in terms of self-confidence visible, such as interviews about personal strengths and weaknesses. It is possible that our experimental tasks, which were not specifically designed for this purpose, possessed less trait-relevance (Tett & Guterman, 2000) for self-esteem.

When looking at the results pattern as a whole, one notices that effects were almost throughout descriptively stronger for the corrugator muscle than for the zygomaticus. A potential explanation for this difference could lie in the fact that recordings of the zygomaticus are technically more challenging than recordings of the corrugator. The corrugator is located at the medial end of the eyebrow and thus easy to detect when placing surface electrodes. The zygomaticus, in contrast, is much longer and extends from the cheekbone to the corners of the mouth. It is therefore possible that larger imprecisions in electrode placement account for the results pattern.

4.4. The overlap with ESE

Both the corrugator score and the $SELF_{diff}$ score were significantly linked to ESE. Hence, persons who responded with a smile reaction to pictures of their own faces also reported high explicit self-esteem. This result matches with some previous studies reporting positive associations between measures of ISE and ESE (e.g., Buhrmester et al., 2011; Jusepeitis & Rothermund, 2022; Krause et al., 2016; Schimmack & Diener, 2003) and indicates that people might base their deliberative evaluations of themselves partly on their physiology-based self-related affect. More generally, the finding converges with results from the attitudes literature showing a small positive correlation between measures of implicit and explicit attitudes (Hofmann et al., 2005). Finally, the findings match with EMG studies reporting positive correlations between EMG based measures of motive dispositions and motive self-reports (Dufner et al., 2015, 2022). The positive correlation between the EMG based measure and ESE thus contributes to accumulating evidence that people have some insight into their implicit personality aspects, at least if implicit is defined as spontaneous, affective"gut reactions"to attitude objects (see Corneille & Hütter, 2020).

Given the overlap between the EMG measure and ESE, we examined the incremental validity of the EMG measure over and above ESE. All correlates, except for other-perceived likability in group, that were linked to the EMG measure were also linked to ESE, a pattern contradicting the double-dissociation assumption, which states that the correlates of implicit constructs are distinct from the ones of their explicit counterparts. Instead, the pattern supports an additive effects model, in which an implicit and an explicit version of the same construct predict the same outcomes (for a description of the different models, see Perugini, 2005). Importantly, the associations with the likability indicators remained significant when ESE was controlled, which indicates that the links between ISE, as measured via the EMG method, and likability exist irrespective of any associations with ESE. This result is in line with recent findings based on other measures of ISE that indicate incremental validity over and above ESE (Back et al., 2009; Krause et al., 2012).

4.5. Limitations and future directions

Several limitations of this investigation should be mentioned. A general limitation of the current research is that the hypotheses and analyses have not been pre-registered. To rule out the possibility of false positive with great confidence, future research should directly replicate the effects.

Another limitation of our work pertains to the internal consistency of the EMG measure, which despite being better than average in comparison to alternative measures of ISE, was only moderate in absolute terms. The imperfect reliability attenuated the associations with the socio-emotional correlates and renders the EMG approach unsuitable for applied settings in which information about individual persons is gathered (because confidence intervals around the test scores would be too large). However, previous research in other content domains has shown that with an increased number of stimulus presentation EMG measures can attain reliabilities of $\alpha = 0.80$ or larger (Dufner et al., 2022).

According to the Spearman-Brown formula (Brown, 1910; Spearman, 1910), 12 trials would be necessary to raise the internal consistency of the $SELF_{diff}$ score to $\alpha = 0.80$. The fact that the number of presented other-related stimuli varied between participants was not ideal from a psychometric perspective. It is possible that the reliability of the other-related EMG reactions, habituation patterns and saliency effects differed from person to person, which would undermine the comparability of the measurements across persons. Future studies would do well to use a constant number of other-related stimuli.

Issues of reliability aside, a disadvantage of the EMG approach is that assessments are not very economic, as they will typically have to take place in a laboratory and require an EMG system. Furthermore, it is possible that assessments are not only affected by implicit aspects of self-esteem, but also by factors, such as, for example, structural differences between persons in terms of skin and muscle features or individual differences in facial expressiveness. Future research will have to explore to what extent such factors are relevant and whether it might perhaps even be possible to assess mimic reactions to self-related stimuli via webcam recordings that are coded by emotion-recognition software (which would render online assessments possible).

The EMG task is a measure of spontaneous affective reactions; participants are not required to do anything but to view a set of photographs. In order the safeguard the spontaneity of the reactions, it is important that participants are not told about the purpose of the assessments or that the EMG system captures smile reactions. However, even if these recommendations are considered, one should keep in mind that facial reactions are recorded over a time window of several seconds and are therefore neither uncontrollable nor immune to faking. Thus, the approach should not be used in settings where faking is to be expected.

Another limitation of the current investigation is our exclusive usage of self-report measures of subjective well-being. As implicit constructs are thought to mainly affect spontaneous, automatic behavior (e.g., Franck et al., 2007; Rudolph et al., 2010; Vandromme et al., 2011), validating them with self-reported outcomes is not ideal (Buhrmester et al., 2011). Future research should use more non self-report outcomes, such as, for example, clinicians' ratings of mental health or well-being (Cunningham et al., 2012).

As we have pointed out in the Introduction, the EMG measure is based on the conceptualization of implicitness as spontaneous physiology-based affective reactions, yet other measures of ISE build upon different aspects of implicitness, such as for example the associative strength between classes of content in the case of the IAT (Greenwald et al., 2002). In fact, past research has shown that different measures that focus on different aspects of ISE are hardly correlated (Bosson et al., 2000). It was not our intention to replace existing ISE measures with the EMG approach, but to provide a tool that is specifically suited for assessing self-related physiological-affective reactions. It will be an interesting task for future research to investigate associations between the EMG measure and alternative measures of ISE. Positive correlations are likely to emerge for measures that also have a strong affective component, such as, for example affective priming tasks (e.g., Krause et al., 2012). Such future work could also examine whether the different measures of ISE predict relevant outcomes incrementally.

Such research could also investigate whether there are specific outcomes that might be particularly well predicted by the EMG measure. It has been argued, for example, that people's spontaneous tendency to associate the self with positive affect leads to memory biases (e.g., better recall of positive than negative self-attributes, Sedikides & Gregg, 2008) and plays a role in conditioning paradigms (e.g., the self as an unconditioned positive stimulus, Zhang & Chan, 2009). Given that the EMG task is a very immediate measure of self-related affect, it should moderate these effects and it should do so over and above ESE and alternative measures of ISE.

Future studies could also examine the overlap between the EMG measure and ESE more closely. According to the MODE model, which considers *M*otivation and *O*pportunity to serve as major *DE*terminants influencing judgments and behaviors (see Fazio & Olson, 2003), the relation between implicit and explicit measures depends on people's motivation and opportunity to deliberate. If either motivation or opportunity is relatively low, explicit measures are expected to correlate with implicit ones (see Koole et al., 2001). From this background, it seems possible that, for example, among participants who are distracted while completing their self-reports the association between the EMG measure and ESE is pronounced.

5. Conclusion

Past research has shown that the EMG recordings can be used to assess implicit aspects of different personality constructs, such as attitudes (McHugo et al., 1991; Vanman et al., 2004), motive dispositions (Dufner et al., 2015, 2018, 2022) and relationship satisfaction (Krause & Dufner, 2020). The current investigation contributes to this growing literature by demonstrating that the EMG approach might also be fruitful for the measurement of ISE. The approach assesses in a rather straightforward manner what is considered a central aspect of ISE, namely the tendency to spontaneously associate the self with positive affect. The present findings provide first evidence that the approach might lead to reliable and valid assessments of individual differences in this tendency. We encourage researchers to build upon the EMG approach to unravel the mysteries of self-esteem.

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Declaration of competing interest

The authors declare no potential conflicts of interest with respect to the research, authorship, or publication of this article.

Data availability

I have shared the link to my data and code in the manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.

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