Psychological Science

How Are You Feeling? Revisiting the Quantification of Emotional Qualia

Assaf Kron, Ariel Goldstein, Daniel Hyuk-Joon Lee, Katherine Gardhouse and Adam Keith Anderson

The online version of this article can be found at:

Published by:
$SAGE

On behalf of:

aps
ASSOCIATION FOR
PSYCHOLOGICAL SCIENCE

Association for Psychological Science

Additional services and information for *Psychological Science* can be found at:

Email Alerts: http://pss.sagepub.com/cgi/alerts

Subscriptions: http://pss.sagepub.com/subscriptions

Reprints: http://www.sagepub.com/journalsReprints.nav

Permissions: http://www.sagepub.com/journalsPermissions.nav

>> Version of Record - Aug 9, 2013

OnlineFirst Version of Record - Jul 3, 2013

What is This?

How Are You Feeling? Revisiting the Quantification of Emotional Qualia

Assaf Kron[1], Ariel Goldstein[2], Daniel Hyuk-Joon Lee[1], Katherine Gardhouse[1], and Adam Keith Anderson[1,3]
[1]University of Toronto, [2]Hebrew University of Jerusalem, and [3]Cornell University

Abstract
Numerous emotion researchers have asked their study participants to attend to the distinct feelings of arousal and valence, and self-report and physiological data have supported the independence of the two. We examined whether this dissociation reflects introspection about distinct emotional qualia or the way in which valence is measured. With either valence (Experiment 1) or arousal (Experiment 2) as the primary focus, when valence was measured using a bipolar scale (ranging from negative to positive), it was largely dissociable from arousal. By contrast, when two separate unipolar scales of pleasant and unpleasant valence were used, their sum was equivalent to feelings of arousal and its autonomic correlates. The association (or dissociation) of valence and arousal was related to the estimation (or nonestimation) of mixed-valence experiences, which suggests that the distinction between valence and arousal may reflect less the nature of emotional experience and more how it is measured. These findings further encourage use of unipolar valence scales in psychological measurement.

It is thought that emotional experience can be decomposed into distinct underlying qualia: arousal and valence. An individual can introspect on an emotional experience and report that he or she felt X amount of arousal and Y amount of valence. In hundreds of experiments in various disciplines, researchers have used valence and arousal to capture unique aspects of emotional experience (e.g., Anders, Lotze, Erb, Grodd, & Birbaumer, 2004; Isbister, Höök, Sharp, & Laaksolahti, 2006; Rhudy, Williams, McCabe, Russel, & Maynard, 2008; Vogt, De Houwer, Koster, Van Damme, & Crombez, 2008). Researchers using distinct arousal and valence scales (see Table 1) have assumed that these qualia arise from distinct sources of emotional feelings and that participants would be able to introspect independently and report on them. In the work reported here, we examined whether dissociations between valence and arousal occur because participants attend to distinct qualia of their emotional experience or because of limitations in how emotion is measured.

Two types of evidence support the assumption that valence and arousal are distinct aspects of emotional experience. First, self-reported arousal and valence do not correlate with each other (e.g., Russell & Mehrabian,

1977). In light of these results, large pools of emotional stimuli—such as words (Bradley & Lang, 1999), sounds (Bradley & Lang, 2007), and pictures (Lang, Bradley, & Cuthbert, 1999)—standardized on valence and arousal have been developed. Although it is not atypical to find a quadratic U-shaped relation between valence and arousal ratings (Bradley, Codispoti, Cuthbert, & Lang, 2001), valence explains less than 20% of the variance in arousal ratings (Lang et al., 1999), which suggests that arousal, though it is somewhat correlated with valence, is a distinct component of emotional experience.

The second type of evidence supporting the arousal and valence distinction comes from their dissociated relationships to a third variable. For example, valence is correlated with facial motor activity, as measured by

Corresponding Authors:
Adam Keith Anderson, Department of Human Development, Martha Van Rensselaer Hall, Cornell University, Ithaca, NY 14853-4401
E-mail: aka47@cornell.edu

Assaf Kron, Department of Psychology, University of Toronto, 100 St. George St., Toronto, Ontario M5S3G3, Canada
E-mail: assaf.kron@mail.huji.ac.il

Table 1. Bipolar and Unipolar Arousal and Valence Scales

Model and scale	Low scale anchor	High scale anchor
Bipolar-valence and -arousal model		
Valence	*unpleasant feelings* (–4)	*pleasant feelings* (4)
Arousal	*calm* (0)	*aroused* (8)
Unipolar-valence model		
Pleasant affect	*no pleasant feelings* (0)	*strong pleasant feelings* (8)
Unpleasant affect	*no unpleasant feelings* (0)	*strong unpleasant feelings* (8)

electromyographic (EMG) activity, whereas arousal is correlated with measures of autonomic arousal, such as electrodermal activity (EDA; Lang, Greenwald, Bradley, & Hamm, 1993). With regard to neural markers, valence has been associated with activation in the orbitofrontal cortices, whereas arousal has been associated with activation of the amygdala (e.g., Anderson et al., 2003). Indeed, to the extent that ratings of arousal and valence reflect separate dimensions of emotional experience, we should expect a relation of the type "X is correlated with arousal but not with valence" and vice versa.

In the previously cited studies, participants were asked to rate their feelings using the standard bipolar valence scale, which ranges from pleasant to unpleasant with a midpoint that represents neutral feelings (no pleasant or unpleasant feelings). Thus, in response to the question of "How are you feeling?" a middling response of "So-so" could mean indifferent or neutral or reflect some good and some bad (Larsen, McGraw, & Cacioppo, 2001). Although people's experience of valence is often conceptualized as antagonistic (Barrett, 2006), some evidence has suggested that individuals can have bittersweet experiences, being happy and sad at the same time (e.g., Larsen & McGraw, 2011). An alternative way to estimate pleasant and unpleasant feelings is to measure them separately on two axes (i.e., unipolar valence; see Table 1), which permits participants to express their pleasant feelings and unpleasant feelings independently (e.g., Ito, Cacioppo, & Lang, 1998). It was found that valence measured using the bipolar scale was highly correlated with the difference between *pleasant* and *unpleasant* scores (i.e., *pleasant* scores minus *unpleasant* scores) estimated using two separate unipolar scales (Larsen, Norris, & Cacioppo, 2003).

A comparison of responses to pictures in the widely used International Affective Picture System (IAPS; Ito et al., 1998; Lang et al., 1999) illustrates the discrepancy of these two scale methods and their relationship to arousal. The valence of pictures was rated on a scale from 1 (*unpleasant*) to 9 (*pleasant*). Picture 4700 has erotic content. The average valence scores for this picture were 5.04, equivalent to neutral valence. Picture 5530, a

picture of a mushroom, was rated as having the same, essentially neutral valence as Picture 4700; only arousal ratings differentiated the two pictures. By contrast, when asked to rate pleasant and unpleasant feelings using two separate unipolar scales (see Fig. 1), participants revealed moderately to strongly valenced feelings about the erotic picture (Ito et al., 1998).

Pleasant and unpleasant feelings cancel each other out when valence is measured using the bipolar scale. As a consequence of lost valence information, significant emotional arousal appears to occur in the absence of either positive or negative valence. Arousal estimation may be needed to recover, in part, what is lost in the bipolar ratings' compression of fully valenced experience. The dissociation between valence and arousal thus might be more an issue of measurement than a reflection of distinct qualia underlying emotional experience.

Historically, the distinction between unipolar valence models (e.g. Watson & Tellegen, 1985) and bipolar valence and arousal models (e.g., Russell, 1980) has generated significant debate and endeavors to integrate them (Tellegen, Watson, & Clark, 1999; Yik, Russell, & Barrett, 1999). However, for several reasons, these studies are less informative about the present issue. First, valence and arousal were latent variables inferred from the interrelation between items. Second, participants in these studies did not rate their feelings elicited by external emotional stimuli (e.g., see Yik et al., 1999). Third, the latent-variable solutions suggest an orthogonal map of stimuli (e.g., emotion words); however, as mentioned earlier, ratings of valence and arousal in response to distinct stimuli have some quadratic relation, which suggests some disagreement between first-person experience and latent-variable structure (Bradley et al., 2001). In sum, it is not clear how these latent-variable accounts relate specifically to the observed feelings of valence and arousal elicited by specific events.

Although several types of relations between unipolar valence and arousal have been suggested (e.g., Bernat, Patrick, Benning, & Tellegen, 2006; Witvliet & Vrana, 1995), in the present research, we examined whether individuals could report distinct qualia of valence and
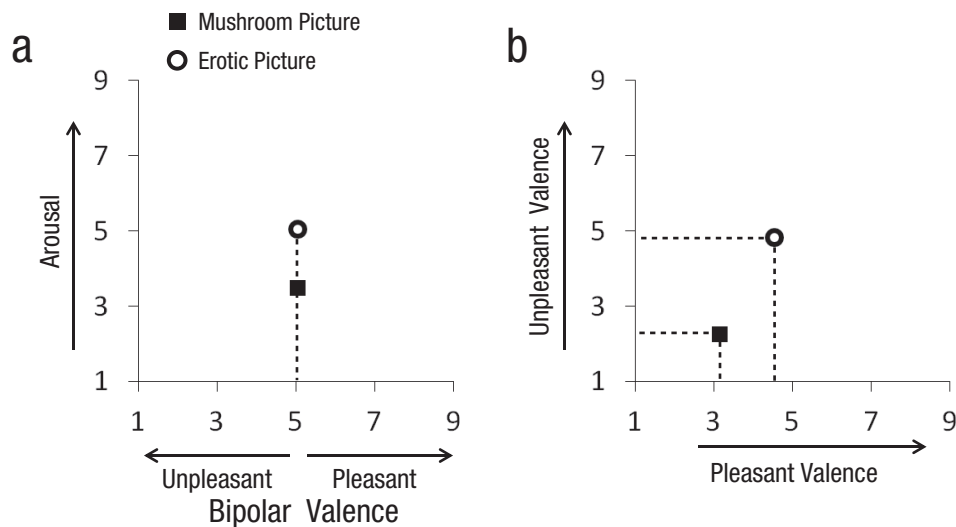
Fig. 1. Ratings of International Affective Picture System (Lang, Bradley, & Cuthbert, 1999) erotic and mushroom pictures (from Ito, Cacioppo, & Lang, 1998). The pictures' valence was rated using either (a) a bipolar scale or (b) separate unipolar scales.

arousal. Participants were asked to look at emotional pictures while their EDA and corrugator EMG activity were recorded and to rate their feelings either using a scale for arousal and a bipolar scale for valence, or using separate unipolar scales for pleasant and unpleasant feelings. As mentioned earlier, ratings of arousal are highly correlated with autonomic arousal, as indexed by EDA, whereas valence is not. By contrast, corrugator EMG activity is monotonically correlated with bipolar valence scores but not with arousal (e.g., Lang et al., 1993). If the dissociation between valence and arousal reflects distinct aspects of emotional experience, then reporting one's level of arousal should not be equivalent to reporting on the intensity of pleasant and unpleasant valence—that is, arousal should be more than the simple sum of pleasant and unpleasant feelings (i.e., *pleasant* scores plus *unpleasant* scores). By contrast, if the sum of reported pleasant and unpleasant valence is equivalent to self-reported arousal and predicts its physiological correlates, then this result would question the distinction between arousal and valence as distinct emotional qualia.

Experiment 1

Method

Participants, stimuli, and physiological measurement. A total of 30 undergraduate students (21 females, 9 males) from the University of Toronto participated in this experiment in return for course credit. Using an in-house algorithm (see Stimuli in the Supplemental Material available online), we sampled 72 pictures from the

IAPS (Lang et al., 1999). Pictures equally represented as much of the valence and arousal space available, resulting in no linear correlation between valence and arousal, $r = -.08$, and a marginal quadratic component, $R^2 = .06$. See Data Reduction and Physiological Response Measurement in the Supplemental Material for parameters for physiological measurement and data reduction.

Design. Pictures were presented while physiological responses and self-reports were collected. Trials began with the presentation of a blank screen for 10 to 21 s, to avoid anticipatory responses (Lang et al., 1993). A picture was then presented for 6 s, followed by the rating scales. To avoid picture repetition, we had each participant rate half of the pictures using unipolar *pleasant* and *unpleasant* scales and half of the pictures using bipolar valence and arousal scales. Although this approach limited our ability to collect data on arousal and unipolar valence on each trial, we chose to use it so that participants would not confuse the four rating scales; our procedure thus kept the scales maximally independent and made them more likely to show differences. Rating scales were presented in fixed order for each participant along the entire experiment. The order of scales was counterbalanced between participants, and the order of blocks and trials was counterbalanced across participants (see Design in the Supplemental Material for details).

Procedure. Instructions for rating valence and arousal followed the IAPS protocol (Lang et al., 1999). Specifically, for the bipolar valence scale, which ranged from *unpleasant feelings* (−4) to *pleasant feelings* (4), participants were

told, "At one extreme of the scale, you feel completely unpleasant, unhappy, annoyed, unsatisfied, melancholic, or despaired. At the other end of the scale, you feel completely pleased, happy, satisfied, content, or hopeful." Participants were further informed that a score of 0, at the scale's midpoint, indicated "a completely neutral, neither pleasant/happy nor unpleasant/sad state."

For the arousal scale, which ranged from *calm* (0) to *aroused* (8), participants were instructed that "one extreme represents feeling stimulated, excited, frenzied, jittery, wide-awake, or aroused; and at the other end of the scale, you feel completely relaxed, calm, sluggish, dull, sleepy, or bored." In the separate unipolar-scales condition, participants followed the same instructions they had used for the bipolar valence scale except that they were instructed to rate their feelings using two separate scales, one ranging from *no pleasant feelings* (0) to *strong pleasant feelings* (8), and the other ranging from *no unpleasant feelings* (0) to *strong unpleasant feelings* (8).

Data analysis. In keeping with research that has shown dissociations between valence and arousal, to provide meaningful comparisons with previous results (e.g., Lang et al., 1993; Larsen et al., 2003), we analyzed the data using item analysis. EMG activity, EDA, and rating scores were averaged for each picture, resulting in 72 data points. For each picture, EMG activity and EDA were drawn from 30 participants. Because each participant rated half the pictures using one of the rating models and half the pictures using the other, rating scores for each model were based on responses from 15 participants.

However, to ensure that our results were not unique to item analysis, we also examined them using hierarchical linear modeling (HLM) analysis (using the SAS PROC MIXED procedure), which allowed us to estimate the relation among *pleasant* and *unpleasant* scores, arousal, and EDA without having to aggregate scores across participants (Thompson, 2008).

Results

Coactivation of pleasant and unpleasant ratings of valence. Figure 2a depicts the distribution of *pleasant* scores, *unpleasant* scores, and arousal scores according to different values of bipolar valence. Around a bipolar-scale valence of 0 (greater than −1 and less than 1), the average *pleasant* scores were higher than 0 ($M = 1.95$) and approached 0 only around a valence of −4, with 71% of items in the *pleasant* wing of bipolar valence having *unpleasant* scores significantly higher than 0. The *unpleasant* scores similarly had a mean of 1.91 and approached 0 around a valence of 4, with 61% of items in the *unpleasant* wing of bipolar valence having *pleasant* scores significantly higher than 0. We next estimated valence coactivation by the intensity of mixed feeling (IMF) factor (Schimmack, 2001). IMF was computed as the minimum *pleasant* or *unpleasant* score for each trial. The mean IMF (0.83) was significantly higher than 0, 95% confidence interval = [0.73, 0.92] (see Fig. 2b). Together, the results of these analyses suggest coactivation of pleasant and unpleasant feelings within a person in response to a given picture.
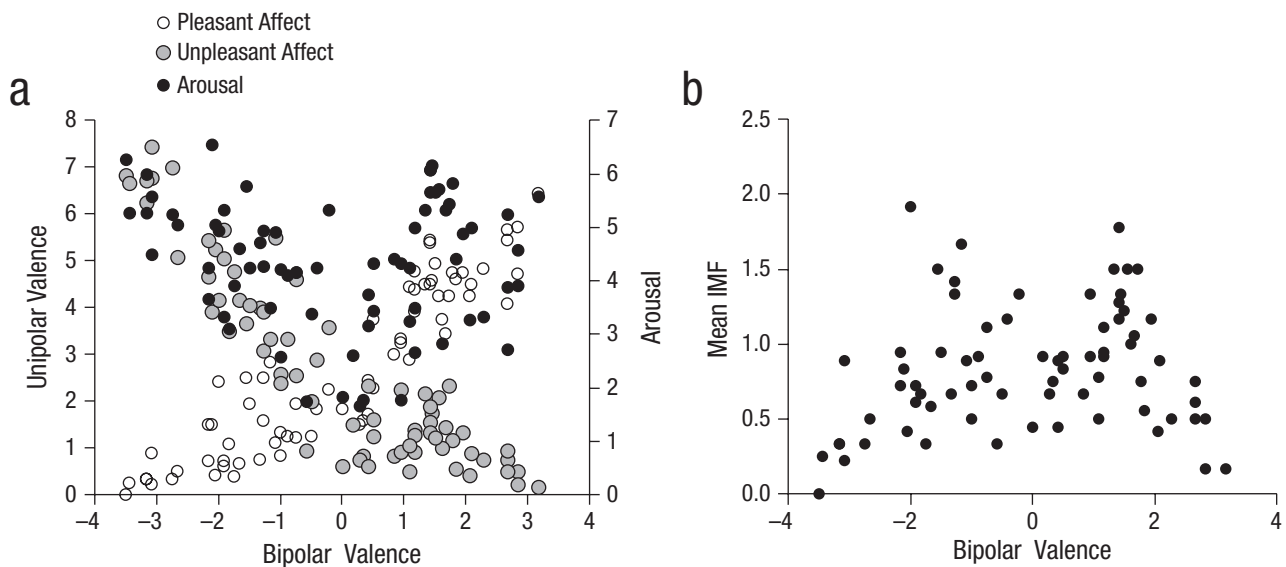

Fig. 2. Self-reported valence during picture viewing. The graph in (a) is a scatter plot of unipolar valence scores (separate *unpleasant* and *pleasant* ratings) and arousal scores distributed over values of bipolar valence scores (ratings made using a scale ranging from *unpleasant feelings*, −4, to *pleasant feelings*, 4). The graph in (b) shows the mean intensity-of-mixed-feeling (IMF) factor as a function of within-subjects bipolar valence values.

Relation of self-reported bipolar and unipolar valence to arousal. Showing levels of independence similar to those in the existing literature (e.g., Ito et al., 1998) and supporting the traditional distinction between valence and arousal, bipolar valence scores were not significantly linearly related to arousal, $r = -.13$, but did show a small but significant quadratic relation, $F(2, 69) = 6.88$, $p < .002$, adjusted $R^2 = .14$. By contrast, when valence was estimated using separate unipolar scales, the sum of *pleasant* and *unpleasant* scores was highly linearly correlated with ratings of arousal, $r = .75$, $p < .0001$ (see Fig. 3a) and explained 57% of the variance. Given that the correlation between the two sets of arousal scores as reflected by the correlation with IAPS norms was .86 (e.g., see Results in the Supplemental Material), the ceiling of variance explained by arousal scores was 73%. Thus, *pleasant* and *unpleasant* scores explained the great majority (77%) of possible variance in arousal (see Fig. 3b for correlation comparisons).

Relation between self-report and physiological arousal (EDA). Replicating previous results (Lang et al., 1993), our results showed that arousal ratings were linearly positively correlated with EDA, $r = .47$, $p < .0001$ (see Fig. 3c). Bipolar valence was negatively linearly associated with EDA, $r = -.35$, $p < .002$, and demonstrated a quadratic relationship, $F(2, 69) = 7.789$, $p < .001$, adjusted $R^2 = .16$. When estimated using unipolar scales, pleasant and unpleasant feelings predicted EDA to the same degree arousal ratings did: The sum of pleasant and unpleasant ratings was significantly positively correlated with EDA, $r = .46$, $p < .0001$ (see Fig. 3c). When we placed unipolar pleasant and unpleasant valence together in the same regression model, they positively predicted EDA, $F(2, 69) = 14.75$, $p < .0001$, adjusted $R^2 = .28$.

Relation between self-report and valence-related facial activity (EMG activity). Our results showed that when pleasant and unpleasant feelings were estimated using unipolar valence scales, their dissociation with self-reported and physiological arousal disappeared. If estimations of valence using bipolar scales represent a loss of valence information relative to unipolar-valence judgments, then the latter may provide a better account of valence-related peripheral activity. To investigate this hypothesis, we next analyzed the relation between bipolar and unipolar valence and valence-sensitive facial motor activity of the corrugator supercilii muscle.

As we had predicted on the basis of previous studies (Larsen et al., 2003), the difference between *pleasant* and *unpleasant* scores derived from unipolar-valence scales were nearly perfectly correlated with scores from the bipolar valence scale, $r = .96$, $p < .0001$. This result suggests that participants employed the two types of scales almost identically. Bipolar valence and the difference between *pleasant* and *unpleasant* scores were similarly negatively correlated with corrugator EMG activity, a
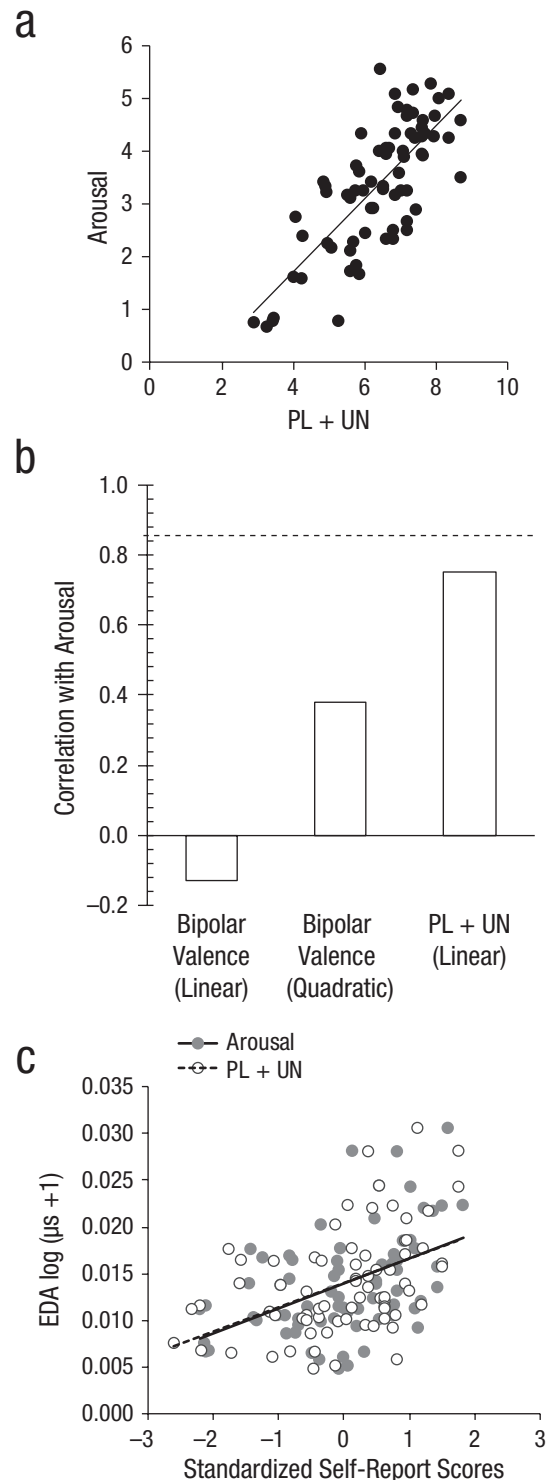

Fig. 3. Results showing the equivalence of experienced arousal and unipolar valence. The graph in (a) is a scatter plot, with a best-fitting regression line, showing the relation between summed pleasant-valence (PL) and unpleasant-valence (UN) ratings and self-reported arousal. The graph in (b) shows the correlation of bipolar valence (linear and quadratic) and summed PL and UN scores with arousal ratings. The dashed line represents correlation between arousal ratings in our sample and normative arousal ratings from the International Affective Picture System. The graph in (c) is a scatter plot, with a best-fitting regression line, showing the relation between electrodermal activity (EDA) and standardized self-report scores (arousal and summed PL and UN scores).

result consistent with their high association—bipolar valence: $r = -.69$, $p < .0001$; difference between *pleasant* and *unpleasant* scores: $r = -.71$, $p < .0001$. When separate unipolar measures of pleasant and unpleasant valence were included in the model, the result was a significant increase in estimation of corrugator activity, $F(1, 69) = 13.01$, $p < .0001$, consistent with a loss of valence information in the bipolar estimation.

Arousal without valence: Analysis of the bipolar valence range of −1 to 1. We next restricted our analyses to examining pictures near the neutral point of bipolar valence. This procedure afforded an examination of whether lost mixed-valence information was responsible for prior dissociations between arousal and bipolar valence. Examining where arousal and valence are most decoupled also provides a stronger test of the potential independent contributions of valence and arousal.

In this window (see Fig. 2), bipolar valence was near 0 ($M = -0.03$, $SD = 0.65$), whereas arousal demonstrated moderate activation ($M = 3.35$, $SD = 1.13$). We next analyzed the relation among bipolar valence, unipolar pleasant and unpleasant valence, arousal, and EDA for the 20 pictures whose bipolar valence fell between −1 and 1. Consistent with their apparent independence, bipolar valence scores showed no significant linear or quadratic relation to arousal, $R^2_{linear} = .02$, $R^2_{quadratic} = .01$. By contrast, placing unipolar pleasant and unpleasant valence together in the same model strongly and positively predicted arousal ratings, $F(2, 18) = 12.9$, $p < .0004$, adjusted $R^2 = .57$. Analyzing EDA revealed a similar pattern. Although bipolar valence did not predict EDA, $R^2_{linear} = .0$, $R^2_{quadratic} = .05$, unipolar *pleasant* and *unpleasant* scores showed marginally significant relation with EDA, $F(2, 18) = 3.35$, $p < .06$, adjusted $R^2 = .20$. By recovering mixed-valence experiences lost in the bipolar scale, we found that arousal no longer occurred without valence and that the dissociation between valence and arousal disappeared.

Relation between self-report and EDA: HLM analysis. To ensure that our results were not attributable to item analysis and aggregation across participants, we compared the relation between arousal ratings and summed *pleasant* and *unpleasant* ratings with EDA via HLM. HLM affords an analysis at the level of participant- and trial-specific responses to each picture (for details, see Model Specification for Experiment 1: Relation Between Self-Reports and EDA in the Supplemental Material). Although our design did not include measures of arousal and unipolar valence on each trial, we nonetheless were able to compare arousal with pleasant and unpleasant valence to account for trial-specific EDA within each participant. If arousal and pleasant and

unpleasant valence are different sources of information, then arousal should be significantly better than summed *pleasant* and *unpleasant* scores in accounting for trial-specific EDA.

Replicating the traditional dissociation between self-reported arousal and valence in predicting EDA, results showed that arousal and summed *pleasant* and *unpleasant* scores were significantly related to EDA, $b = 0.001$, $t(2119) = 3.46$, $p < .0006$, whereas bipolar valence and the difference between *pleasant* and *unpleasant* scores showed no significant relation, $t(2119) = 1.02$. By contrast, there was no significant difference between rating types (arousal vs. the sum of *pleasant* and *unpleasant* scores) in predicting EDA, $t(2126) = 0.41$. A separate simple-effect analysis confirmed this finding: Both arousal, $b = 0.0009$, $t(1049) = 2.44$, $p < .01$, and summed unipolar valence scores, $b = 0.001$, $t(1049) = 4.03$, $p < .0001$, were significantly related to EDA. Replicating the results of the item analysis, results of the analysis of within-subjects trial-level responses revealed that when valence information was lost in the bipolar measure of valence, there was a dissociation between self-reported valence and physiological arousal (EDA), but when valence information was retained, their underlying association was revealed.

Experiment 2

The dissociation between arousal and valence need not imply that valence and arousal are separate feeling qualia. Rather, it may reflect a loss of information inherent to the bipolar valence rating scale and, thus, how these experiences are quantified. Arousal and bipolar valence rating scales may both represent pleasant and unpleasant feelings but do so in different ways: arousal as the combination of the two, and valence as the difference between them. Arousal would then be the sum of pleasant and unpleasant feelings, whereas bipolar valence would reflect the degree to which emotional experience is more pleasant than unpleasant, or vice versa. In Experiment 2, we actively imposed this model on participants to assess its account of self-reported and physiological arousal compared with the traditional model of bipolar valence and arousal. Additionally, in Experiment 1, the instructions to attend to pleasant and unpleasant valence but not arousal may have altered how participants attended to their feelings, causing them to focus more on valence. In Experiment 2, we changed the focus so that overall emotional intensity (i.e., arousal) was the primary attended dimension.

In Experiment 2, participants were first asked to rate the overall intensity of their feelings and then to rate how much of this intensity was composed of pleasant and unpleasant feelings (see Fig. S1: Intensity Scale in the Supplemental Material). Thus, the scores given to

unipolar pleasant and unpleasant valence were secondary and mathematically equivalent to overall emotional intensity. So, conceptually and mathematically, the rating scales reflected the model derived in Experiment 1 (i.e., arousal = *pleasant* plus *unpleasant* valence). Participants in a second condition were given standard instructions for arousal and bipolar valence rating scales (Lang et al., 1999). If arousal is distinct from the sum of experienced positive and negative valence, then the imposed model condition should underperform the standard protocol in predicting self-reported and physiological arousal.

Method

Seventy participants (48 females, 22 males) from the University of Toronto were allocated to two separate conditions: an intensity-focus condition (in which participants rated emotional intensity and then divided it into unipolar pleasant and unpleasant valence) and a control condition (in which participants rated bipolar valence and arousal). With the exception of the rating scales (see Fig. S1: Intensity Scale in the Supplemental Material) and the between-subjects design, this experiment was identical to Experiment 1.

Results

The overall intensity scores in the intensity-focus condition were highly correlated with arousal in the control condition, $r = .86$, $p < .0001$, similar to the degree arousal correlates with itself across experiments. Thus, participants employed emotional intensity and arousal as highly similar experiential constructs. Arousal scores were once again correlated with EDA, $r = .50$, $p < .0001$, whereas bipolar valence demonstrated neither significant linear nor quadratic trends. By contrast, when we considered summed *pleasant* and *unpleasant* scores from the intensity-focus condition, valence was significantly correlated with EDA, $r = .58$, $p < .0001$, a result replicating Experiment 1 (see Fig. 4a). Most critically, overall emotional-intensity scores that were restricted to be mathematically equivalent to unipolar valence (summed *pleasant* and *unpleasant* scores) predicted EDA to a degree similar to that of an independent assessment of self-reported arousal that was free to differ from valence (arousal: $r = .50$; emotional intensity: $r = .59$).

We next considered valence-specific EMG responses. Both bipolar valence and the difference between *pleasant* and *unpleasant* scores were negatively correlated with EMG activity—bipolar valence: $r = -.69$, $p < .0001$; *pleasant* minus *unpleasant* scores: $r = -.74$, $p < .0001$ (see Fig. 4b). When unipolar pleasant and unpleasant valence were included in a model with bipolar valence, the result once again was a significant increase in estimation of valence-related corrugator activity, $F(1, 69) = 13$, $p < .0001$, consistent with these factors' better account of valence. These results suggest that when arousal was the primary attentional focus and *pleasant* and *unpleasant* ratings were constrained to be equal to the overall level of emotional arousal (i.e., providing no additional
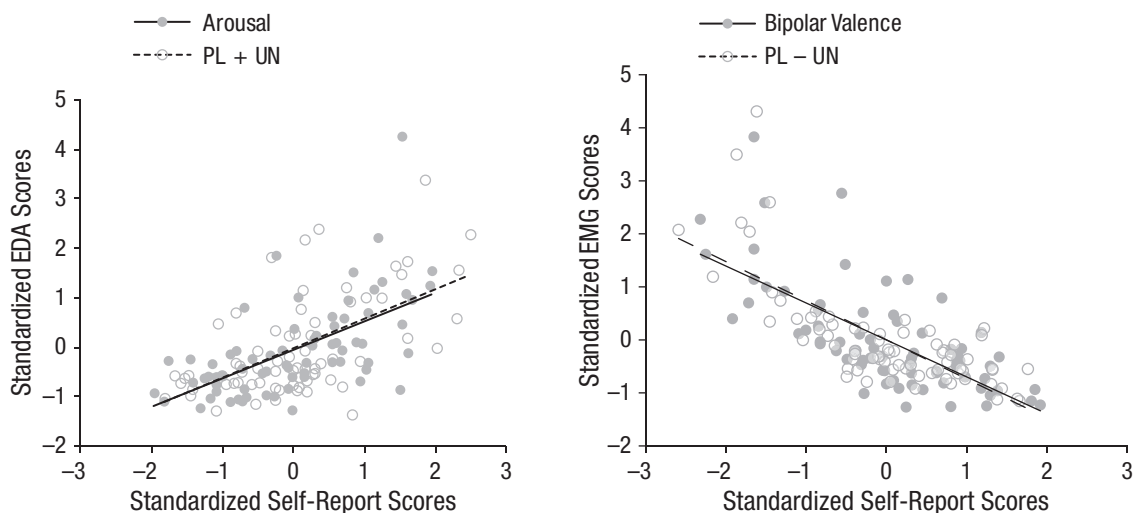

Fig. 4. Results showing the equivalence of arousal and bipolar valence with unipolar positive and negative valence. The graph in (a) is a scatter plot, with best-fitting regression lines, showing the relation of standardized electrodermal activity (EDA) to self-reported arousal scores and to summed pleasant-valence (PL) and unpleasant-valence (UN) scores in Experiment 2. The graph in (b) is a scatter plot, with best-fitting regression lines, showing the relation of standardized electromyographic (EMG) activity to self-reported bipolar valence scores and to the difference between PL and UN scores in Experiment 2.

information), no information was lost. This model did not underperform independent measures of arousal (in predicting EDA) and valence (in predicting EMG activity) but, in fact, showed evidence of being superior.

Discussion

Consistent with prior findings, results showed that ratings of bipolar valence were correlated with valence-specific facial motor activity (EMG activity) but were dissociated from self-reported arousal and peripheral EDA. Our findings demonstrate that distinct unipolar ratings of pleasant and unpleasant valence were highly related to experienced arousal and its peripheral physiologic correlates. A focused analysis around the bipolar valence of 0 (i.e., neutral), at which bipolar valence and arousal showed their greatest dissociation, revealed that this dissociation specifically reflected the inability to estimate mixed-valence experiences (Larsen et al., 2001; Schimmack, 2001). These findings were replicated in Experiment 2, in which emotional arousal was the primary rated dimension and was mathematically constrained to be equivalent to valence. By treating positive and negative valence as antagonistic, in a winner-take-all response, critical information may be lost that arousal ratings are needed to recover. Rather than there being distinct qualitative experiences of valence and arousal, the dissociation of the two may reflect the measuring stick more than what is being measured.

It could be argued that distinct *pleasant* and *unpleasant* scales might alter how participants attend to their feelings, altering the relationship between valence and arousal. Contrary to this interpretation, as in prior work (Larsen et al., 2003), we found that bipolar valence ratings were highly correlated with the difference between *pleasant* and *unpleasant* ratings. Furthermore, making emotional intensity the primary focus did not alter the pattern of findings. Instead, our data suggest that separate ratings of positive and negative valence allow an individual to express a mixture of valenced experiences rather than being forced to pick the dominant one. This underscores a larger issue regarding the use of unipolar versus bipolar scales in psychological measurement (e.g., Rice & Rubin, 2009). The classic semantic differential approach (Osgood, Suci, & Tannenbaum, 1957) infers internal mental states from bipolar, opposing adjectives (e.g., good vs. bad) and does not allow for mixed responses. Whether one conceives of the experience of valence as bipolar or not, the present findings encourage the use of unipolar as opposed to bipolar scales in psychological research.

One of the limitations of our experiments was the use of pictures in general and the IAPS specifically. How the relationship among valence, arousal, and measures of EDA would unfold in studies using other types of stimuli or vignettes is not known. However, pictures are a commonly used apparatus in emotion research and, most important, have been used to demonstrate the dissociation between valence and arousal. It is possible, however, that these results may differ from those yielded by paradigms assessing moods or current affect (e.g., Yik et al., 1999), which do not require evaluations of external stimuli. It is also unclear how distinctions in experienced arousal types, such as tense (tense/calm) versus energetic (awake/tired; Thayer, 1989), which may be distinct from bipolar valence (Schimmack & Reisenzein, 2002), can be explained by unipolar pleasant and unpleasant valence.

The current findings do not indicate that arousal is not associated with distinct peripheral and central physiological responses to valence. Rather, they call into question whether an individual can readily attend to and distinguish these components as qualitatively unique types of emotional experience when they are combined. When injected with adrenalin (e.g., Maranon, 1924) or taking a run in the park, one may feel aroused without necessarily having pleasant or unpleasant feelings. But the fact that we can feel arousal without pleasant and unpleasant states (and vice versa) does not prove that valence and arousal are separable during an emotional response triggered by an external event (e.g., Zillmann, 1971). Although we can hear a cello when it is played alone, this does not mean that we will recognize its sound when the whole orchestra is playing—nor is such recognition necessarily required to experience the music. Arousal and valence are components of emotional experience, but our ability to reflect on them as distinct appears to be limited.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Supplemental Material

Additional supporting information may be found at http://pss.sagepub.com/content/by/supplemental-data

References

Anders, S., Lotze, M., Erb, M., Grodd, W., & Birbaumer, N. (2004). Brain activity underlying emotional valence and arousal: A response-related fMRI study. *Human Brain Mapping*, *23*, 200–209.

Anderson, A. K., Christoff, K., Stappen, I., Panitz, D., Ghahremani, D. G., Glover, G., . . . Sobel, N. (2003). Dissociated neural representations of intensity and valence in human olfaction. *Nature Neuroscience*, *6*, 196–202.

Barrett, L. F. (2006). Valence is a basic building block of emotional life. *Journal of Research in Personality*, *40*, 35–55.

Bernat, E., Patrick, J. C., Benning, D. S., & Tellegen, A. (2006). Effects of picture content and intensity on affective physiological responses. *Psychophysiology*, *43*, 93–103.

Bradley, M. M., Codispoti, M., Cuthbert, B. N., & Lang, P. J. (2001). Emotion and motivation I: Defensive and appetitive reactions in picture processing. *Emotion*, *1*, 276–298.

Bradley, M. M., & Lang, P. J. (1999). *Affective Norms for English Words (ANEW): Stimuli, instruction manual and affective ratings* (Tech. Rep. No. C-1). Gainesville: University of Florida, Center for Research in Psychophysiology.

Bradley, M. M., & Lang, P. J. (2007). *The International Affective Digitized Sounds (IADS-2; 2nd ed.): Affective ratings of sounds and instruction manual*. Gainesville: University of Florida, Center for the Study of Emotion and Attention.

Isbister, K., Höök, K., Sharp, M., & Laaksolahti, J. (2006). The sensual evaluation instrument: Developing an affective evaluation tool. In R. Grinter, T. Rodden, P. Aoki, E. Cutrell, R. Jeffries, & G. Olson (Eds.), *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1163–1172). New York, NY: ACM Press.

Ito, T. A., Cacioppo, J. T., & Lang, P. J. (1998). Eliciting affect using the International Affective Picture System: Trajectories through evaluative space. *Personality and Social Psychology Bulletin*, *24*, 855–879.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1999). *International Affective Picture System (IAPS): Affective ratings of pictures and instruction manual*. Gainesville: University of Florida, Center for the Study of Emotion and Attention.

Lang, P. J., Greenwald, M. K., Bradley, M. M., & Hamm, A. O. (1993). Looking at pictures: Affective, facial, visceral, and behavioral reactions. *Psychophysiology*, *30*, 261–273.

Larsen, J. T., & McGraw, A. P. (2011). Further evidence for mixed emotions. *Journal of Personality and Social Psychology*, *100*, 1095–1110.

Larsen, J. T., McGraw, A. P., & Cacioppo, J. A. T. (2001). Can people feel happy and sad at the same time? *Journal of Personality and Social Psychology*, *81*, 684–696.

Larsen, J. T., Norris, C. J., & Cacioppo, J. T. (2003). Effects of positive and negative affect on electromyographic activity over zygomaticus major and corrugator supercilii. *Psychophysiology*, *40*, 776–785.

Maranon, G. (1924). Contribution a l'étude de l'action emotive de l'adrenaline [Contribution to the study of the emotive action of adrenalin]. *Revue Francaise d'Endocrinologie*, *2*, 301–325.

Osgood, C. E., Suci, G., & Tannenbaum, P. (1957). *The measurement of meaning*. Urbana: University of Illinois Press.

Rhudy, J. L., Williams, A. E., McCabe, K. M., Russell, J. L., & Maynard, L. J. (2008). Emotional control of nociceptive reactions (ECON): Do affective valence and arousal play a role? *Pain*, *136*, 250–261.

Rice, H. J., & Rubin, D. C. (2009). I can see it both ways: First and third person visual perspective at retrieval. *Consciousness and Cognition*, *18*, 877–890.

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, *39*, 1161–1178.

Russell, J. A., & Mehrabian, A. (1977). Evidence for a three-factor theory of emotions. *Journal of Research in Personality*, *11*, 273–294.

Schimmack, U. (2001). Pleasure, displeasure, and mixed feelings: Are semantic opposites mutually exclusive? *Cognition & Emotion*, *15*, 81–97.

Schimmack, U., & Reisenzein, R. (2002). Experiencing activation: Energetic arousal and tense arousal are not mixtures of valence and activation. *Emotion*, *2*, 412–417.

Tellegen, A., Watson, D., & Clark, A. L. (1999). On the dimensional and hierarchical structure of affect. *Psychological Science*, *10*, 297–303.

Thayer, R. E. (1989). *The biopsychology of mood and arousal*. New York, NY: Oxford University Press.

Thompson, G. (2008). Eliminating aggregation bias in experimental research: Random coefficient analysis as an alternative to performing a "by-subjects" and/or "by-items" ANOVA. *Tutorials in Quantitative Methods for Psychology*, *4*, 21–34.

Vogt, J., De Houwer, J., Koster, E. H. W., Van Damme, S., & Crombez, G. (2008). Allocation of spatial attention to emotional stimuli depends upon arousal and not valence. *Emotion*, *8*, 880–885.

Watson, D., & Tellegen, A. (1985). Toward a consensual structure of mood. *Psychological Bulletin*, *98*, 219–235.

Witvliet, V. C., & Vrana, R. S. (1995). Psychophysiological responses as indices of affective dimensions. *Psychophysiology*, *32*, 436–443.

Yik, S. M., Russell, A. J., & Barrett, L. F. (1999). Structure of self-reported current affect: Integration and beyond. *Journal of Personality and Social Psychology*, *77*, 600–619.

Zillmann, D. (1971). Excitation transfer in communication-mediated aggressive behavior. *Journal of Experimental Social Psychology*, *7*, 419–434.