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Development, Validation, and Comparison of Self-Report Measures for Positive and Negative Affect in Intensive Longitudinal Research

Leonie Cloos

Eva Ceulemans

Peter Kuppens

Faculty of Psychology and Educational Sciences, KU Leuven, Leuven, Belgium

Author Note

The preregistration and other supplementary files are available online: https://osf.io/485qy/ Correspondence concerning this manuscript should be addressed to Leonie Cloos, Faculty of Psychology and Educational Sciences, Katholieke Universiteit Leuven, Tiensestraat 102, 3000 Leuven, Belgium. Email: leonie.cloos@kuleuven.be

Abstract

Affect is central to human functioning. Due to its dynamic nature, it is often studied with intensive longitudinal designs, yet the development and validation of measures for this purpose have received little systematic attention. In the current study, we review theoretical and methodological conceptualizations of affect that are relevant for repeated momentary positive and negative affect measurement. We developed a questionnaire including six dimensional affect and 22 discrete emotion items that allowed us to measure alternative momentary affect constructs with single and multi-item scores. The items were operationalized into two bipolar, six positive, and six negative momentary affect measures. We compared the measures with three quantifiable criteria of construct validity: the amount of within-person variance, within-person sensitivity to emotional events, and between-person relations to depression and neuroticism. The criteria were empirically investigated with a preregistered experience sampling study (N = 153). We identify the measures with the strongest validity evidence across all criteria and evaluate their suitability for specific research questions, by looking at individual criteria. The overall findings provide strong evidence supporting the use of single-item measures of momentary affect. Furthermore, they provide an efficient low-burden assessment tool that is comparable across studies. For multi-item scales, it is recommended to combine discrete emotion items of similar intensity, while simply selecting and averaging discrete emotion items is problematic concerning our validity criteria. In the future, we encourage the field to conduct systematic research on the use and interpretation of scores that aggregate different emotion items together.

Keywords: affect, measurement, intensive longitudinal data, construct validity, scale construction

Public Significance: Daily life is generally accompanied by positive and negative emotional experiences that are central to psychological well-being. In this article, we present the first systematic investigation of measures to track affective states in daily life, providing evidence about the suitability of alternative self-report measures for intensive longitudinal research.

Development, Validation, and Comparison of Self-Report Measures for Positive and Negative Affect in Intensive Longitudinal Research

Affective experiences are central to many psychological domains so that phenomena as diverse as motivation, decision making, attitudes, communication, and mental health are studied in relation to emotions, mood, or positive and negative affect (Barrett & Bliss-Moreau, 2009; Dukes et al., 2021). Affect is not a constant but a fluctuating phenomenon, driven by external events and internal regulation efforts (Kuppens & Verduyn, 2017). To study affect in its' dynamic form, it is necessary to obtain intensive longitudinal data (ILD) consisting of multiple subsequent self-reports of momentary affect. Daily life studies using the Experience Sampling Method (ESM; Csikszentmihalyi & Larson, 1987) are prime examples of ILD designs and have received considerable interest in contemporary emotion research (see e.g., Hamaker & Wichers, 2017). Nonetheless, relatively little effort has gone into systematically studying and validating self-report instruments for the measurement of momentary positive and negative affect.

Measuring Momentary Affect in Daily Life

Self-report questionnaires remain the most popular tools to measure affect. The importance of the subjective nature of affect (Gray & Watson, 2007) and the lack of objective (or physiological) markers for affective experiences (Coppin & Sander, 2016) are crucial considerations in this respect. Self-reports are especially suited for ESM research since real-time ratings of emotions tend to be less prone to recall bias and thus more valid than retrospective reports (Mauss & Robinson, 2009). Currently, the prevailing practice in the field is to administer a number of positive and negative emotion items at every occasion, and use their averages as indicators of positive affect (PA) and negative affect (NA). However, the number and content of items making up these scores vary widely across studies, hampering the reproducibility of findings and scientific progress (Brose et al., 2020). While great effort has been devoted to measuring more stable properties like personality and intelligence (Simms, 2008), or to improving methods to collect (van Berkel, 2017) and analyze ILD (Ariens et al., 2020), the development of valid instruments to measure affect has lagged behind for several reasons.

Problems

First and foremost, the lack of a consensual theory of affect makes it difficult to establish standard measurement instruments for emotion research (Barrett, 2016; Kuppens, 2019). Each theory specifies a different measurement model involving either a single bipolar, separate unipolar, or multiple distinct latent factors (see literature below). In face of the many options, researchers regularly fail to report the conceptual rationale for using a scale (Ekkekakis & Russell, 2013). ILD researchers have adopted the practice to measure constructs with multiple items (e.g. Dejonckheere, Mestdagh, Houben, et al., 2019) often without justifying the conceptual or analytical justification for the item selection (Brose et al., 2020).

Secondly, these different theoretical assumptions are often not aligned with practical methods of intensive measurement. For example, in the course of a day positive *and* negative emotions can both (co-)occur, so that one may operationalize items as two independent *unipolar* PA and NA constructs (Larsen et al., 2001). However, stress decreases the capacity to distinguish emotions and strengthens the focus on their valence (i.e., positive *versus* negative; Barrett et al., 2004), which would indicate a single *bipolar* construct with negatively correlated PA and NA items (Dejonckheere et al., 2019). Also, specific stimuli and events give rise to distinct emotion responses that depend on a person's appraisal of the context (Erbas et al., 2015; Moors, 2009). Different emotion states like anger, sadness, or guilt are not experienced in perfect synchrony (Zelenski & Larsen, 2000). Therefore, computing the average across items, may not capture the intense negative affect someone feels when they are very angry without being sad. Indeed, the dynamic patterns found in single emotion analyses can be very different from those obtained with a mean score (e.g. Wichers et al., 2020). Moreover, the measurement model underlying mean scores assumes that every item contributes the same amount of information to one construct (McNeish & Wolf, 2020). Given the considerations above, this is unlikely the case for all occasions (McNeish et al., 2021; Vogelsmeier et al., 2021).

Third, there are only few guidelines on how to systematically develop momentary affect measures or test the validity of the scores' interpretations. The traditional psychometric methods (e.g. classical test theory) are rooted in between-person designs and strive toward consistency, which is rather paradoxical when the phenomenon of interest is variable (Schuurman & Hamaker, 2019). As is well known, validity evidence at the trait level does not provide validity evidence of state scores (Horstmann & Ziegler, 2020).

On account of these problems, most (but not all, see for instance Wilhelm & Schoebi, 2007) develop measures '*on the fly*' (Flake & Fried, 2020), and there is very little systematic research on how different assessment and scoring methods compare in terms of validity. We aim to fill this gap by considering theoretical, practical, and statistical assumptions for the measurement of momentary affect and compare different measurement options, following the process of construct validation.

The Need for Construct Validation

The assumption in psychological research that responses to a questionnaire reflect a non-observable construct is a hypothesis that should be regularly tested and revised in a process called construct validation (Cronbach & Meehl, 1955). Empirical evidence supporting the theory and measurement of psychological phenomena is a prerequisite of rigorous research, as it provides the foundation for study design, data analyses, and interpretation of findings (Benson, 1998; Flake, 2021). To address this need we apply Loevinger's (1957) process of construct validation, which is structured into three sequential components: substantive, structural, and external. First, the substantive component consists of determining the theoretical and empirical foundations of a measure. Based on a literature review, theories and existing instruments of the target construct are examined to conceptualize the content, scope, and theoretical context for its measurement (Netemeyer et al., 2003). Measures that are new, revised, or used in alternative contexts should first be tested in an independent representative sample (Ziegler, 2014). The second, structural component consists of psychometric investigations of empirical data to obtain evidence about the mapping of the scores onto the hypothesized psychological process (Messick, 1995). The final, external, component tests how the scores relate to a set of other theoretical constructs in a *nomological network* (Campbell & Fiske, 1959; Cronbach & Meehl, 1955).

Construct Validation Framework for Momentary Affect Measures

In the following, we address the substantive component with a literature review of current affect theories and existing affect measures (Bringmann et al., 2022; Grahek et al., 2021). Based on theoretical and methodological evidence we establish a clear conceptualization of *momentary affect* and develop an ESM questionnaire with different measurement and scoring procedures. For the structural and external components of this validation framework we propose three criteria to determine the psychometric evidence for the affect scores (Clark & Watson, 2019).

Literature Review

The current affect literature offers a range of theoretical models that conceptualize positive and negative affect in several different ways (Barrett et al., 2019). Constructionists propose that valence (aside arousal) is a crucial, bipolar dimension underlying core affect, where positive and negative emotional experiences are opposing each other (Barrett & Russell, 1998; Russell, 2009). An alternative theory presents affect as *two unipolar* dimensions of positive and negative affect that are reflected by positive and negative emotions (Watson et al., 1999). General affect and specific emotions vary in duration, frequency, intensity, and activation pattern (Gray & Watson, 2007). Many theories consider that specific emotional states closely interact with or reflect different underlying affect dimensions so that categorical and dimensional models can be combined (Mauss & Robinson, 2009). While general affect is always present, emotions are episodes that involve or are constructed from affect in response to specific internal or external stimuli (Russell, 2005). Our attention to and interpretation of these stimuli determine the quality of an emotional episode (Scherer & Moors, 2019).

These different theoretical models can apply in repeated measurement. Firstly, the difference in item formats and response scales can influence the rating of the construct towards bipolarity or independence (Russell & Carroll, 1999). Secondly, since the construct is investigated inter- and intra-individually on different timescales, the alternative theories and respective measurement models are equally justifiable (Eadeh et al., 2019; Vogelsmeier et al., 2021). Third, individuals use different emotion words to communicate the level of arousal and valence they experience (Moors, 2009). These properties of the selected items influence the measurement model as well (Barrett, 2004). Finally, if items are too heterogeneous, it is risky to interpret an average score across items as unidimensional, since it may reflect multiple dimensions (Eisele et al., 2021; Ziegler & Hagemann, 2015).

Measurement Conceptualization

Based on the above review, we conceptualize momentary affect as dimensional constructs of *bipolar* affect (BA) or *unipolar* PA and *unipolar* NA. Several options exist for measuring these constructs. Firstly, a single item can be used to measure valence (Russell et al., 1989), positivity or negativity (Larsen et al., 2009). Secondly, unlike BA, PA and NA are usually assessed with multi-item scales (Kuppens et al., 2013). Third, high and low-intensity can be distinguished within the PA and NA scales (Reisenzein, 1994). Lastly, when a person experiences an intense emotion in absence of other, same-valenced emotions (say, anger but not sadness), they may experience high levels of affect that are not captured with the other items in this scale. In other words, on some occasions, people may determine the most important emotion for each moment and give this item more weight on the scale. Thus, the maximum scoring emotion can measure the intensity of PA and NA across moments with the most relevant item (Ebner-Priemer et al., 2007; Heiy & Cheavens, 2014; Southward & Cheavens, 2020).

ESM Questionnaire Development

Existing Affect Measures and Item Pool

Based on literature review, we identified several established affect measures (Supplement Table S1). Of the 18 questionnaires, 16 were developed for between-person assessment, two of which were also adapted into within-person measures (Cranford et al., 2006; Wilhelm & Schoebi, 2007). The most cited instruments were the *unipolar* Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988) and the *bipolar* Affective Circumplex (Russell, 1980). Additionally, we consulted an open source ESM item repository for single-item affect measures (osf.io/kg376/; Kirtley et al., 2021). The 179 unique items from the questionnaires and 7 single items from the repository constituted an item pool that covered "all possible content […] according to all […] alternative theories" (Loevinger, 1957, p. 659). To integrate practical considerations (e.g. burden, time-frame) with the theoretical conceptualization we systematically selected the items in the following steps.

Step 1: Total Length of ESM Questionnaire

It has been shown that longer questionnaires are more burdensome and decrease the compliance of participants (Eisele et al., 2022). Furthermore, the estimated within-person variability in momentary affect measurement is typically higher in protocols with fewer items (Hasselhorn et al., 2021). Since compliance, as well as within-person variability are crucial for ILD research, we limited the total number of items to 30 (28 affect items, 2 event items).

Step 2: Single Items

Single-item measures are indispensable to ILD research as they decrease participant burden, involve fewer decisions regarding item selection or scale composition, and facilitate comparability between longitudinal studies (Lucas & Donnellan, 2012). For each construct (BA, PA, and NA), we selected two alternative measures from the ESM item repository (Kirtley et al., 2021). We compared BA items on the mode of assessment and PA and NA items for wording and response scale (Russell & Carroll, 1999). The first BA item (*verbalBA*) asked participants ‘How do you feel right now?’ on a negative (-50) neutral (0) positive (50) slider scale. The second BA item (*smileyBA*) was a smiley pictogram that could be manipulated with a slider (left for negative, right for positive). Two unipolar items rated the question ‘How positive/negative do you feel right now?’ from ‘Neutral’ (0) to ‘Very positive/negative’ (100) (labeled *neutrPA*, and *neutrNA* because of the *neutral* anchor). Two unipolar items rated ‘To what extent do you experience positive/negative emotions right now?’ from ‘Not at all’ (0) to ‘Very strong positive/negative emotions’ (100) (labeled *absPA* and *absNA* because of the *absent* anchor).

Step 3: Discrete Emotions

To assess PA and NA with discrete, but like-valanced positive and negative emotion items (Harmon-Jones et al., 2016), we focused on 11 questionnaires that contained discrete emotion scales. Across questionnaires we found 25 different sub-scales, some of which displayed overlap in items, tapping the same emotion under another label (a phenomenon referred to as *'jangle fallacy'*; Kelley, 1927). We examined to what extent the emotion scales contained similar items and consulted additional resources to differentiate them from each other (Brose et al., 2020; Weidman et al., 2017). We found 14 distinguishable scales. Of these, scales for self-esteem, confusion, and disgust were discarded, respectively because it is not considered central to affect, is not clearly marked in valence, and is not sufficiently common for ILD measurement, (Deonna & Scherer, 2010; Moors, 2022; Ortony et al., 1987; Russell, 2003). Eventually, we determined four *positive* (Happiness, Vigor, Love, Calmness) and seven *negative* (Sadness, Fatigue, Shame, Guilt, Anger, Anxiety/Fear, Stress) discrete emotion constructs. The items of the respective subscales were pooled together for each construct.

Step 4: Emotional Intensity

Within each item pool, we rank-ordered the items according to their valence score on the normed index of affective ratings for words in Dutch (Moors et al., 2013). This valence norm score reflects the intensity for each item on a scale from 1 (*very negative*) to 7 (*very positive*). The high and low-intensity items in the positive emotion categories were: *happy, satisfied* (Happiness); *energetic, alert* (Vigor); *loving, caring* (Love); *relaxed, calm* (Calmness). The ones in the negative emotion categories were: *depressed, gloomy* (Sadness); *exhausted, tired* (Fatigue); *ashamed, shy* (Shame); *guilty, regretful* (Guilt); *angry, irritated* (Anger); *anxious, concerned* (Anxiety-Fear); *stressed, nervous* (Stress).[1]

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[1] Note that intensity ratings were obtained from the Dutch norms, and may therefore have different connotations when translated to English. For items not available in the index or selected highest/lowest across categories, we consulted additional references (Supplement Section S2). For positive emotions higher ratings reflect higher intensity, for negative emotions lower ratings reflect higher intensity

Step 5: Scores

Table 1 summarizes the scoring procedure. The six *dimensional* items for BA, PA, and NA were simply *raw scores*. Considering the multiverse of scores that can be computed with 22 discrete emotion items, we used theoretical reasoning to determine 8 alternative multi-item *composite scores* for *PA* and *NA*. First, we treated all items as equal indicators and averaged the positive and negative emotion items into separate *PA* and *NA mean scores*. Second, to accommodate the idea that the intensity of affect may be best captured by the most strongly experienced emotion of that valence, we determined the highest score within the positive and negative emotion items, to measure *PA* and *NA maximum*. Third, we ranked items for positive emotions and items for negative emotions by their valence score on the ANEW index, to measure *high-intensity PA* and *NA* and *low-intensity PA* and *NA*. Lastly, we compared the *raw score* of each *discrete* emotion to the single items.

Validity Criteria

The alternative scores were compared to one other on three theoretically relevant criteria.

Criterion One: Variability

Firstly, dynamic affect measures should be sensitive to within-person processes of change and capture *moment-to-moment variability* (Brose et al., 2020). The proportion of variance at the within-person level is thus an indicator of structural validity (Hox et al., 2012). There is no clear threshold of “sufficient” but the average observed within-person variance for affect measures in empirical studies is 53% (SD = .16) (Podsakoff et al., 2019). Another relevant and often used indicator of within-person variability is the person-specific standard deviation (*iSD*), reflecting *intra-individual variability* of affect (Schreuder et al., 2020).

Criterion Two: Sensitivity to Within-Person Associations

Secondly, a theoretical model of change should determine an underlying psychological process that explains the variation in momentary affect scores (Collins, 2006; Hopwood et al., 2022). Research on appraisal processes has shown that moment-to-moment changes in affect in daily life are partially determined by the cognitive appraisal of external and internal stimulus events (Kuppens et al., 2012; Scherer, 2005). External validity evidence at the within-person level, therefore, requires that momentary affect measures are sensitive to the association between affect and the appraised pleasantness of encountered events.

Criterion Three: Sensitivity to Between-Person Characteristics

Lastly, subject-specific affect dynamic characteristics derived from individuals' time-series of momentary affect scores, such as the average level and degree of variation, are theoretically related to trait measures of mood and personality (Trull & Ebner-Priemer, 2013). The external validity of momentary affect measures at the between-person level is established if affect dynamic scores are meaningfully related to trait measures in a *nomological network* (Campbell & Fiske, 1959). The literature suggests that the average level of momentary affect should be related to depression, a condition of prolonged negative mood and the relative absence of positive mood, among others (American Psychiatric Association, 2013; Bos et al., 2019; Panaite et al., 2020). Moreover, the variability of momentary affect should be related to neuroticism, a personality type of fluctuating mood (Eid & Diener, 1999; Kuppens et al., 2007).[2]

[2] The variability in affect scores is higher in neurotic individuals, but, findings are conflicting therefore analyses need to account for average levels of affect (Kalokerinos et al., 2020; Mestdagh & Dejonckheere, 2021).

Method

Participants

Participants were required to be Dutch-speaking and own a personal smartphone. The sample consisted of students and volunteers recruited through the universities' participant management system, advertisement and social media platforms. We used Monte-Carlo-based power simulations to determine the number of participants needed to detect both within and between-person effects (Supplement Section S3). The simulations were based on empirical estimates from data collected under a similar ESM paradigm (Koval et al., 2015). In the preregistration we reported to aim for a minimum sample size of 120. Our final sample included 153 individuals with a mean age of 22 years (*SD* = 7.1), an approximately equal male (49.7%) to female (49.0%) gender ratio, with two participants not identifying as either (1.3%). The average compliance rate was 88% (range = 51% – 100%).

Procedure

The study was approved by the Social and Societal Ethics Committee – KU Leuven, Belgium. Eligible participants were invited to a video conference session where participants together with a researcher, set up the ESM platform m-Path (www.m-path.io) on their smartphones and were instructed about the ESM procedure, compliance, and informed consent. After completing the session participants received an anonymized code that was entered into the app to enroll in the study. They were required to agree to the informed consent and answered demographic and baseline questionnaires. Lastly, they selected their preferred 12-hour timeframe. For the next 14 days, participants received 10 notifications per day, asking them to answer the 30-item ESM questionnaire (Supplement Table S4). The completion time was unrestricted, but questionnaires expired 30 minutes after the notification or at the next notification. Notifications occurred within a 12-hour timeframe that was split into 10 blocks of 72 minutes. Within each block one notification was sent at a random moment and followed by a reminder if the questionnaire was not started after 5 minutes. After the 10th notification on the last day participants were given an end-questionnaire to complete the study. Participants could earn up to 50€ (or 8 credits for research participation required for first-year psychology students). The reward was based on overall compliance so that 75% compliance was sufficient to earn the full reward, but each decrease of 10% was associated with a deduction of 1 credit/6€.

Materials

Baseline Questionnaires

Before the ESM assessment started, participants had to fill in five baseline questionnaires, report their age, identified gender, and select their preferred sampling window. We used the following baseline measures for the analyses.

Depression. The Dutch version of the Center for Epidemiologic Studies Depression (CES-D) Scale (Bouma, 2012) was used to measure depressive symptoms. The 20-item scale asks about the extent to which participants experienced different symptoms of depression over the past week from 1 (*rarely or none of the time*), to 4 (*most or almost all the time*).

Neuroticism. The 8-item neuroticism subscale of the Dutch version of the Big Five Inventory (BFI; Denissen, Geenen, van Aken, Gosling, & Potter, 2008) was used to measure neuroticism. Participants were asked to rate statements about their personality from 1 (*strongly disagree*) to 5 (*strongly agree*).

ESM Questionnaire

Affect Items. At each notification (i.e. “*beep*”) participants rated the 28 affect items on a visual slider scale starting at the midpoint. They were presented before the event items in random order. The *bipolar* scale of *verbalBA* ranged from -50 (*Very negative*) to 50 (*Very positive*) with the mid-point being 0 (*Neutral*). The pictogram item *smileyBA* ranged from 0 (*Negative*) to 100 (*Positive*). The '*neutral* endpoint scales' of *neutrPA* and *neutrNA* ranged from 0 (*Neutral*) to 100 (*Very positive/negative*). The '*absent* endpoint scales' of *absPA* and *absNA ranged* from 0 (*I don't experience positive/negative emotions*) to 100 (*I experience very strong positive/negative emotions*). Each *discrete* emotion item presented in the question 'How [item] do you feel at the moment?', was rated from 0 (*Not at all [item])* to 100 (*Very [item]*). Table 1 presents all items in English, the original items are listed in the supplement Table S4.

Event Items. The intensity of affective events was measured for positive and negative events separately. The item 'Think about the most positive/negative event since the last beep. How intense was this event?' was rated on a scale from 0 (*There was no positive/negative event*) to 100 (*Very positive/negative*). The items were randomized and presented after all affect items.

Analyses and Results

The data was processed and analyzed using R (version 4.0.5; R Core Team, 2021). The analyses were preregistered (https://osf.io/9yuf7; minor deviations from the preregistration are documented in footnotes). Before the data analyses, we determined participants' compliance and invalid responses. Participants with compliance rates below 50% (*N* = 6) or with more than 30% of responses rated as invalid were removed (*N* = 2).[3] The average number of valid responses for the remaining 153 participants was 123 (*SD* = 14.60; *range* = 72 – 140), providing a total of 18,822 valid data points for the analyses.

[3] Responses to questionnaires that did not expire, were answered double, had missing due to technical issues, with more than 15 consecutive items answered in the same 15-point range on the slider, the response time was above 15 minutes, or if more than 15 items were answered < 500ms. Deviating from the preregistration we did not exclude response times < 60s since they were realistic for all subjects.

Data Processing

Momentary Affect: Within-Person Scores

First, we computed the 14 alternative momentary affect scores as operationalized above (Table 1). The *dimensional single items* were raw scores (1. *verbalBA*, 2. *smileyBA*, 3. *neutrPA*, 4. *absPA*, 5. *neutrNA*, 6. *absNA*). From the 22 *discrete emotion items,* we computed four *composite scores* for PA and NA each. First, the average of 8 positive (7. *PA Mean*) and 14 negative (11. *NA Mean*) emotion items. Second, the highest value of the positive (8. *PA Max*) and negative (12. *NA Max*) emotion items. Third, the average of the 4 positive high-intensity (9. *PA High*) and 7 negative high-intensity (13. *NA High*) items. Fourth, the average of the 4 positive low-intensity (10. *PA Low*) and 7 negative low-intensity (14. *NA Low*) items. Additionally, we compared the performance of the *dimensional single items* to the *discrete emotion items* on each criterion and report them in the Supplement (Figures S1-S7).

Affect Dynamic Characteristics: Between-Person Scores

From each pf the scores, we estimated two affect dynamic measures to examine between-person characteristics. Firstly, the mean level (*iM*), was computed as the average of the respective momentary scores across all observations of each individual. Secondly, the variance was computed as the intra-individual standard deviation (*iSD*) of these scores.

Validity Criteria

Before analyzing the criteria, we examined the distribution of all measures separately by inspecting their mean, variance, range, and skew (Table 2).

Criterion One: Variability

First, we compare the measures' sensitivity to within-person affect variance by computing a reversed intraclass correlation coefficient (*rICC*). We decomposed the variance of each measure into within-person and between-person variance components using intercept-only multilevel models in which scores at each measurement occasion (Level 1) are nested within persons (Level 2). We specified models including the affect score as the dependent variable, a random intercept to estimate variance at the between-person level (${\sigma_{u_0}}^2$), and serially correlated residuals across measurement occasions (${\sigma_{e_t}}^2$) using a first-order autoregressive (*AR₁*) correlation structure. We divided the between-person variance by the total variance (which also contains residual unsystematic variance, however) and reversed the value to compare how much of the total variance in the different affect measures is situated at the within-person level. Higher values can thus be interpreted as higher sensitivity to momentary changes.

$$rICC = 1 - \frac{{\sigma_{u_0}}^2}{{\sigma_{u_0}}^2 + {\sigma_{\varepsilon_t}}^2} \tag{1}$$

Figure 1 presents the *rICC* for each measure. All of the PA measures captured more within-person than between-person affect variance (*rICC* > 50%). For the NA and BA measures, the single items showed the highest proportion of within-person variance. It is known that single items contain more measurement error (i.e. residual variance) than composite scores, which induces a positive bias on the *rICC* estimates of single items (Wilms et al., 2020). To disentangle the residual from systematic within-person variance, we estimated three-level models, in which moments were nested in days, which were nested in persons. The day level variance, which contains only systematic variance, was the highest among the single items (Figure 2). Additionally, the comparison of all single items showed that the dimensional single items performed better than the discrete emotion items (Supplement Figures S1-S7).

Secondly, we estimated how much individual affect variability each measure captured on average. We grand-standardized the scores and calculated the mean of the intra-individual standard deviations *M(iSD)* for each measure to compare them to each other. Figure 3 shows that the single items have higher average within-person standard deviations than the composite scores. For the average individual in our sample, the NA single-item measures captured the most affect variability. Of the composite measures those with items of high and low-intensity only captured more affect variability than mean scores.

Criterion Two: Sensitivity to Current Positive and Negative Events

For each measure, we estimated the strength of the momentary association between *affect* and appraised *event* intensity. First, we specified separate multilevel models for PA, BA, and positive emotion item scores, where positive *event* intensity was used to predict the respective *affect* score. Second, we specified separate multilevel models for each NA, BA, and negative emotion item scores, where negative *event* intensity was used as the predictor of the *affect* scores. The temporal dependency of the within-person observations was accounted for by including serially (AR_1) correlated errors. Each variable was mean-centered within persons and standardized across all observations. Since the marginal means of *affect* and *event* are 0 for each individual there is no random intercept in the multilevel model (Wang et al., 2019).

$$\begin{aligned} affect_{it} &= \beta_{1i}\, event_{it} + \varepsilon_{it} \\ \beta_{1i} &= \gamma_{10} + u_{1i} \end{aligned} \qquad (2)$$

The effect of interest was the *standardized fixed slope* γ_{10}, which represents the relation between positive or negative *events* and *affect* for the average subject. We used the within-person proportion of variance explained by the fixed slope parameter ($R_w^{2(\gamma_{10})}$) as effect size to compare the measures' sensitivity to within-person associations. The centered intercept-only model contains only residual variance, therefore the decrease in residual variance from a null model to the random slope model showed the same results as directly estimating the $R_w^{2(\gamma_{10})}$.

The results can be found in Figures 4 and 5. We found that positive *event* intensity explained between 9% to 17% of the within-person variance in PA and BA measures. These percentages had a lower range than those obtained when associating the NA and BA measures with negative *event* intensity ($R_w^{2(\gamma_{10})}$ = 7% - 19%). The single items with the zero anchor *absPA* and *absNA* had the highest sensitivity to *event* intensity. For the BA measures the single item *smileyBA* was more sensitive to positive, while *verbalBA* was more sensitive to negative *events*.

Criterion Three: Sensitivity to Between-Person Differences

Firstly, we investigated the relation between depression and person-specific average levels of affect (*iM*). For each measure, we estimated a separate linear regression model using the affect measure's *iM* estimate to predict depression (*CES-D*) scores. We determined the standardized slope β_{iM} and the proportion of variance the *iM* scores explain in *CES-D*. The *iM* scores from PA and BA measures negatively predicted depressive symptoms, while the relationship was positive for NA measures (Table 3). As shown in Figure 6 the *iM* scores of BA and NA measures explained more variance in depression than any of the *PA* measures.

Secondly, we examined relations between neuroticism and person-specific affect variability (*iSD*). For each affect measure, we conducted a two-step multiple regression, by fitting a model which only included the measure's *iM* estimate as a predictor of the neuroticism scores first ($Model_{iM}$) and adding the *iSD* estimates as an additional predictor in the second step ($Model_{iM+iSD}$). We estimated how much variance each affect measure's *iSD* estimate explains in neuroticism while controlling for the *iM*.

$$\Delta R^2 = {R_{Model\ iM+iSD}}^2 - {R_{Model\ iM}}^2 \quad (3)$$

Table 3 reports the standardized slope (β_{iM}, β_{iSD}) for each predictor from the second step. Figure 7 visualizes the proportion of variance in neuroticism that is uniquely explained by a measure's *iSD*. All NA measures, except *NA Max*, uniquely explained a high amount of variance in neuroticism. Overall neuroticism was more strongly associated with NA than PA variability. In PA measures the *iSD* of *PA Mean*, *PA Low* and the measures were able to explain unique variance in neuroticism over *iM*. Overall the *single items* of NA here seem to perform best.

General Validity Evidence of Affect Measures

To compare the validity of the different affect measures across all criteria we combined the above results into one "Validity Index". The validity evidence of measures across criteria was examined separately for PA and NA. We account for differences in scale, range, and variance across the criteria, by transforming them into a percentage score. For each criterion, we summed the validity estimates (*V*) of the 8 measures for PA and NA respectively, and then divided the individual value of each measure (*m = 1.. 8*) by this total score.

$$V'_m = \frac{V_m}{\sum_{m=1}^{8} V_1 + \cdots + V_8} x100 \qquad (4)$$

For each criterion, the transformed value (V') reflects the validity of a measure relative to all other measures that belong to this construct. Since the transformed values are scaled and comparable across all criteria, we summed and averaged them across the five criteria to determine their average "Validity Index" ($VI_m = \frac{\sum_{c=1}^{5} V'_{m1} + \cdots + V'_{m5}}{5}$) and ranked them on this score (Table 4). The BA single items had the highest average validity to measure PA. For NA the ranking clearly shows that NA single items are the most valid measures.

Comparison to Discrete Emotion Items

Since the good performance of the single items stood out across criteria we conducted analyses to compare the *dimensional single items* to *discrete emotion items* (Supplement Figure S1-S7). The first criterion, addressing variability, showed that positive emotion items *relaxed*, *calm*, and *energetic* had higher *rICC* and *M(iSD)* estimates than the dimensional PA and BA single items. However, their systematic variance across *days* was notably lower than that of the dimensional single items. None of the negative emotion items outperformed the *dimensional NA and BA single items in these analyse*s. For the second criterion, evaluating the sensitivity to events, the discrete emotion items were not better than the dimensional BA, PA, and NA single items. Lastly, on the between-person relation criterion, the items *happy*, *satisfied*, *sad*, *depressed*, and *anxious* were better predictors of Depression, whereas *guilty*, *depressed*, and *angry* were better predictors of Neuroticism, than dimensional single items. Yet, no unique discrete emotion item was consistently better than the dimensional single items across these validity criteria.

Discussion

The goal of this paper was to compare the validity of several candidate measures of momentary positive and negative affect. We followed the process of construct validation as a systematic and theory-based framework to develop these measures and empirically examined them in an independent sample, using three criteria. Our analyses established strong validity evidence for single-item measures of affect.

Practical Guidance

The results have several immediate practical implications for the state of the art in ESM study design. Our findings indicate the importance of considering one's affect measures in correspondence with the theoretical model and planned analysis (Table 5). The validity of a measure depends on the theoretical and methodological context of the research questions.

A dimensional BA *single item* may be sufficient to study momentary affect or control for its overlap with other momentary constructs (e.g. the affective component of situations; Horstmann & Ziegler, 2019). This item is an efficient measure to study the intra-individual (dynamic patterns of) momentary affect. These results are especially relevant for clinicians, who seek recommendations for a simple standardized instrument to follow their clients' well-being and therapeutic progress (Dejonckheere et al., 2022). In our sample a verbal item seemed to work better than a pictogram, however, the difference was marginal and might not generalize to other procedures. For researchers who wish to study positive and/or negative affect independently, two unipolar *single items* for PA and NA may be preferred, since our evidence suggests that using these measures does not come with a significant decline in validity. If momentary associations between affect and other target constructs are of primary interest, *single items* with an *absence* anchor (also referred to as "strictly unipolar" measures; Russell & Carroll, 1999, p. 9) are most suitable. When researchers are investigating between-person differences in affect, we recommend the use of *single items,* since they offer more explanatory power than *mean* scores. Specifically, the *i(M)* estimates are better predictors of depression when they are estimated from *high-intensity* NA items. Furthermore, the BA *single items* and the NA *single item* with a *neutral* anchor explain more variance in depression than *mean scores*. The *i(SD)* estimates from the NA *single items* carries the most unique information about neuroticism. Single *discrete emotion items* may have more explained variance than dimensional single items, in cases where they are more closely related to the target construct (e.g. anger related to borderline; Ellison et al., 2016).

Limitations

These recommendations should be interpreted in light of the methodological nature of this study which focused on the development of a self-report questionnaire for the measurement of affect in daily life. Accordingly, questions regarding the sampling rate, contingency, or the use of slider versus Likert scales cannot be answered with this data. Research on ESM design can be found in Adolf et al., 2021; Eisele et al., 2022; Hasselhorn et al., 2021; Himmelstein et al., 2019.

A limitation of the analyses is that the *rICC* as a measure of within-person variance limits the comparison of single items versus composite scales because it contains residual variance. Composite scales aim to decrease the error variability of a measure, which could explain the decreases within-person variance for multi-item measures. Whether this is due to a decrease in residual or in within-person variance is difficult to disentangle at this point. Nonetheless, the three-level models separate the residual variance from the within-person variance at the day-level and found that the dimensional single items were most sensitive to variance at this level.

Lastly, our findings to not provide an overall truth of how to measure affect but offer solutions for different purposes, theoretical focus, and methodological possibilities of ESM studies. We, therefore, advise using the criteria that fit the research question as guidelines to determine a measure. The process of construct validation we applied here aligns with the perspective of validity described in the *Standards* (2014). There are a variety of other approaches within this perspective (e.g. factor analyses, reliability; see Eisele et al., 2021; Schuurman & Hamaker, 2019), but also other theoretical perspectives regarding validity, which we consider equally important (Borsboom, 2008; Markus & Borsboom, 2013; Michell, 1997; Slaney, 2017).

Conclusion

Though many ESM studies mention the constraints in questionnaire length as a complicating factor, the use of multi-item scales remains prevalent. We have shown that the common practice of calculating mean scores across a number of like-valenced emotion items to measure momentary PA and NA is not optimal. Researchers should consider alternative affect measures to increase the validity of their findings. Moving forward not only practical, but also theoretical and quantitative guidelines to measure ILD are necessary. This is the case for affect as well as other constructs that are measured in daily life.

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Table 1.

Operationalization of Momentary Affect Scores

Raw Scores	Dimensional Single Items Measures	
	Valence Scale	
Bipolar Affect	**verbalBA** *"How do you feel?"* *-50 = Very negative 0 = Neutral 50 =Very positive*	**smileyBA** *Pictogram* *0 = Negative 100 = Positive*
	Neutral Scale (*neutr*)	Absent Scale (*abs*)
Positive Affect	**neutrPA** *"How positive do you feel?"* *0 = Neutral* *100 = Very positive*	**absPA** *"To what extent do you experience positive emotions?"* *0 = I don't experience positive emotions* *100 = Very positive*
Negative Affect	**neutrNA** *"How negative do you feel?"* *0 = Neutral* *100 = Very negative*	**absNA** *"To what extent do you experience negative emotions?"* *0 = I don't experience negative emotions* *100 = Very negative*
Composite Scores	Dimensional Multi-Item Measures	
	"How … do you feel right now?" *0 = Not at all … 100 = Very …*	
	Positive Affect Scale *Categories: Happiness Vigour Love Calmness*	***Negative Affect Scale*** *Categories: Sadness Fatigue Shame Guilt Anger Anxiety-Fear Stress*
Average Score	**PA Mean** *all discrete positive emotion items* **PA High** *happy, energetic, loving, relaxed* **PA Low** *satisfied, alert, caring, calm*	**NA Mean** *all discrete negative emotion items* **NA High** *depressed, exhausted, ashamed, guilty, angry, anxious, stressed* **NA Low** *gloomy, tired, shy, regretful, irritated, concerned, nervous*
Maximum Score	**PA Max** *highest score of discrete positive emotion items*	**NA Max** *highest score of discrete negative emotion items*

Note: verbal = worded item; smiley = image item; neutr = neutral anchor; abs = absent anchor; High = high intensity scale; Low = low intensity scale; Max = maximum score; BA = bipolar affect; PA = positive affect; NA = Negative Affect

Table 2.

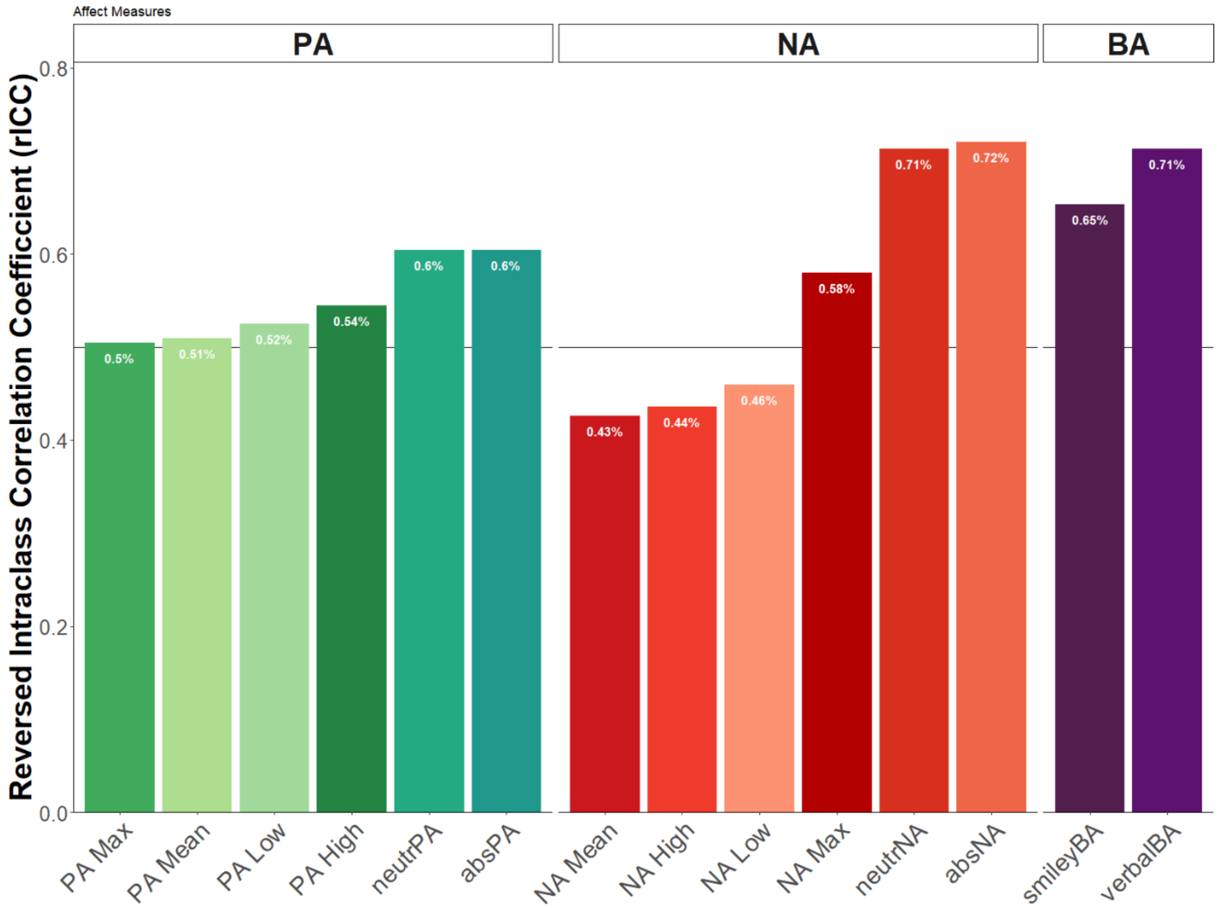
Distributional Properties of Affect Measures

	Mean	Variance (SD)	Min	Max	Skew	Kurtosis
verbalBA	64.46	18.06	0.00	100.00	-0.78	0.81
smileyBA	65.26	15.18	0.00	100.00	-0.47	0.71
neutrPA	55.40	26.30	0.00	100.00	-0.73	-0.50
absPA	55.93	24.00	0.00	100.00	-0.69	-0.30
neutrNA	17.54	20.40	0.00	100.00	1.41	1.54
absNA	20.99	21.40	0.00	100.00	1.14	0.73
PA Mean	55.68	16.12	0.00	100.00	-0.30	0.00
PA Max	76.68	14.86	0.00	100.00	-0.75	1.29
PA High	57.09	18.02	0.00	100.00	-0.34	-0.17
PA Low	54.26	16.37	0.00	100.00	-0.14	0.05
NA Mean	18.97	14.38	0.00	96.00	0.93	0.72
NA Max	53.71	26.68	0.00	100.00	-0.36	-0.79
NA High	17.19	14.34	0.00	96.43	1.11	1.31
NA Low	20.75	15.24	0.00	95.57	0.79	0.31

Note: The default options of m-Path did not allow to change the scale of bipolar items in the app itself at the time of data collection. Therefore we transformed the scale of the *verbalBA* and *smileyBA* items from a -50 – 50 to a 0 – 100 scale to match the other scores.

Figure 1.

Reversed Intraclass Correlation (rICC) for each Affect Measure



Note: All of the figures in the manuscript are ordered from low to high values on each validity criterion and within the construct they belong to.

Figure 2.

Day Variance for each Affect Measure

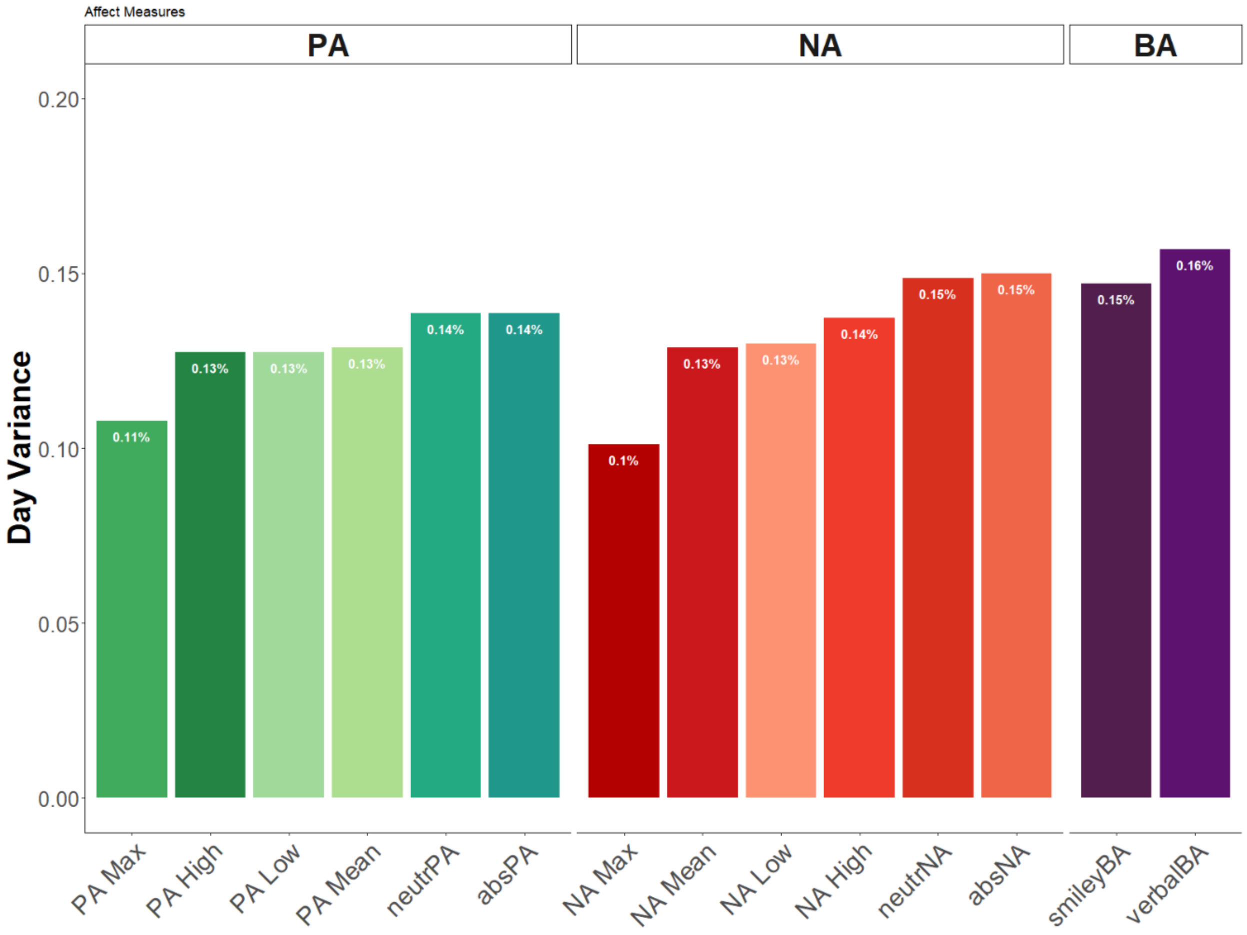


Figure 3.

Sample Average Intra-Individual Standard Deviation of Affect (M(iSD)) of each Measure

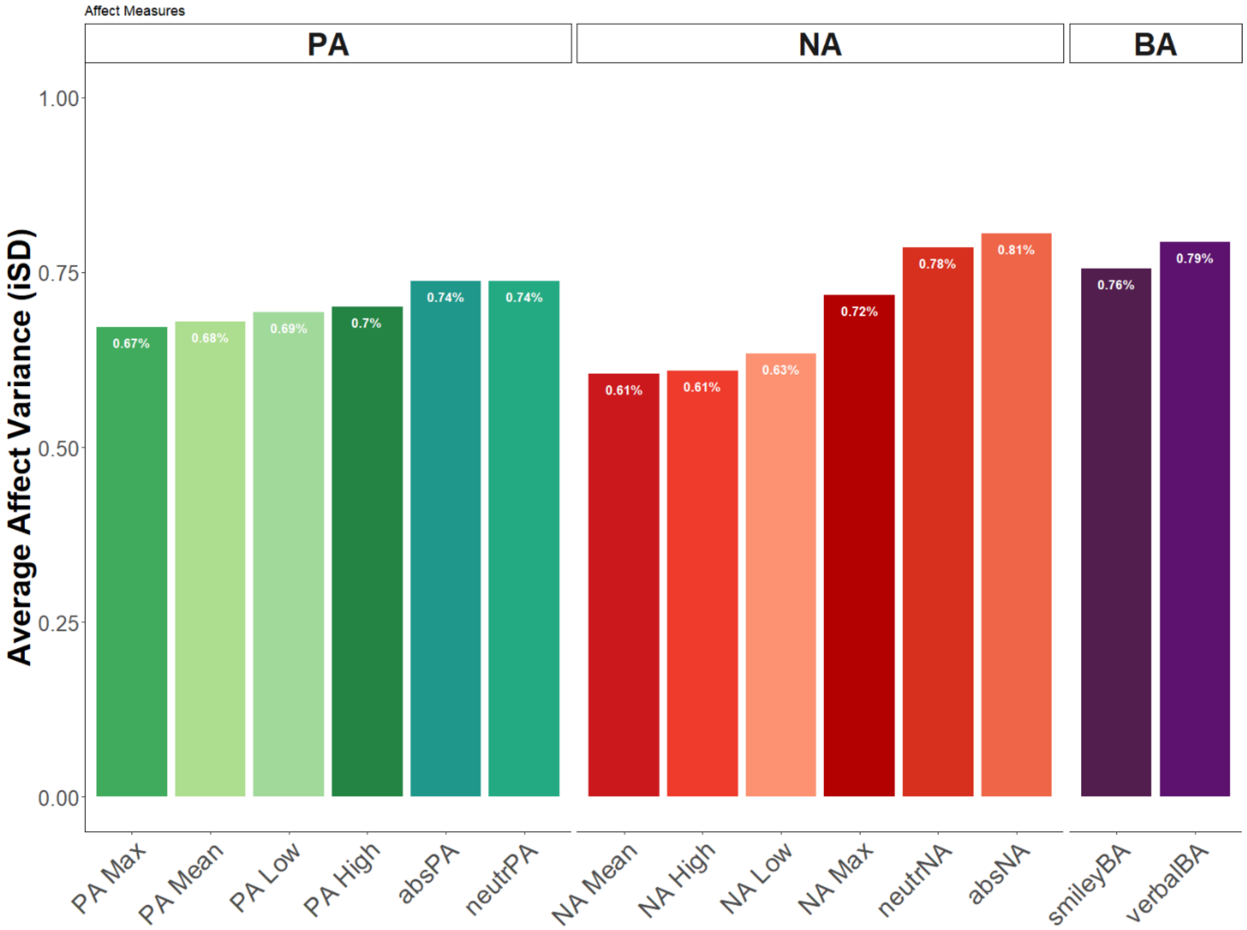
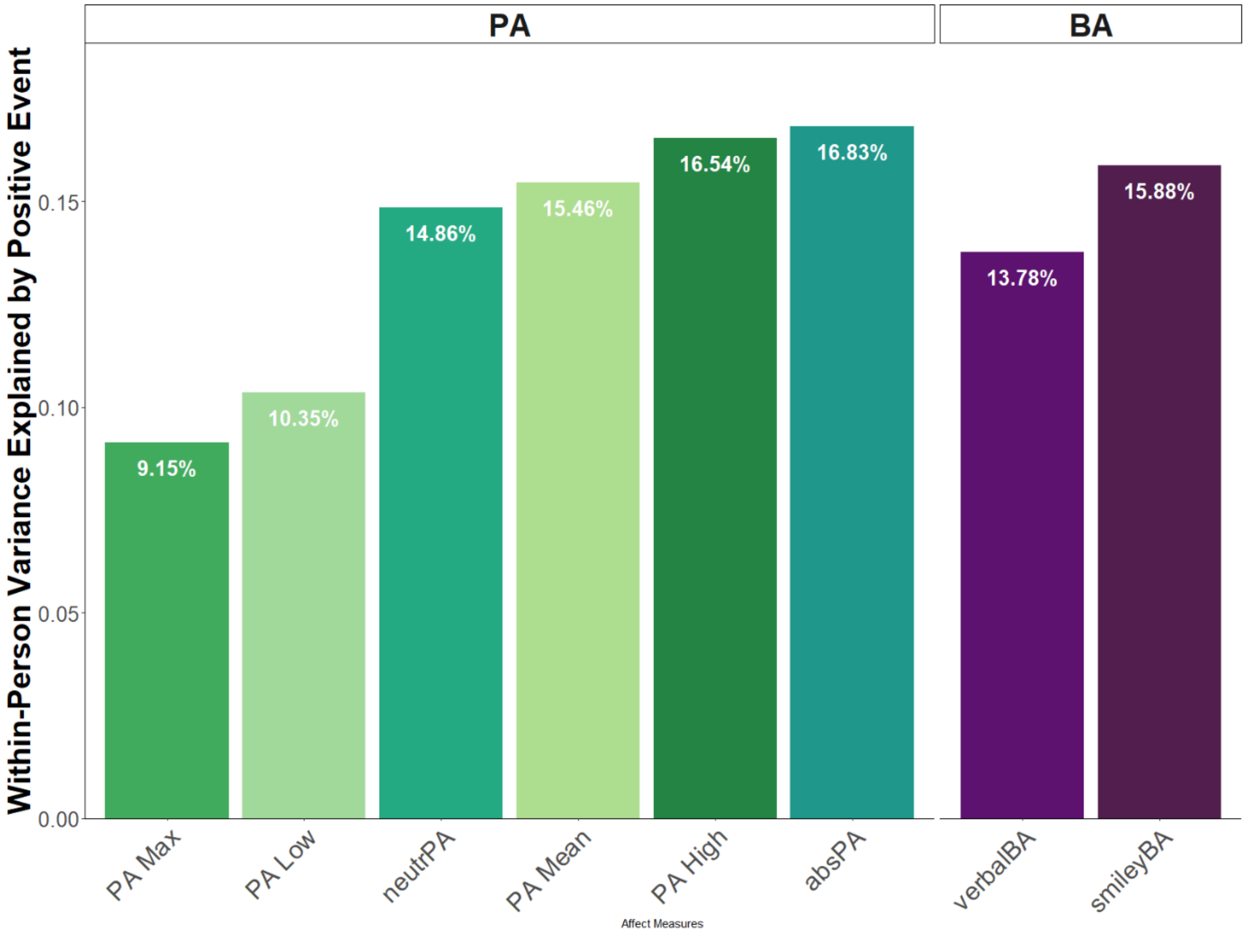


Figure 4.

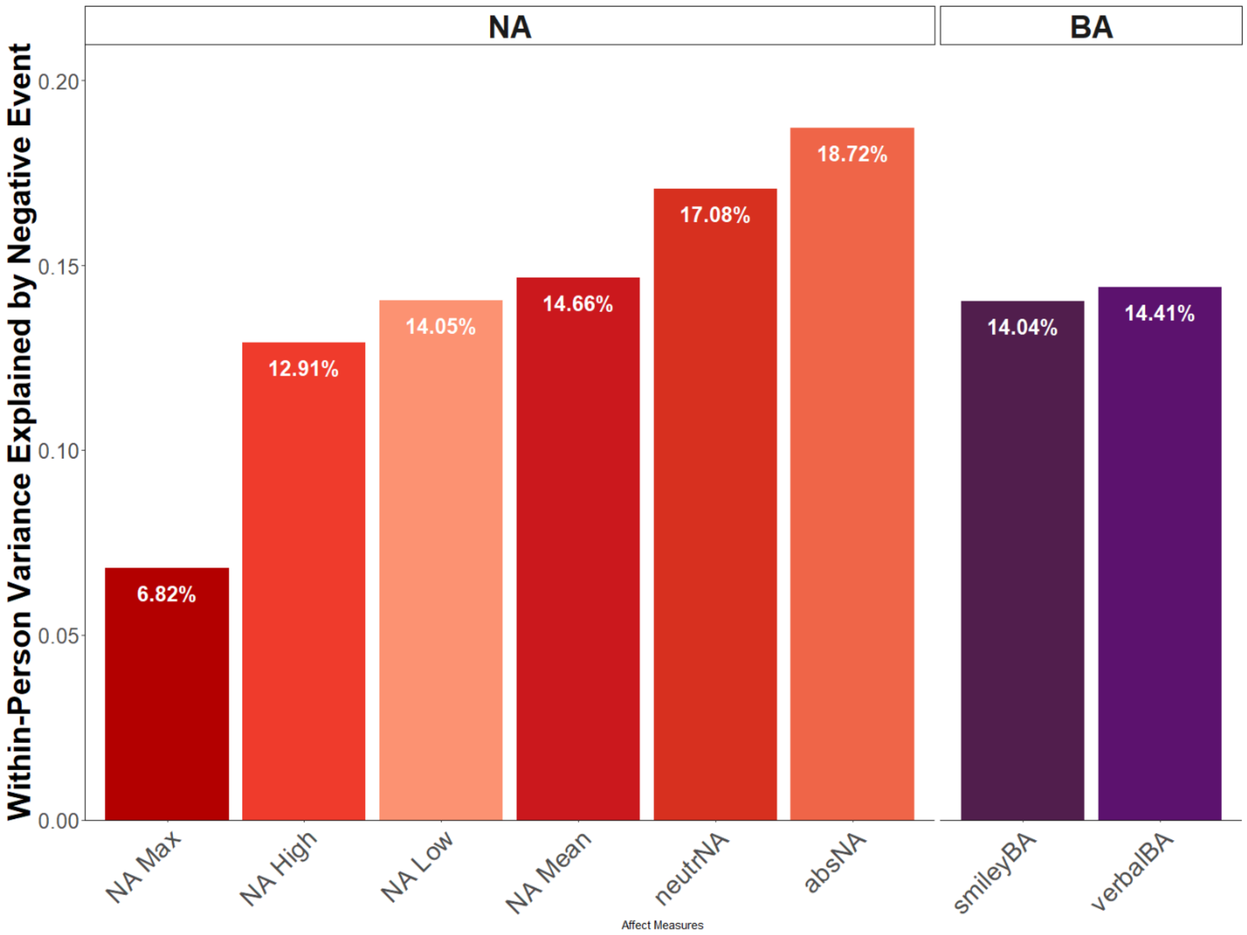
Amount of Within-Person Variance Explained by Fixed Slope $R_w^{2(\gamma_{10})}$ *Positive Event*



Note. All of the relations were statistically significant p < .001

Figure 5.

Amount of Within-Person Variance Explained by Fixed Slope $R_w^{2(\gamma_{10})}$ *Negative Event*



Note. All of the relations were statistically significant p < .001

Table 3

Relation Between Mean Affect (iM), Affect Variability (iSD), Depression, and Neuroticism

Models	*Depression|iM*	*Neuroticism| iSD + iM*	
	β_{iM}	β_{iSD}	β_{iM}
Positive Measures			
PA Mean	-0.37	0.21	-0.37
PA High	-0.38	0.18	-0.43
PA Low	-0.34	0.21	-0.29
PA Max	-0.24	0.11	-0.28
neutrPA	-0.39	0.16	-0.33
absPA	-0.38	$0.12^{n.s.}$	-0.30
Bipolar Measures			
verbalBA	-0.47	0.17	-0.42
smileyBA	-0.46	0.18	-0.46
Negative Measures			
NA Mean	0.43	0.25	0.24
NA High	0.45	0.26	0.23
NA Low	0.40	0.23	0.25
NA Max	0.41	$0^{n.s.}$	0.44
neutrNA	0.42	0.31	$0.16^{n.s.}$
absNA	0.40	0.25	0.25

n.s. = not statistically significant p > .05

Figure 6.

Variance Explained in Depression by Average Levels of Affect (iM)

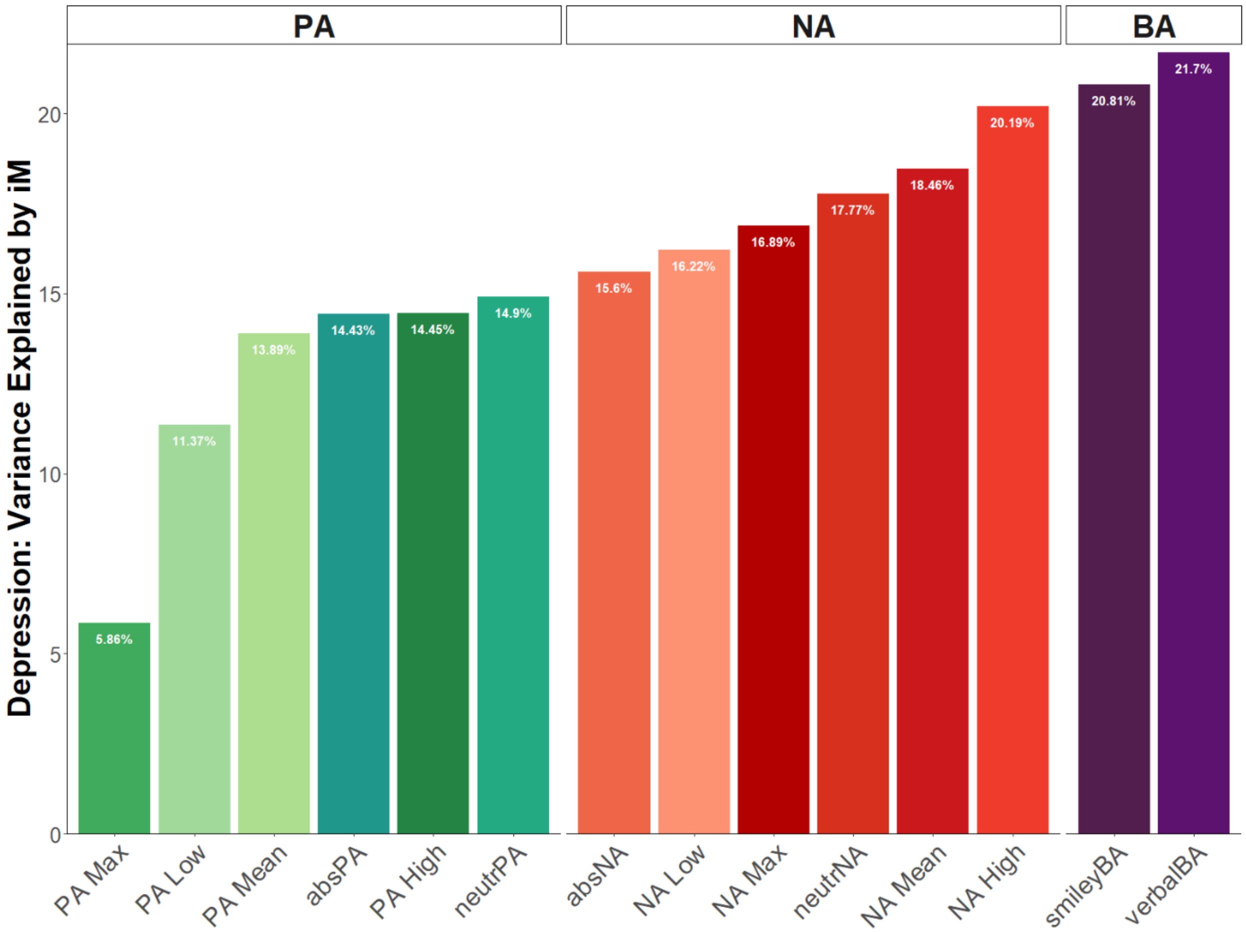


Figure 7.

Variance Explained in Neuroticism by Intra-Individual Affect Variability (iSD)

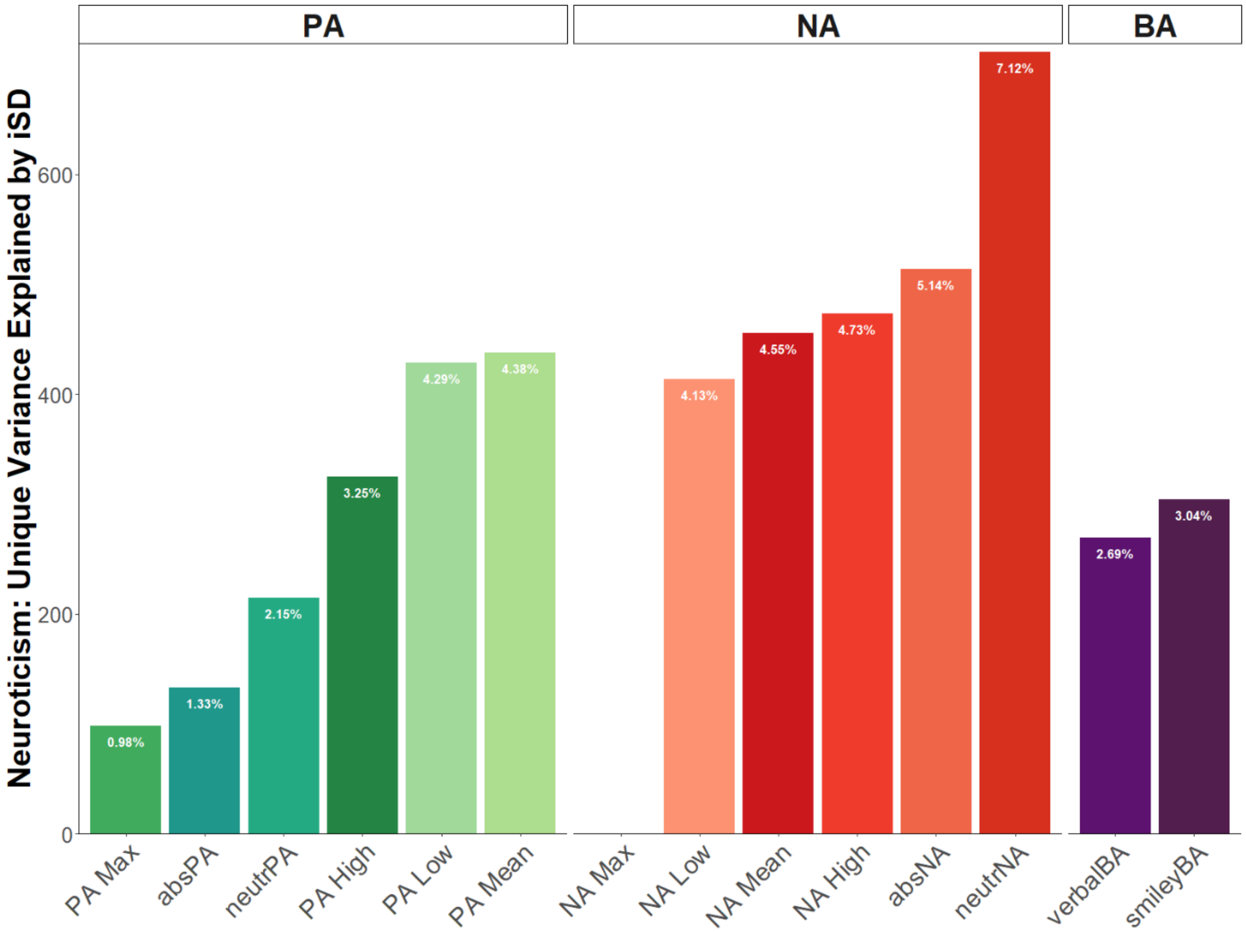


Table 4.
Synthesis of Validity Evidence Across Criteria

	Positive Affect Measures			Negative Affect Measures	
	Affect Measure	Average VI (%)		Affect Measure	Average VI (%)
1	*smileyBA*	14.54	1	*neutrNA*	15.75
2	*verbalBA*	14.39	2	*absNA*	14.60
3	*PA Mean*	13.61	3	*verbalBA*	13.03
4	*PA High*	13.10	4	*smileyBA*	12.68
5	*PA Low*	12.30	5	*NA High*	12.03
6	*neutrPA*	12.27	6	*NA Mean*	11.93
7	*absPA*	11.79	7	*NA Low*	11.50
8	*PA Max*	8.00	8	*NA Max*	8.48

Table 5.
Practical Guidance

Target Construct	Measure	Use and Interpretation of Score
Affect Variability	Single Items e.g. *smileyBA; verbalBA*	Study general patterns of affect over time Controlling for affect as momentary covariate Efficient low burden affect measure
Momentary Affect	Single Items e.g. *absPA; absNA*	To detect associations with other momentary variables
Affect Dynamics	Weighted/Similar Items e.g. *NA High; PA High* Single Items *neutrPA/neutrNA; verbalBA/smileyBA*	To detect individual differences in psychopathology