

The Relation Between Valence and Arousal in Subjective Experience

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Affect is basic to many if not all psychological phenomena. This article examines 2 of the most fundamental properties of affective experience—valence and arousal—asking how they are related to each other on a moment to moment basis. Over the past century, 6 distinct types of relations have been suggested or implicitly presupposed in the literature. We critically review the available evidence for each proposal and argue that the evidence does not provide a conclusive answer. Next, we use statistical modeling to verify the different proposals in 8 data sets (with *N*s ranging from 80 to 1,417) where participants reported their affective experiences in response to experimental stimuli in laboratory settings or as momentary or remembered in natural settings. We formulate 3 key conclusions about the relation between valence and arousal: (a) on average, there is a weak but consistent V-shaped relation of arousal as a function of valence, but (b) there is large variation at the individual level, so that (c) valence and arousal can in principle show a variety of relations depending on person or circumstances. This casts doubt on the existence of a static, lawful relation between valence and arousal. The meaningfulness of the observed individual differences is supported by their personality and cultural correlates. The malleability and individual differences found in the structure of affect must be taken into account when studying affect and its role in other psychological phenomena.

Keywords: valence, arousal, pleasure, structure of affect, structure of emotion

Affect as subjectively experienced in emotions, moods, and other feelings is a central aspect of mind. As early as 1897, Wilhelm Wundt wrote that people are likely “never in a state entirely free from feeling” (1897/1998, p. 92), such that all mental states, including thoughts and perceptions, are infused with affect (for similar ideas, see Spencer, 1855; Sully, 1892). Since then, research has shown that affect is important to diverse psycholog-

ical phenomena ranging from attitudes (e.g., Cacioppo & Berntson, 1994; Eagly & Chaiken, 1998; Ito & Cacioppo, 2001) to well-being (e.g., Davidson, 2000, 2004; Davidson, Pizzagalli, Nitschke, & Putnam, 2002) and from basic processes such as memory and perception (e.g., Cahill & McGaugh, 1998; Kensinger & Schacter, 2008; Phelps, 2006; Phelps, Ling, & Carrasco, 2006; Vuilleumier, 2005) to higher order processes such as moral judgments of right and wrong (e.g., Greene, Sommerville, Nystrom, Darley, & Cohen, 2001; Haidt, 2001). And, of course, affect is central to emotions and moods (Barrett, Mesquita, Ochsner, & Gross, 2007; Clore & Ortony, 2008; Russell, 2003). If affect is indeed such a central aspect of the mind, then questions about its nature and structure are relevant for almost any research topic and touch at the core of psychology. In the present article, we address a fundamental but neglected question about affect, asking how two of its basic dimensions—valence and arousal—are related to one another in subjective experience.

Valence and Arousal

Wundt (1912/1924) was among the first psychologists to argue that affective experiences involve at least two properties: valence (ranging from feeling pleasant to unpleasant) and arousal (ranging from feeling quiet to active). Since Wundt, there have been other proposals on what constitutes the fundamental dimensions of affect. These proposals vary in several respects, such as the number of dimensions and their exact labeling (e.g., Barrett & Russell, 1999; Fontaine, Scherer, Roesch, & Ellsworth, 2007; Lang, 1995; Larsen & Diener, 1992; Osgood, May, & Mirron, 1975; Reisen-

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zein, 1994; Russell, 1980; Schlosberg, 1952; Thayer, 1989; Watson & Tellegen, 1985), but they all converge in terms of identifying valence and arousal (or some combination thereof) as fundamental to the nature of affect (Carroll, Yik, Russell, & Barrett, 1999). In this article, we focus on valence and arousal, not necessarily as the only dimensions of affect but as fundamental to the description of affect. Of course, both valence and arousal have their underlying physiological and behavioral correlates, but our interest here is limited to the level of subjective experience. We examine self-reports of affect as the currently most feasible way to access subjective experience and leave for the future analysis of other measures.

Several fundamental questions can be asked about these two properties of affect. One question is whether valence is best conceptualized as one bipolar dimension or as two separate dimensions; theory and research on this question have made considerable progress (Cacioppo, Gardner, & Berntson, 1999; Larsen & McGraw, 2011; Larsen, To, & Fireman, 2007; Russell & Carroll, 1999; Watson, Wiese, Vaidya, & Tellegen, 1999). A similar question can be raised about whether arousal is best conceptualized as one dimension or two (Thayer, 1989). Here we focus on an issue that is equally fundamental but on which less progress has been made and on which little consensus exists: How are valence and arousal related to each other? Does arousal provide or reflect the intensity of valence? Are the two related in a nonlinear (*V*-shaped or inverted-*U*-shaped) way? Or do valence and arousal constitute independent influences on other psychological phenomena? If valence is related to arousal, how strong is that relation? The scientific literature currently lacks agreement on whether arousal is a property that is independent of valence or whether the two are related in some way. Indeed, these questions are rarely raised.

Clarifying the nature of the relation between valence and arousal is fundamental to understanding the nature and role of affect, for various reasons. For one, how valence and arousal are related to each other has direct implications for how affect can be studied empirically. For instance, if arousal reflects the intensity of positive and negative valence, it would be difficult to measure or manipulate the two independently. Such an observation would be relevant to the interpretation (or reinterpretation) of hundreds of psychology experiments.

Second, the relation between valence and arousal in subjective experience derives from the fundamental organization of the human affective system. If their relation in subjective experience is fixed, then that relation is evidence of a universal underlying architecture. If, on the other hand, the relation between valence and arousal is malleable and varies with other factors, then the two dimensions do not, in any given instance, represent their specific underlying nature. For example, within the broader affective workspace in the brain, which includes, for example, the amygdala, ventral striatum, orbitofrontal cortex, and anterior insula (Barrett & Bliss-Moreau, 2009), researchers have tried to localize valence to certain brain regions (e.g., orbitofrontal cortex) and arousal to others (e.g., the amygdala), but results have been inconsistent across studies, and even meta-analytic studies show variability (e.g., Kringelbach & Rolls, 2004; Lindquist, Wager, Kober, Bliss-Moreau, & Barrett, 2012; Posner et al., 2009; Wager et al., 2008). Any variability in the relation between experienced valence and arousal across individuals might help explain this inconsistency

across studies and allow for more targeted hypotheses in cognitive and affective neuroscience.

Third, such variability, if it exists, would have its own implications for the interpretation of data. For example, there is fair consensus that arousal is a *V*-shaped function of valence in the domain of affective ratings of visual scenes (Lang, 1994). If the *V*-shaped relation is found to be inherent in the arousal–valence relation generally, then its occurrence in visual scenes can be explained by the nature of affect. If, on the other hand, the *V* shape is unique to visual scenes, then its occurrence will require a different type of explanation, perhaps something about the sample of scenes or about visual perception.

Finally, should the valence–arousal relation vary across individuals, then the role of these properties in emotional experiences and moods may vary across individuals as well—a principle that would help us understand the variability of human emotional experience more generally (e.g., Barrett, 2009; Kuppens, 2008). Furthermore, the relation between valence and arousal determines how affect can contribute to health, psychopathology, memory, attention, perception, decision making, or any other psychological domain. Indeed, any systematic valence–arousal relation implies that valence may not affect other phenomena independent of arousal and vice versa. Again, individual variation in the valence–arousal relation implies that accounts of how affect contributes to other psychological phenomena should take the shape and distribution of this variation into account.

Psychology needs a systematic, comprehensive, and empirical answer to the question of the relation between valence and arousal. Our aim in the present article is to make progress on this front. We first review the various conflicting suggestions, proposals, and presuppositions on the relation between valence and arousal. These possibilities coexist in the psychological literature, sometimes in different domains, sometimes with no apparent awareness of the existence of one another. We critically review the available evidence for each proposal and argue that the evidence does not provide a conclusive answer, especially across domains, on both the aggregate (nomothetic) level and the individual (idiographic) level. As we explain, one reason for uncertainty on these questions is that the magnitude of any relation has not been emphasized. A second reason is that some of the evidence relied on overly simple statistical models. Therefore, we next apply appropriate statistical methods to analyze both new and existing data in a way that allows a more comprehensive and systematic exploration of the relation between valence and arousal.

Possible Relations Between Valence and Arousal

To be as inclusive as possible, we outline six different possibilities on the relation between valence and arousal. Figure 1 presents an overview of these six. In the first five, arousal is expressed as a function of valence; in the sixth, valence is a function of arousal.

Independence

Several theoretical models of affect assume that valence and arousal are independent of one another (see Figure 1a; e.g., Barrett & Russell, 1999; Carver & Scheier, 1990; Larsen & Diener, 1992;

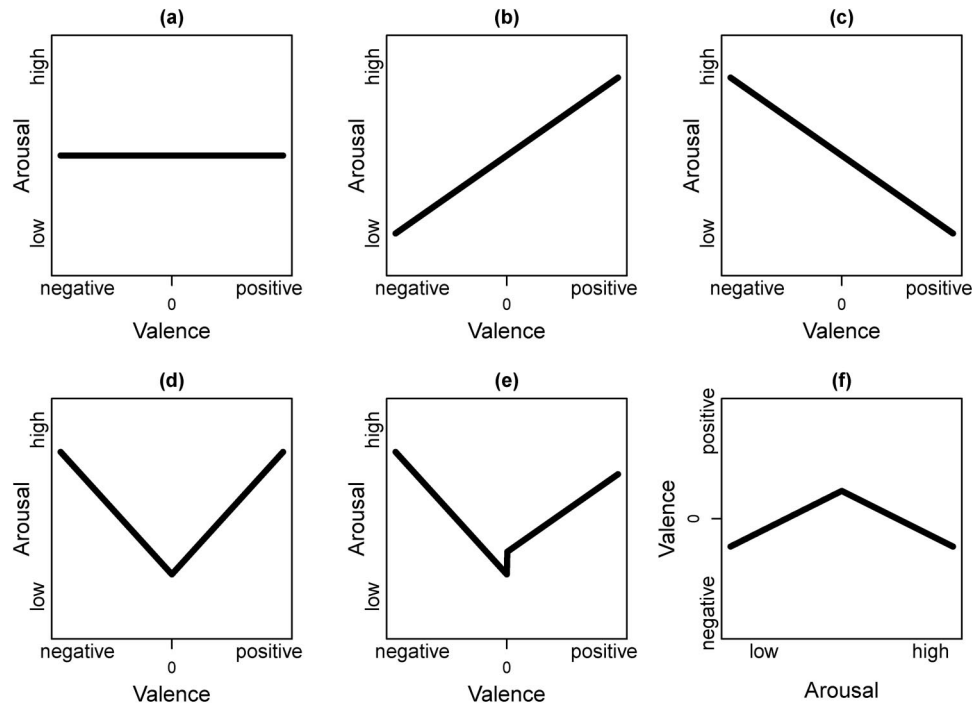


Figure 1. Overview of possible relations between valence and arousal: (a) independence, (b) positive linear relation, (c) negative linear relation, (d) symmetric V-shaped relation, (e) asymmetric V-shaped relation including both positivity offset and negativity bias, and (f) an inverted V-shaped relation when valence is a function of arousal.

Reisenzein, 1994; Russell, 1980). Accordingly, valence and arousal are depicted geometrically as orthogonal dimensions (see Figure 1a). Thus, one can feel pleasantly activated (e.g., excited), pleasantly deactivated (calm), unpleasantly activated (distressed), or unpleasantly deactivated (tired). How pleasant one is feeling gives no information about how activated one is feeling and vice versa. That is, the intensity or extremity of positive and negative feelings is not given by (indeed, is independent of) arousal. One can feel intensely or extremely calm or tired. One can feel extremely activated but be neutral on valence (as in certain cases of surprise, before it is known whether the surprise is positive or negative).

Independence of valence and arousal is often assumed in self-report questionnaire measures of affect (e.g., Larsen & Diener, 1992; Mehrabian & Russell, 1974; Russell, Weiss, & Mendelsohn, 1989). The assumption of independence was seen as supported by near-zero correlations between the two measures or by the fit of orthogonal factor models or multidimensional scaling solutions to various data sets, including self-reported mood or feeling (Feldman, 1995b; Kuppens, Van Mechelen, Nezlek, Dossche, & Timmermans, 2007; Mehrabian & Russell, 1974; Russell, 1980; Thayer, 1967, 1989, 1996; Yik, Russell, & Barrett, 1999), judged similarities among affect words (Barrett & Fossom, 2001; Bush, 1973), semantic differential ratings of words (Averill, 1975; Osgood, 1969), and analyses of facial and vocal expressions of emotion (e.g., Bullcock & Russell, 1984; Pittam & Scherer, 1993; Schlosberg, 1954; for overviews, see, e.g., Barrett & Russell, 1999; Larsen

& Diener, 1992; Reisenzein, 1994). Watson and Tellegen (1985) offered a consensual structure of mood by reanalyzing correlational structures available at that time. Although Watson and Tellegen emphasized the concepts of positive and negative affect (now called positive and negative activation; Watson et al., 1999) and called theirs a structure of mood, their full structural model contained the dimensions of valence (pleasant–unpleasant) and activation (which they termed engagement) depicted as orthogonal to one another (see Figure 1 on p. 221 of Watson & Tellegen, 1985). Moreover, their proposed structure of mood holds for feelings “right now” (Watson & Clark, 1997) and therefore is relevant to what we are calling affect.

A Positive Linear Relation

Although we know of no formal, empirically supported model with the assumption of a positive linear relation, theorists in Western psychology sometimes consider arousal to covary positively with valence. In a simplified version of this idea, valence equals arousal (see Figure 1b). In this view, the affective spectrum is seen as one dimension ranging from sadness (negative valence, low arousal) to happiness (positive valence, high arousal; e.g., Pettinelli, 2008). This assumption may have its roots in the documented Western preference for highly aroused positive affect (Tsai, Knutson, & Fung, 2006). In a milder version of this idea, the prototype of a positive feeling is excitement (i.e., pleasure accompanied by high arousal) and its opposite is sadness and gloom (i.e., displeasure accompanied by low arousal).

A Negative Linear Relation

Conversely, another perspective suggests the assumption that valence varies inversely with arousal. Again, a cultural preference—in this case, Asian—for low arousal positive affect (Tsai et al., 2006) may give rise to the view that valence negatively covaries with arousal (see Figure 1c). In the extreme version of this view, valence and arousal reduce to a single dimension, a spectrum ranging from a calm, relaxed, serene feeling at one end to a tense, distressed feeling at the other. Such a negative relation between valence and arousal can also be inferred from Freud's (1915/1957) writings on emotion, specifically from the notion that pleasure results from tension reduction. According to Freud, negative emotions are manifest in high levels of tension and anxiety, and positive emotions are manifest in their absence. Early learning theories in which reward was equated with drive reduction suggest similar ideas (Hull, 1943; Miller & Dollard, 1941).

A V-Shaped Relation

A fourth proposal is that valence and arousal take on a V-shaped relation. According to this proposal, as graphed in Figure 1d, arousal equals the intensity or extremity of positive and negative valence. This suggestion has its roots in psychobiological theories of motivation and personality (e.g., Depue & Iacono, 1989; Elliot & Thrash, 2002; Fowles, 1987; Gray, 1987, 1990; Konorski, 1967) in which what is felt and reported as arousal reflects the level of activity of two independent subsystems, one a positive appetitive subsystem and the other a negative aversive subsystem (Carver & White, 1994; Lang, Bradley, & Cuthbert, 1992, 1998; Watson & Tellegen, 1985; Watson et al., 1999). One version of this proposal was formulated as two different types of arousal, one positive and the other negative (e.g., Thayer, 1989). In another version, the assumption is that the more strongly the appetitive/positive subsystem or the aversive/negative subsystem is activated, the more energy (reflected in arousal) is mobilized to cope with the environmental demands. Conversely, lower levels of activation of either subsystem result in lower levels of energy.

With or without this psychobiological basis, some theorists hypothesizing a V-shaped relation assume that arousal reflects the intensity of pleasure or displeasure (arousal = intensity; e.g., Duffy, 1957; Mandler, 1984; Schachter & Singer, 1962; Schlosberg, 1954). For instance, Clore, Ortony, and Foss (1987) wrote that "arousal . . . reflects little more than intensity" (p. 752), and Lang (1994) wrote, "arousal is a general intensity dimension (perhaps the same as Frijda's 1986 impact). It always has valence—either positive or negative affect" (p. 75). The "arousal = intensity" hypothesis implies the V-shaped function of Figure 1d.

Considerable evidence for a V-shaped relation in people's subjective affect has been offered by Lang, Bradley, and colleagues in their observation of a "boomerang" shape in averaged data on arousal and valence ratings of people's reactions to affectively laden stimuli such as the International Affective Picture System (IAPS; e.g., Bradley & Lang, 2007; Lang, 1995; Lang et al., 1992, 1998). Similar findings were obtained in response to other mood induction methods (Jennings, McGinnis, Lovejoy, & Stirling, 2000) and with physiological indices of arousal and valence (e.g., Bernat, Patrick, Benning, & Tellegen, 2006; Bradley, Codispoti, Cuthbert, & Lang, 2001; Greenwald, Cook, & Lang, 1989).

An Asymmetrical V-Shaped Relation

In their evaluative space model, Cacioppo, Berntson and Gardner (Cacioppo & Berntson, 1994; Cacioppo, Berntson, Norris, & Gollan, 2012; Cacioppo & Gardner, 1999; Cacioppo, Gardner, & Berntson, 1997, 1999) theorized that positive and negative valence are separate, potentially independent dimensions. Although these authors did not directly take up the relation between valence and arousal, their model has the heuristic value of suggesting one possibility. Using activation as a proxy for arousal (e.g., Ito & Cacioppo, 2005; Ito et al., 1998), the evaluative space model suggested to us the possibility that positive and negative valence covary differently with equal levels of their respective input or activation, resulting in asymmetry in the relation between valence and arousal. The empirical standing of this suggestion does not affect the empirical standing of the evaluative space model per se, but it does allow us to test additional valence–arousal relations that are implied in the literature.

A first instance of this asymmetry (called *positivity offset*) is that higher levels of positive affect are generated at low levels of input or activation compared to levels of negative affect. The adaptive significance of this offset is that it motivates the organism to approach novel stimuli and environments, enabling it to learn and explore.

The second asymmetry (called *negativity bias*) is that negative valence is more reactive than positive valence, such that increasing activation produces more negative affect than positive affect. Put simply, negative is stronger than positive (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Peeters & Czapinski, 1990; Taylor, 1991). The underlying rationale is that although positive opportunities may require less immediate action, negative events are associated with higher levels of energy to enable the organism to deal immediately with the environmental or social threats posed (Cacioppo & Gardner, 1999; Fredrickson, 2001). Evidence for positivity offset and negativity bias is based on a higher intercept and less steep slope for the positive compared to negative activation function in studies on people's affective responses to stimuli (e.g., Ito & Cacioppo, 2005; Ito, Cacioppo, & Lang, 1998).

This specific asymmetrical V-shaped relation between valence and arousal in subjective experience is graphically displayed in Figure 1e. In this figure, positivity offset is represented by the discontinuous shift at zero valence, and negativity bias is represented in the steeper slope for negative than for positive valence.

Valence as a Function of Arousal

Valence can also be considered as a function of arousal, as is done in some theoretical viewpoints. Whereas proposals of independence and linear relations are identical from such a viewpoint, this viewpoint does offer one unique account of the valence–arousal relation. The theory of optimal arousal (Hebb, 1955; Yerkes & Dodson, 1908) posits that an organism functions optimally at medium levels of arousal. This theory suggests that affect is most pleasant at medium levels of arousal and becomes more unpleasant as arousal deviates from the optimal medium level. Berlyne (1960), for example, offered evidence that the pleasantness of stimuli is maximized at an intermediate level of arousal.

This position posits an inverted-*V*-shaped relation when valence is considered a function of arousal (see Figure 1f).

A Critical Evaluation of the Available Empirical Evidence

Conflicting possible accounts of the relation between valence and arousal continue to coexist in the published literature because the available evidence for each account has not been considered definitive or may be domain specific. And, indeed, that evidence can be faulted on a number of grounds.

First, the proposal of valence–arousal independence rests on a zero association obtained with correlational techniques such as zero-order correlations, factor analyses, or regression analyses. Yet, a correlation coefficient measures the strength only of a linear relation. A correlation of zero does not imply independence because it is consistent with various nonlinear dependencies (such as the proposed *V*-shaped relation).

Indeed, in several studies scatterplots of raw data suggested a boomerang shape and support for a *V*-shaped relation. Visual inspection of the scatterplot was often complemented by computing the valence–arousal correlation or slope separately for positive valence and negative valence, or by testing the significance of the quadratic component in predicting arousal from valence (e.g., Bradley, Cuthbert, & Lang, 1990; Cuthbert, Bradley, & Lang, 1996). Although such techniques provided support for the hypothesized *V*-shaped relation, they do not allow a firm conclusion on whether the *V* shape (or another shape) is indeed the best way to capture the data. What is needed are statistical comparisons of the various alternatives modeled with flexible assumptions and with appropriate assessment of their fit.

Second, many of the studies, especially those offered as support for a nonlinear relation, examined valence and arousal responses to affect-inducing stimuli (such as the IAPS pictures). Of course, standardized stimulus sets and studies of responses to them are extremely useful. Nonetheless, for the topic of this article, these studies are not sufficient because they are limited to a single domain (i.e., responses to static, visual images), and the relation between valence and arousal within the person may be confounded with the relation between valence and arousal within the stimulus set. Thus, the apparent relation of arousal to valence might have resulted from the people responding to the stimuli or from an oversampling of the valence–arousal space in certain regions and an undersampling in others, and there is no straightforward way to separate these two alternatives. Put differently, suppose that valence and arousal are completely independent in the psychology of the individual but that, simply due to sampling, the IAPS stimulus set includes many pictures that elicit high arousal pleasant reactions, high arousal unpleasant reactions, and low arousal neutral valence reactions but relatively few pictures that elicit high arousal neutral valence reactions, low arousal pleasant reactions, or low arousal unpleasant reactions. If so, a *V*-shaped relation will be found because of stimulus sampling. Thus, we cannot discount the possibility that the resulting *V* shape depicts the valence and arousal distribution of the pictures themselves, rather than informing us of the organization of people's subjective affective experiences. Another possibility is that the *V*-shaped relation is more general than the set of visual stimuli, but is still restricted to immediate reactions to the presentation of salient stimuli, and does not generalize to momentary states that occur in the absence of such stimulation. Therefore, we need converging evidence from a variety of additional and balanced

types of stimuli and from a variety of momentary states that do not necessarily include salient stimulation, along with appropriate statistical modeling, to provide a complete test of the relations between valence and arousal in general.

Third, a problematic issue common to both correlational and experimental studies is that valence and arousal must be measured. We here focus on self-report scales used to measure subjective experience. Verbal scales have their own pitfalls that make it difficult to test the valence–arousal relation. Scales that confound valence with arousal produce relations built into the scales. For example, Watson and Tellegen's (1985) commonly used mood scales PANAS were designed to assess mixtures of valence and arousal. Their PA scale was designed to assess the combination of positive valence and high arousal. Their NA scale was designed to assess the combination of negative valence and high arousal. A more subtle version of the same problem is that response scales may sometimes implicitly suggest a relation between valence and arousal. Such a suggestion would occur when, for example, positive affect is assessed with items such as *enthused* and *cheerful*, whereas negative affect is assessed with items such as *sad* and *depressed*. Such items point to the further problem that individual differences may occur in the interpretation of particular items rather than in subjective experiences the items are meant to assess. Needed is convergence of conclusions from many different scales, especially ones that avoid presupposing a specific relation between valence and arousal.

Fourth, another problematic issue common to the available correlational and experimental studies is that these studies were typically conducted in a laboratory setting, which can lack the social complexity and ambiguities of daily life. Variance in affect can be greatly restricted if everyone is sitting for an hour in a lab or a classroom completing a questionnaire. Greater ecological validity can be achieved by also studying people's subjective experiences in real-life circumstances, outside the confined space of a laboratory room. Although previous research has examined valence and arousal in daily life (e.g., Barrett, 1998, 2004; Feldman, 1995a; Kuppens, 2008; Kuppens, Oravecz, & Tuerlinckx, 2010; Kuppens et al., 2007; Nezlek, 2005), it has not explicitly focused on the relation between valence and arousal or looked beyond merely linear relations.

Finally, and most important, most previous research has examined the relation between valence and arousal at the nomothetic level (i.e., on average, across persons or stimuli) and used it to address proposals framed at the idiographic level (i.e., processes within the individual). Yet, relations at the nomothetic level need not coincide with those at the idiographic level. In fact, relations within and between persons often do not coincide (Molenaar & Campbell, 2009). The mistaken inference of the idiographic from the nomothetic has been named the "nomothetic fallacy" (Allport, 1937) or "ecological fallacy" (Robinson, 1950). Much of the available evidence addresses the nomothetic level and tells us very little about how valence and arousal are related at the level of the individual. Yet, it is precisely this level that matters most, as affect has implications for other psychological phenomena, such as emotion, judgment, perception, and memory, only at this level. Our concern here can be addressed through multilevel statistical models that incorporate both a nomothetic (i.e., population) structure and idiographic variations in the nomothetic structure (i.e., individual differences modeled as random effects).

Idiographic Variation Around a Weak V-Shaped Relation?

Although far from definitive, the available evidence leads us to offer three hypotheses about the relation between valence and arousal. First, at the nomothetic level, the weight of current evidence suggests that increasing either pleasure or displeasure is accompanied by increasing arousal, resulting in a V-shaped relation. The many studies advanced as evidence for independence between valence and arousal provide no evidence against a V-shaped relation because, as we said, the correlational methods used do not speak for or against nonlinear relations. On other grounds, it is plausible to suppose that increasing valence, either in a positive or a negative direction, mobilizes energy resources, which are then experienced as the affective feeling of arousal.

Second, however, we immediately qualify this hypothesis: The nomothetic V-shaped relation is not a strong one, and so arousal cannot be equated with the intensity or extremity of valence. A change in valence is only one of many factors that can change a person's energy mobilization (consider immune responses, hormone changes, drugs, cumulative hassles and uplifts of the past, and the like) and hence the subjective experience of arousal. The available evidence also suggests a weak relation. The scatterplots that show a boomerang-shaped distribution (e.g., Figure 1 on p. 374 in Lang, 1995) show considerable variation around that shape. Moreover, the strict arousal = intensity hypothesis makes three counterintuitive predictions that can be seen in the empty places left by the V-shaped function within Figure 1d. First, it predicts that states of high pleasure but low activation do not occur. Yet, intuitively, serenity and relaxation are just such states. Second, it predicts that intensely unpleasant low activation states do not occur. Yet, intuitively, depression, fatigue, and boredom are such states. Third, it predicts that neutrally or only mildly valenced states of high activation do not occur. Yet, intuitively, the high arousal state of surprise exists and can be slightly pleasant, slightly unpleasant, or neutral in valence. We therefore predict that the V-shaped relation between valence and arousal at the nomothetic level is weak and probabilistic. By this prediction, we mean that increasing pleasure or increasing displeasure will on average more likely be experienced in combination with higher arousal, but—and the following is our second proposition—in principle all possible combinations of valence and arousal can occur.

Our third hypothesis is that the relation between valence and arousal shows wide variation at the idiographic level and that individual differences in this relation are meaningful. Different sources of evidence point to large individual differences in the structure of affect at the individual level (Barrett, 2009; Kuppens, Stouten, & Mesquita, 2009), but the establishment of the meaning of stable patterns is just beginning. For example, one reason that individuals differ in their typical relation of valence to arousal is that they differ in how much they focus on valence versus the arousal aspects of their feelings (Feldman, 1995a). Differences in valence focus and arousal focus, in turn, relate to a host of other psychological variables, such as neuroticism, extraversion, self-esteem lability, and interoceptive sensitivity. Furthermore, in studies that examined simply the possible linear relations between valence and arousal, different individuals were found to display wide variability in that linear relation, ranging from a strongly negative through zero to a strongly positive relation, with this variability reliably related to individual differences in reward responsiveness (Kuppens, 2008). Individuals also show substantial

variation in the level of positivity offset and negativity bias in their affective responses (Ito & Cacioppo, 2005). Finally and more generally, research and theory on the relation of emotion to personality abound with emotional traits that suggest individual differences in the habitual experience of specific combinations of valence and arousal, such as neuroticism and extraversion (Larsen & Ketelaar, 1991), positive and negative activation (Watson & Tellegen, 1985), trait depression (Radloff, 1977), trait anxiety and trait anger (Spielberger & Sydeman, 1994), behavioral activation and inhibition (Carver & White, 1994), regulatory focus (Higgins, Shah, & Friedman, 1997), and so forth. Any idiographic combination of such traits in principle predicts a different within-person valence and arousal relation. In all, the evidence strongly suggests large differences in the valence–arousal relation at the idiographic level, depending on a person's learning and reinforcement history, cultural background, personality, and so forth. Indeed, at this stage, we see no limit to the form that this relation can take for a particular individual.

Overview of Present Studies

We compiled eight data sets that provide information on valence and arousal in subjective experience. Because, as we argued, the type of stimuli or context can shape this relation, we looked for converging evidence for a particular relation in data on affective responses to a variety of experimental stimuli (such as the IAPS image set but also to explicitly balanced and to ambiguous stimuli) as well as data on naturally occurring affect as currently experienced or remembered. In the same vein, we examined data obtained using a variety of response scales and emotion terms. We examined data that allow a nomothetic analysis in Study 1 and data that allow idiographic analysis in Study 2. Table 1 provides details of each study.

For each data set, we tested alternative mathematical models that reflect the different theoretical possibilities illustrated in Figure 1. Each data set was analyzed by means of a series of theoretically informed statistical models that express arousal as a function of valence and a series of models that express valence as a function of arousal. For each, we also included an additional nonparametric model that does not make any assumption about the shape of the relation between valence and arousal. In particular, when modeling arousal as a function of valence (AfV), we tested models expressing (a) independence, (b) a linear relation, (c) a symmetric V shape, (d) asymmetric V shape with positivity offset, (e) asymmetric V shape with negativity bias, (f) asymmetric V shape with both, and (g) a nonparametric model. To enable testing the optimal arousal hypothesis against the other theoretically relevant options when considering valence as a function of arousal, we additionally modeled valence as a function of arousal (VfA) including models for (a) independence, (b) a linear relation, (c) a V shape (inverted), and (d) a nonparametric model.¹ Comparing the fit of the different models by means of appropriate model selection strategies allowed us to conclude which relation is present in the data for each direction of the relation.

We next detail the statistical models (illustrated for the case when arousal is a function of valence, with valence and arousal centered around zero for modeling purposes) in the form of normal

¹ For valence as a function of arousal, we consider only the four models that were theoretically meaningful, which did not include asymmetrical models.

Table 1
Overview of Studies

Study	<i>N</i>	Participants	Target of rating	Assessment of valence and arousal
Studies on nomothetic relation				
Study 1a: IAPS data from Lang et al. (2008)	Approximately 100 per 60 pictures (Lang et al., 2008)	College students, half of them female	956 IAPS pictures	SAM
Study 1b: Current affect	1,331	College students, 864 female Mean age = 21 years	Current affect	Adjectives with 3 response formats
Study 1c: Remembered affect	1,417	College students, 892 female Mean age = 20 years	Remembered affect	Adjectives with 3 response formats
Studies on nomothetic and idiographic relation				
Study 2a: Idiographic IAPS data from Ito et al. (1998)	264	College students, 152 female Mean age = 19 years	480 IAPS pictures	SAM
Study 2b: Balanced IAPS data from Barrett (2004)	131	College students, 88 female Mean age = 20 years	16 IAPS pictures	Adjectives
Study 2c: Modern art paintings	167	College students, 132 female Mean age = 18.5 years	9 modern art paintings (see footnote 3)	Adjectives + SAM
Study 2d: Experience sampling data from Timmermans et al. (2009)	80	College students, 48 female Mean age = 22 years	Momentary experience throughout daily life	Affect Grid (Russell et al., 1989)
Study 2e: Experience sampling data from Barrett (2004)	349	College students, 198 female Mean age = 19 years	Momentary experience throughout daily life	Adjectives

Note. IAPS = International Affective Picture System (Lang, Bradley, & Cuthbert, 2008); SAM = Self-Assessment Manikin (Bradley & Lang, 2007).

regression models that are appropriate for studying nomothetic relations. The more complex, hierarchical regression model formulations to study the relations at the idiographic level are introduced in Study 2 and in the Appendix.

Model 1: Independence

A first model implies independence between valence and arousal:

$$Arousal_i = \beta_0 + \epsilon_i, \tag{Model 1}$$

with *i* denoting the *i*th observation (e.g., a stimulus or a person) and ϵ_i being the residual. Depending on the particular study, *Arousal* may refer to the average arousal elicited by a particular stimulus, the particular arousal state of an individual, and so on. For convenience, we assume that the residuals ϵ_i are independently normally distributed with mean 0 and standard deviation σ_ϵ (we entertain this assumption about the residuals consistently for all models). As is apparent from the model formulation, arousal is predicted by an intercept and error, whereas valence plays no part. Figure 1a is a graphical illustration of this model.

Model 2: Linear Relation

A second model implies a linear relation (which is positive when $\beta_1 > 0$ and negative when $\beta_1 < 0$) between valence and arousal and is written as (see Figures 1b and 1c):

$$Arousal_i = \beta_0 + \beta_1 Valence_i + \epsilon_i. \tag{Model 2}$$

Model 3: Symmetric V-Shaped Relation

A third model allows for a symmetric *V*-shaped relation between valence and arousal (see Figure 1d):

$$Arousal_i = \beta_0 + \beta_1 |Valence_i| + \epsilon_i. \tag{Model 3}$$

In this model, arousal is regressed onto the absolute value of valence, which means that if β_1 is positive, the model implies a symmetric *V*-shaped relation between valence and arousal (if β_1 is negative, it implies an inverted symmetric *V*-shaped relation).

Models 4–6: Asymmetric V-Shaped Relation

The following three models evaluate different possible instantiations of an asymmetric *V*-shaped relation between valence and arousal that include positivity offset, negativity bias or both:

$$Arousal_i = \beta_0 + \beta_1 |Valence_i| + \beta_2 I_i + \epsilon_i, \tag{Model 4}$$

$$Arousal_i = \beta_0 + \beta_1 |Valence_i| + \beta_3 I_i |Valence_i| + \epsilon_i, \tag{Model 5}$$

$$Arousal_i = \beta_0 + \beta_1 |Valence_i| + \beta_2 I_i + \beta_3 I_i |Valence_i| + \epsilon_i, \tag{Model 6}$$

where *I_i* denotes a dummy variable that indicates whether *Valence_i* is positive (*I_i* = 1) or negative (*I_i* = 0) and allows for testing for the presence of positivity offset and negativity bias. If β_2 is positive, the arousal slope for positive valence has a higher intercept than for negative valence, indicating positivity offset. In turn, if β_3 is negative, the arousal slope for negative valence is steeper than for positive valence, indicating negativity bias. Thus, Model 4 includes a positivity offset but no negativity bias, Model 5 includes a negativity bias but no positivity offset, and Model 6 incorporates both (see Figure 1e for an illustration of Model 6).

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Model 7: Nonparametric Relation

All previous models assume a specific parametric form for the relation between valence and arousal derived from the alternative theoretical predictions. To ascertain that these models do not impose too many restrictions on the patterns available in the data, we additionally included a model that does not make prior parametric assumptions such as linearity or a V shape and allows for more flexibility. The nonparametric regression model can be formulated as follows:

$$\text{Arousal}_i = \beta_0 + f(\text{Valence}_i) + \beta_2 I_i + \varepsilon_i, \quad (\text{Model 7})$$

where f is an arbitrary but smooth function that has to be estimated. Because the predictors in Model 7 are additive, such a model is called an additive model (Faraway, 2006; Wood, 2006).² We incorporate in Model 7 a term that allows for positivity offset because the function f is required to be sufficiently smooth and therefore cannot handle a discontinuous jump at neutral valence. Negativity bias can be detected by studying the function f graphically. If a flexible regression model such as Model 7 does not outperform (in terms of better relative fit to the data) one or more of the theoretically inspired models, we may conclude that the theoretical assumptions of our parametric model(s) are sufficient in characterizing the relation between valence and arousal. If, however, a flexible nonparametric model would outperform the theoretical models, its characteristics can be used to gain novel knowledge about how valence and arousal are related.

Model Selection Strategy

To decide which model best fits the data (separately for AfV and VfA), we used two kinds of tools for model selection: traditional hypothesis testing tools and an information criterion rooted in a (quasi-)Bayesian approach (for more information on model selection, see the 2000 and 2006 special issues on model selection in *Journal of Mathematical Psychology*; Myung, Forster, & Browne, 2000; Waldorp & Wagenmakers, 2006).

In traditional hypothesis tests, the null hypothesis that a particular parameter of one model equals zero in the population is evaluated on the basis of p values. In this way, we can judge the presence of a V shape, positivity offset, or a negativity bias, as they are represented by single parameters in the model (e.g., the test on the presence of a positivity offset is a test of $H_0: \beta_2 = 0$ vs. $H_1: \beta_2 \neq 0$). Despite the many problems that surround p values (see Wagenmakers, 2007), they are easily understood and are indeed useful in this case to evaluate the tenability of simple null hypotheses.

Although the classical hypothesis testing approach is very commonly used and standard in the field of psychology, a major disadvantage is that this approach only allows for a comparison of nested models (a Model A is nested in Model B if Model A can be obtained from Model B as a special case). Yet, not all models we have presented have a nested relation (e.g., Models 2 and 3 are not nested). A useful approach to compare and select among all formulated models is the Bayesian information criterion (BIC; Raftery, 1995; Schwarz, 1978). The BIC is calculated as

$$-2 \times \text{LogLikelihood} + \log(N) \times k,$$

where k is the number of parameters. The BIC equals the badness of fit (indexed by $-2 \times \text{LogLikelihood}$ or deviance) penalized for

the number of parameters. Given there is a trade-off between badness of fit and the number of parameters (adding parameters decreases the deviance), the goal is to find the optimal point in the trade-off; this point is achieved by the model with the lowest BIC. In other words, the model with the lowest BIC provides the optimal balance between model fit and complexity.

There is another feature of the BIC that makes it attractive in the present context. The BIC can be used to calculate an approximate posterior probability of each of the models studied (see, e.g., Raftery, 1995; Ramsey & Schafer, 2002; Wagenmakers, 2007):

$$\Pr(\text{Model } m \mid \text{data}) = \frac{\exp\left(-\frac{1}{2} \text{BIC}_m\right)}{\sum_{h=1}^7 \exp\left(-\frac{1}{2} \text{BIC}_h\right)},$$

for $m = 1, \dots, 7$ ($m = 1, \dots, 4$ for the models where valence is a function of arousal). The advantage of using the posterior probability is that it gives a quantification of uncertainty as a probability statement (i.e., after having seen the data, what is the probability that the model is true?), which is a very natural way of expressing uncertainty.

Study 1: Nomothetic Relation Between Valence and Arousal

Study 1a: Aggregated Affective Experiences in Response to the IAPS Pictures

Method. In Study 1a, we analyzed the publicly available normative IAPS data set (Lang, Bradley, & Cuthbert, 2008). The data consist of average scores of ratings of 956 affectively laden pictures on valence and arousal. Each picture was rated by approximately 100 male and female college students in sets of around 60 pictures. The pictures were rated with the Self-Assessment Manikin (SAM; e.g., Bradley & Lang, 2007). The SAM consists of two 9-point bipolar ratings scales (ranging from 1 to 9) with pictorial manikins representing varying values of pleasure (ranging from unpleasant to pleasant) and arousal (ranging from low to high arousal). We subtracted the scores by 5 such that they ranged from -4 to 4 . For more detailed information on these data, see Lang et al. (2008).

Results and discussion. Table 2 presents an overview of the model selection statistics of the seven AfV models, and Table 3 presents an overview for the four VfA models. The AfV results confirmed the presence of an asymmetric V shape in the data including a negativity bias but no positivity offset, indicating that increasing positive and negative valence are related to increasing arousal, with the relation being stronger for negative than positive valence. This conclusion can be inferred from the BIC values identifying Model 5 (which is characterized by a V shape, $\beta_1(\text{Model 5}) = 0.79$, $p < .001$, and negativity bias,

² In estimating the unknown function f , one has to balance two contrasting desires: Fitting the data as well as possible (i.e., the function f should be close to the data points) and having a smooth curve (i.e., with not too many irregularities). The equilibrium between fit and smoothness will be determined in an automatic way by minimizing a penalized loglikelihood, which is an addition of the loglikelihood (goodness of fit) and a penalty for the nonsmoothness (for more details, see Wood, 2006).

Table 2
Summary of Model Selection Statistics When Arousal Is Modeled as a Function of Valence (A|V) for Each Study

Study	Model 1 Independence		Model 2 Linear relation		Model 3 Symmetric V		Model 4 Asymmetric V positivity offset		Model 5 Asymmetric V negativity bias		Model 6 Asymmetric V positivity offset + negativity bias		Model 7 Nonparametric		R ²
	BIC	PostP	BIC	PostP	BIC	PostP	BIC	PostP	BIC	PostP	BIC	PostP	BIC	PostP	
Studies on nomothetic relation															
Study 1a: IAPS data	3,033	.00	2,964	0.00	2,695	.00	2,668	.00	2,644	0.21	2,649	0.02	2,641	.77	.34 ^a
Study 1b: Current affect	2,714	.00	2,698	0.00	2,703	.00	2,681	.00	2,664	0.96	2,671	0.04	2,676	.00	.06
Study 1c: Remembered affect	3,940	.00	3,937	0.00	3,854	.01	3,860	.00	3,854	0.01	3,846	0.58	3,847	.40	.08
Studies on nomothetic and idiographic relation															
Study 2a: Idiographic IAPS	64,604	.00	62,297	0.00	61,819	.00	59,536	.00	59,017	0.00	58,998	1.00	59,022	.00	.18
Study 2b: Balanced IAPS	8,633	.00	8,492	1.00	8,625	.00	8,549	.00	8,644	0.00	8,572	0.00	9,906	.00	.09
Study 2c: Modern art paintings	4,200	.00	4,174	0.15	4,175	.09	4,181	.00	4,171	0.75	4,252	0.00	4,799	.00	.03
Study 2d: Experience sampling study, Europe	19,380	.00	19,254	0.00	19,282	.00	19,261	.00	19,201	1.00	19,217	0.00	19,219	.00	.01
Study 2e: Experience sampling study, U.S.	299,621	.00	296,639	0.00	295,807	.00	294,697	.00	294,443	0.00	294,212	1.00	294,423	.00	.01

Note. The values of the best fitting model are displayed in bold. BIC = Bayesian information criterion (lower values indicate better fit); PostP = posterior probability of each model, given the data, among the set of seven models; IAPS = International Affective Picture System.

^a Gives the R² of the best fitting model. In case of idiographic analyses (hierarchical models), R² values are calculated as the proportional reduction in the sum of the residual and Level 1 random intercept variance due to including the explanatory variables in the model, following Snijders and Bosker (2011).

β₃(Model 5) = -0.27, *p* < .001) from the theoretically informed models as well as Model 7 (which displays a negativity bias but no significant positivity offset, β₂(Model 7) = 0.27, *ns*) as the best fitting models. Figure 2a displays both models graphically, together with the data.

The VfA results, in turn, point to a negative linear relation between arousal and valence from the theoretically informed models (β₁(Model 2) = -0.42, *p* < .001), which is, however, outperformed by a nonparametric curve that follows a slight inverted U shape (see Figure 2b for the graphical representation of both models).

The results from this study provide solid evidence on what features do and do not characterize the normative IAPS data. Our

analyses are only partially in line with previous results that had suggested both positivity offset and negativity bias in response to the IAPS pictures (Ito & Cacioppo, 2005; Ito et al., 1998). Yet the latter were based on only subsets of the complete IAPS picture set and did not involve alternative model comparisons. The optimal arousal hypothesis receives some support in these data as well.

Study 1b: Momentary Affective Experience

Study 1b combined data from five different samples that assessed how people were feeling at the moment using a variety of response items and formats, yielding information on people's

Table 3
Summary of Model Selection Statistics When Valence Is Modeled as a Function of Arousal (V|A) for Each Study

Study	Model 1 Independence		Model 2 Linear relation		Model 3 Symmetric V		Model 4 Nonparametric		R ²
	BIC	PostP	BIC	PostP	BIC	PostP	BIC	PostP	
Studies on nomothetic relation									
Study 1a: IAPS data	3,843	.00	3,775	0.00	3,849	.00	3,762	1.00	.10 ^a
Study 1b: Current affect	2,714	.00	2,698	1.00	2,721	.00	2,725	0.00	.02
Study 1c: Remembered affect	3,940	.12	3,936	0.88	3,947	.00	3,963	0.00	.008
Studies on nomothetic and idiographic relation									
Study 2a: Idiographic IAPS	65,281	.00	63,199	0.00	65,049	.00	63,035	1.00	.03
Study 2b: Balanced IAPS	8,526	.00	8,506	0.91	8,510	.09	11,500	0.00	.01
Study 2c: Modern art paintings	4,721	.00	4,682	1.00	4,725	.00	5,425	0.00	.00
Study 2d: Experience sampling study, Europe	18,417	.00	18,283	1.00	18,384	.00	18,299	0.00	.00
Study 2e: Experience sampling study, U.S.	313,460	.00	310,588	0.00	310,974	.00	NA ^b	NA ^b	.01

Note. The values of the best fitting model are displayed in bold. BIC = Bayesian information criterion (lower values indicate better fit); PostP = posterior probability of each model, given the data among the set of four models; IAPS = International Affective Picture System.

^a Gives the R² of the best fitting model. In case of idiographic analyses (hierarchical models), R² values are calculated as the proportional reduction in the sum of the residual and Level 1 random intercept variance due to including the explanatory variables in the model, following Snijders and Bosker (2011). ^b Results are not available because the model could not be estimated.

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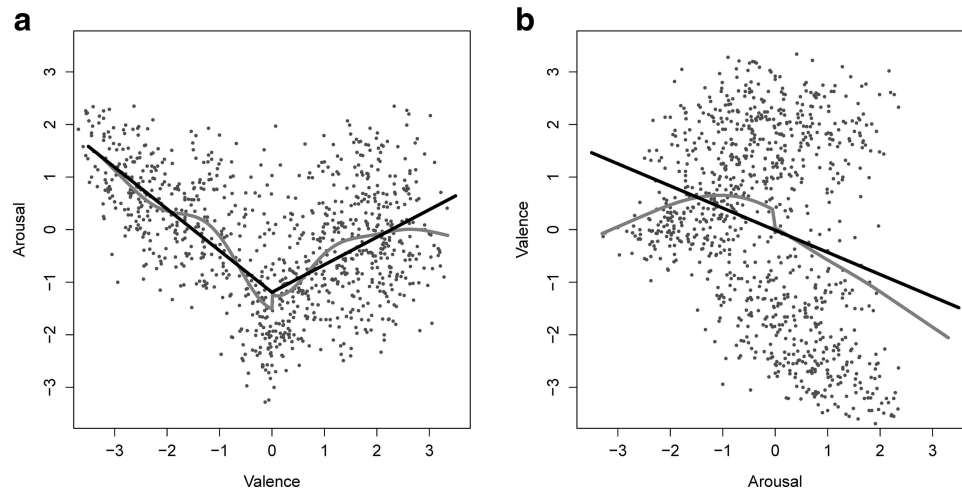


Figure 2. Relation in the normative IAPS data between (a) valence and arousal according to Model 5 (black line; reflecting an asymmetric V-shaped relation) and Model 7 (gray line; reflecting a nonparametric relation) and (b) arousal and valence according to Model 2 (black line; linear relation) and Model 4 (gray line; nonparametric relation). The points are the plotted data (Study 1a). IAPS = International Affective Picture System.

affective state as it occurs more or less naturally at a certain point in time, or at least not in response to particular standardized stimuli. Although the five studies were performed at different times and places, they used identical methods. For this reason, we combined the data and analyzed them jointly.

Method. Participants consisted of five large samples of college students from three large universities in the United States and Canada. Each participant was asked to “stop for a moment and think about how you are feeling right now” and describe those feelings by completing three separate questionnaires developed by Barrett and Russell (1998). Each questionnaire included four unipolar subscales (positive valence, negative valence, low arousal, and high arousal) but in different response formats: a list of adjectives accompanied by a 5-point Likert scale, a set of statements with which respondents indicated their degree of agreement, and a set of statements for each of which respondents indicated how much it described their feeling (see the appendix in Barrett & Russell, 1998, for details). An individual’s score on each subscale was taken as the mean of responses to individual items. For each response format, the negative valence was subtracted from the positive valence subscale, and likewise for arousal (with opposite scales being negatively correlated in each case, $ps < .001$), to create scales for valence and arousal per response format. Next, a principal-components analysis was performed separately on the resulting three valence scales and the three arousal scales (yielding clear unidimensional components), and the component scores were used as final indicators of the valence and arousal level of participants’ current affect.

Results and discussion. The AfV results (see Table 2) show that the relation between valence and arousal in a large sample of people’s current affect conforms to a V-shaped relation that is asymmetrical (Model 5; $\beta_1(\text{Model 5}) = 0.16, p < .01$). The found relation is graphically presented in Figure 3a. Contrary to the possibility we took from the evaluative space model, however, the asymmetry did not involve a positivity offset and instead of a

negativity bias demonstrated a steeper slope for positive valence than for negative valence ($\beta_3(\text{Model 5}) = 0.46, p < .001$).

In turn, when valence was modeled as a function of arousal (see Table 3), the best fitting model was one that involves a positive linear relation between arousal and valence (Model 2; $\beta_1(\text{Model 2}) = 0.15, p < .001$; see Figure 3b). The VfA result supports the results from the AfV analyses: If most data are located in the positive realm of valence (which is the case), and given that our analyses looked at functions only (i.e., each arousal value can be related to only one valence value), the expected best fitting VfA model, given a V-shaped AfV result, is a positive linear relation.

Study 1c: Remembered Affective Experience

Affect experienced while sitting in a laboratory can be restricted in variance (Yik, Russell, & Steiger, 2011). Most participants will be in a relatively neutral affective state when completing the questionnaire, and such data provide only a limited window on how the complete realm of people’s affective experiences is organized. We therefore next examined data from five studies in which participants had been asked to remember a particular time in the recent past when they experienced an emotion and report on their affective state at that time. Again, as the studies shared identical methods, we discuss and analyzed them jointly.

Method. Five large samples of college students were asked to remember “the very last time you had an emotion of any kind.” Next, they were asked to report on how they were feeling at the particular time using the same three questionnaires as in Study 1b. Valence and arousal compound scores were calculated analogously to in Study 1b (with opposite scales being negatively correlated in each case, $ps < .001$).

Results and discussion. The AfV results again supported an asymmetric V-shaped relation. Model 6 provided the best fit to the data (see Table 2). It involves a V-shaped relation between valence and arousal ($\beta_1(\text{Model 6}) = 0.30, p < .001$) that is characterized

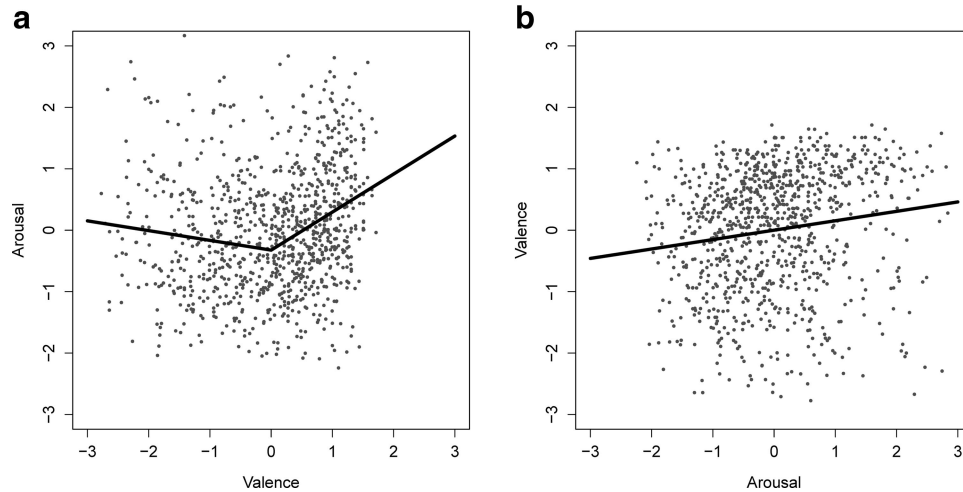


Figure 3. Relation in current affect between (a) valence and arousal according to Model 5 (asymmetric V-shaped relation) and (b) arousal and valence according to Model 2 (linear relation). The points are the plotted data (Study 1b).

by the opposite of both positivity offset and negativity bias: a higher intercept for negative valence ($\beta_2(\text{Model 6}) = -0.46, p < .001$) and steeper slope for positive valence ($\beta_3(\text{Model 6}) = 0.55, p < .001$; see Figure 4a). Again, the VfA results (see Table 3) supported a linear positive relation (Model 2; $\beta_1(\text{Model 2}) = 0.09, p < .001$; see Figure 4b).

Study 2: Idiographic Relation Between Valence and Arousal

The results from Study 1 showed that when arousal is considered as a function of valence, valence and arousal display a V-shaped relation at the nomothetic level and predominantly a

positive linear relation when valence is viewed as a function of arousal. The data from Study 1, however, cannot shed light on how valence and arousal covary within a person across occasions or time. Therefore, in a second series of data sets we examined the relation between valence and arousal in idiographic data. We used multilevel or hierarchical extensions of the regression models described above (see, e.g., Raudenbush & Bryk, 2002; Snijders & Bosker, 2011). Next to describing the relation between valence and arousal at the nomothetic level, the use of such models additionally allowed us to model how each individual participant's valence and arousal scores were related and observe the variability in these relations (for more details, see the Appendix).

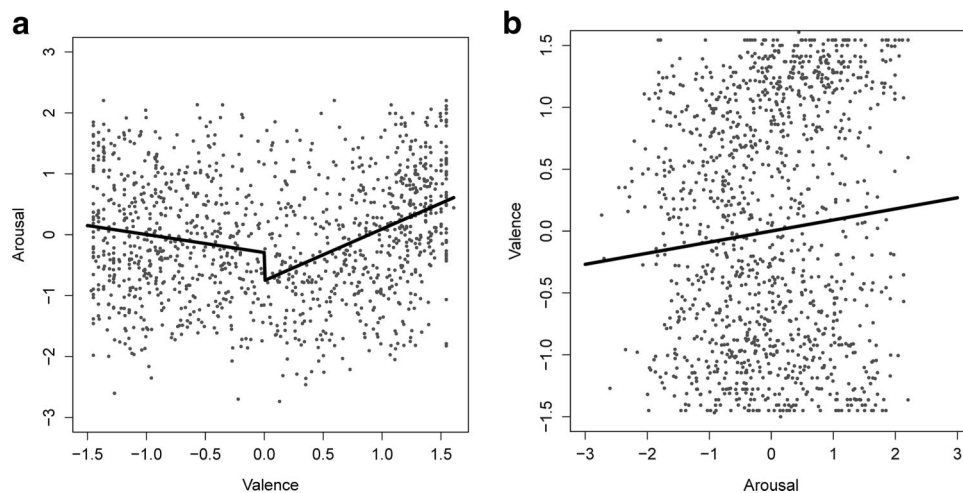


Figure 4. Relation in remembered affect between (a) valence and arousal according to Model 5 (asymmetric V-shaped relation) and (b) arousal and valence according to Model 2 (linear relation). The points are the plotted data (Study 1c).

Study 2a: Idiographic Affective Experiences in Response to the Full Range of IAPS Pictures

Method. The data from this study were collected by Ito et al. (1998) and involved individual participants' responses to subsets of the IAPS picture set. Eight groups of on average 33 participants each were presented different sets of 60 slides from the IAPS picture set. Participants rated each picture on valence and arousal using the SAM rating scales (which we centered around zero). For more detailed information, see Table 1 and Ito et al. (1998).

Results and discussion. As these data are characterized by a nested structure (with pictures nested within persons), models with random effects for persons were fit. At the nomothetic level, the AfV analyses again support a modal V-shaped relation between valence and arousal, this time characterized by a positivity offset and bias: The BIC/posterior probability values (see Table 2) identified Model 6 as the best fitting model. It is graphically presented in Figure 5a and can be seen to follow a V shape ($\beta_1(\text{Model 6}) = 0.48, p < .001$) that is characterized by a positivity offset ($\beta_2(\text{Model 6}) = 0.60, p < .001$) and by a steeper slope for positive than for negative valence ($\beta_3(\text{Model 6}) = 0.18, p < .01$). However, it can be seen in Figure 5 that there are large individual differences in the relation between valence and arousal as well. In fact, almost any relation between valence and arousal can be observed in this sample of data.

When valence is a function of arousal (see Table 3), a positive linear relation was the best fitting theoretical model (Model 2; $\beta_1(\text{Model 2}) = 0.17, p < .001$), with also large individual differences variability in the direction of this relation (see Figure 5b). The nonparametric model outperforms this model, however, in terms of fit. Yet, its shape (see Figure 5b) does not deviate much from a linear positive relation (and does not support an optimal level view).

Although these findings are informative, a remaining concern is that the results are driven by the particular distribution that is

present in the stimuli themselves (i.e., certain areas in affective space are overrepresented and others are underrepresented in the IAPS stimulus set). Moreover, some of the stimuli convey very explicit affective information, possibly shrinking idiographic variation. Therefore, in the next two studies, we examined people's idiographic affective reactions to stimuli that were selected to uniformly cover the entire affective space (Study 2b) and in addition do not convey explicit affective information (Study 2c).

Study 2b: Idiographic Affective Experiences in Response to Balanced IAPS Pictures

Method. The data for this study were taken from Barrett (2004), Study 2. Participants used multiple adjectives to rate their affective reactions to 16 IAPS pictures (numbers 1710, 2050, 2205, 2800, 5000, 5621, 5760, 5920, 6230, 6550, 7010, 7080, 7234, 8160, 8190, and 9001; see Barrett, 2004, for more information). In order to minimize possible stimulus selection bias, pictures were selected to represent a balanced combination of all possible positions in the valence/arousal affective space (based on the normative ratings provided by Lang et al., 2008). Unlike the previous study, the ratings were made using multiple adjectives designed to tap valence and arousal using a 7-point Likert scale (0 = *not at all*; 6 = *very much*), hereby avoiding potential response bias using single scores. A bipolar valence score was obtained by subtracting a displeasure (sad, disappointed) subscale from a pleasure subscale (happy, satisfied). A bipolar arousal score was obtained from subtracting a low arousal subscale (quiet, still) from a high arousal subscale (surprising, aroused; with multilevel regression indicating negative relations between opposite subscales, $ps < .001$).

Results and discussion. As all participants rated all pictures on multiple adjectives, the data conformed to a fully crossed structure and allowed fitting the hierarchical models with both person and stimulus random effects (so-called crossed random

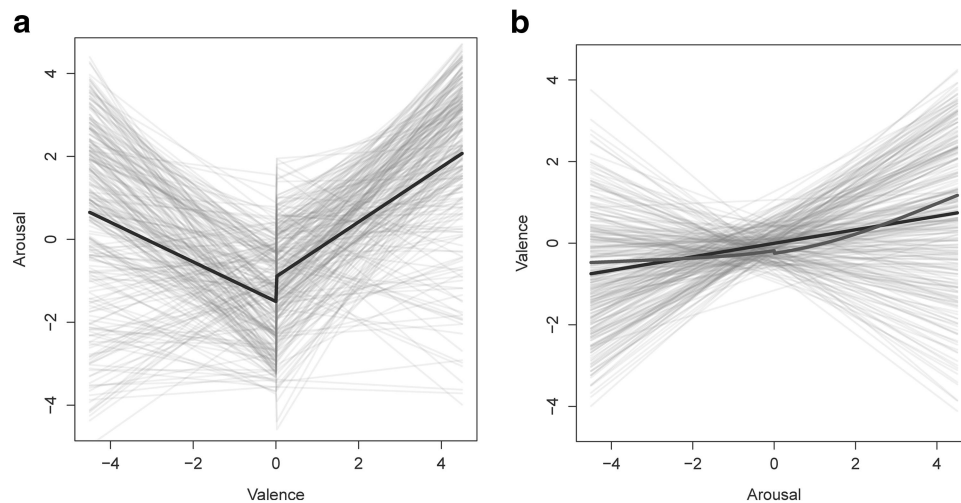


Figure 5. Relation in idiographic IAPS data from Ito et al. (1998) between (a) valence and arousal according to Model 6 (asymmetric V-shaped relation) and (b) arousal and valence according to Model 2 (bold black line; linear relation) and Model 4 (bold gray line; nonparametric relation). The bold lines represent the average relation. The individual gray lines represent the relation for each participant separately (Study 2a). IAPS = International Affective Picture System.

effects models; see the [Appendix](#)). The model selection parameters reported in both [Table 2](#) and [Table 3](#) indicate that valence and arousal were linearly related at the nomothetic level (Model 2). Model 2 from the AfV and VfA is presented graphically in [Figures 6a](#) and [6b](#). At the nomothetic level, a linear, slightly positive relation between valence and arousal ($\beta_2(\text{Model } 2) = 0.07, p < .05$) and conversely between arousal and valence is observed ($\beta_2(\text{Model } 2) = 0.08, p < .05$). Again, however, there is large idiographic variability in this relation, ranging from negative to positive.

Study 2c: Affective Experiences in Response to Ambiguous Stimuli

A selection of nonfigurative modern art paintings was chosen as stimuli for Study 2c. The choice of nonfigurative art was guided by the idea that art is capable of eliciting affective reactions, but nonfigurative art does not contain clear explicit emotional cues for the type of emotional reactions it should elicit. The rationale was therefore that the affective reactions to such stimuli should primarily reflect the characteristics of the valence–arousal relation in people’s experiences while reducing demand characteristics.

Method. The stimuli were selected from a broader sample of paintings in a pilot study such that all portions of affective space were represented (with each picture representing a particular combination of high/medium/low pleasantness with high/medium/low arousal).³ The paintings were presented on a computer screen after being resized to have the same height (approx. 14 cm.).

Participants were asked to rate to what extent each painting elicited various affective reactions assessed by a number of adjectives while the painting was continuously displayed on the screen. We included multiple measures, both unipolar and bipolar, to assess the affective reactions to the stimuli in order to neutralize measurement or scale effects. A first set of items consisted of the valence and arousal SAM items ([Bradley & Lang, 2007](#)), scored after centering around zero. Second, two bipolar items assessed valence and arousal using 9-point rating scales with verbal labels to denote various levels of valence (ranging from *very unpleasant* to *very pleasant*) and arousal (ranging from *very sleepy* to *very activated*), respectively (each coded from -4 to 4). Finally, a third set of 12 unipolar items assessed affective reactions using more specific affective labels representing the endpoints of the two dimensions of valence (positive valence: pleasant, happy, good; negative valence: unpleasant, unhappy, bad) and arousal (high arousal: tense, active, excited; low arousal: calm, sleepy, and passive) using a 7-point scale (ranging from *not at all* to *very strong*, coded from 0 to 6). The average negative valence score of these items was subtracted from the average positive valence score and the average low arousal score was subtracted from the average high arousal score to form scores of valence and arousal, respectively (with multilevel analyses indicating negative relations between opposite subscales, $ps < .001$). Finally, compound scores for valence and arousal were calculated by calculating for each the average of the bipolar SAM, the bipolar verbal scale scores, and the valence and arousal scores based on the unipolar items. The reliability of these compound scores was good (Cronbach’s alphas calculated across all person–painting combinations equaled 0.92 and 0.83, respectively). The presentation order of the paintings and the presentation order of the affect items per painting were ran-

domized. In the end, each participant rated his or her reactions to all nine paintings on all 20 affect items.

Results and discussion. As the data conform to a crossed structure, we fit hierarchical models with person- and painting-specific parameters.⁴ The AfV analyses again supported the hypothesized V-shaped relation between valence and arousal at the nomothetic level. The model selection parameters (see [Table 2](#)) identified Model 5 that implies a V-shaped relation between valence and arousal ($\beta_1(\text{Model } 5) = 0.13, p < .05$) that was characterized by a steeper slope for positive than for negative valence ($\beta_3(\text{Model } 5) = 0.13, p < .05$). Model 5 is shown in [Figure 7a](#). As is clear from this figure, the observed relations between valence and arousal at the idiographic level displayed sizable individual differences.

When valence is modeled in function of arousal (see [Table 3](#)), the nomothetic relation is again best characterized as a positive linear relation (Model 2; $\beta_1(\text{Model } 2) = 0.14, p = .001$), with again considerable idiographic variation in this relation, ranging from strongly negative over zero to strongly positive (see [Figure 7b](#)).

Study 2d: Affective Experiences in European Daily Life

The experience sampling method collects data at multiple moments during participants’ daily activities. It can therefore provide a window on the within-person structure of people’s affective experiences during normal daily life. The experience sampling method offers the further advantage of not having to rely on memory, eliminating cognitive biases of information storage and retrieval ([Barrett, 1997](#); [Robinson & Clore, 2002a, 2002b](#); [Stone et al., 1998](#)). Experience sampling allows researchers to collect data across a broad range of different circumstances, and the method is ecologically valid because data collection occurs within real-life

³ An initial sample of 45 paintings was taken from modern art books. They were selected based on their nonfigurative nature and because they potentially depicted a broad range of valence and arousal values. In a pilot study, the 45 selected paintings were rated by six researchers in emotion in terms of how much pleasant or unpleasant feelings and how much arousal they could elicit, using the Affect Grid ([Russell, Weiss, & Mendelsohn, 1989](#)), a single-item measure of valence and arousal. The Affect Grid is a visual 9×9 two-dimensional grid, with unpleasant/pleasant feelings forming the horizontal and arousal/sleepiness forming the vertical dimension, with end points and neutral points being marked with emotion words to facilitate reporting. Each position on the grid thus corresponds to a particular valence and arousal score. On the basis of the ratings, the following nine paintings were selected, representing all positions in affective space: Guston—*The clock* (negative valence/low arousal); Murtic—*White background* (negative valence/medium arousal); Millares—*Quadro 66* (negative valence/high arousal); Newman—*Midnight blue* (neutral valence/low arousal); Van Doesburg—*Constructivism* (neutral valence/medium arousal); Delaunay—*Terk prisms electroniques* (neutral valence/high arousal); Marden—*Grove group one* (positive valence/low arousal); Van Gogh—*Sunrise at St-Rémy* (positive valence/medium arousal); and Picasso—*Bather with a beachball* (positive valence/high arousal).

⁴ It should be noted that at some points we fitted a slightly different model than discussed in the [Appendix](#) because of numerical problems. For instance, it was impossible to fit Model 6 with random person intercepts, all regression coefficients random across persons and only random stimulus intercepts in Study 2c (it led to perfectly correlated random effects). However, if we allowed random stimulus effects for all regression coefficients, the model gave acceptable results, which were reported instead.

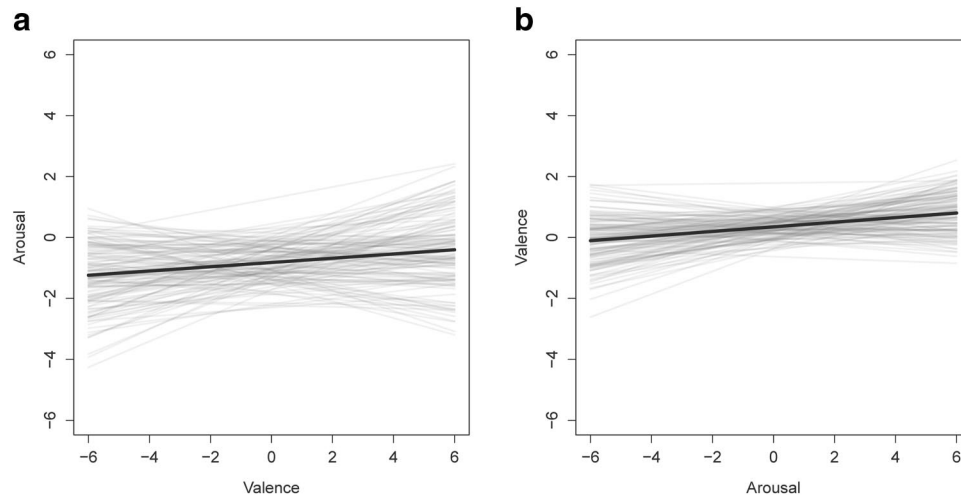


Figure 6. Relation in idiographic IAPS data with balanced picture selection between (a) valence and arousal according to Model 2 (linear relation) and (b) arousal and valence according to Model 2 (linear relation). The bold line represents the average relation. The individual gray lines represent the relation for each participant separately (Study 2b). IAPS = International Affective Picture System.

circumstances rather than in artificial contexts (Bolger, Davis, & Rafaeli, 2003; Conner, Tennen, Fleeson, & Barrett, 2009). In Study 2d, we reanalyzed data on valence and arousal collected throughout daily life in a study by Timmermans, Van Mechelen, and Nezlek (2009).

Method. Participants were recruited via the university job service and were paid for participation. Participants received seven diary booklets (one for each day of the study) and a Casio PC Unite wristwatch that was programmed to beep nine times a day at random intervals for seven consecutive days. For each programmed beep, the booklet presented the Affect Grid (Russell et al., 1989; see footnote 3). After an introductory session explaining the method and device, participants rated their feelings of valence

and arousal in the booklet at each beep by marking the position in the Affect Grid that best corresponded to how they felt at that moment. On average, participants completed 59 of the maximum of 63 reports.

Results and discussion. The resulting data have a nested structure with beeps nested in persons, and we analyzed them using models with person-specific intercepts and slopes. The AfV results favor a V-shaped relation at the nomothetic level (Model 5 in Table 2; $\beta_1(\text{Model 5}) = 0.23, p < .001$) that is characterized by a slight negativity bias (that is in itself not significant, however; $\beta_3(\text{Model 5}) = -0.05, p = .49$) but no positivity offset. The relation is graphically presented in Figure 8a. As can be seen from the individual lines in Figure 8, there are again large individual

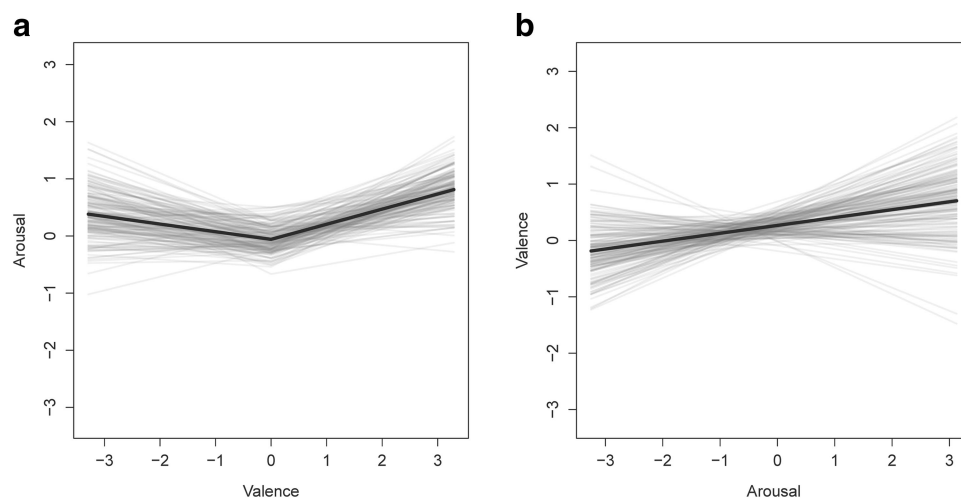


Figure 7. Relation in people's affective reactions to modern art paintings between (a) valence and arousal according to Model 5 (asymmetric V-shaped relation) and (b) arousal and valence according to Model 2 (linear relation). The bold line represents the average relation. The individual gray lines represent the relation for each participant separately (Study 2c).

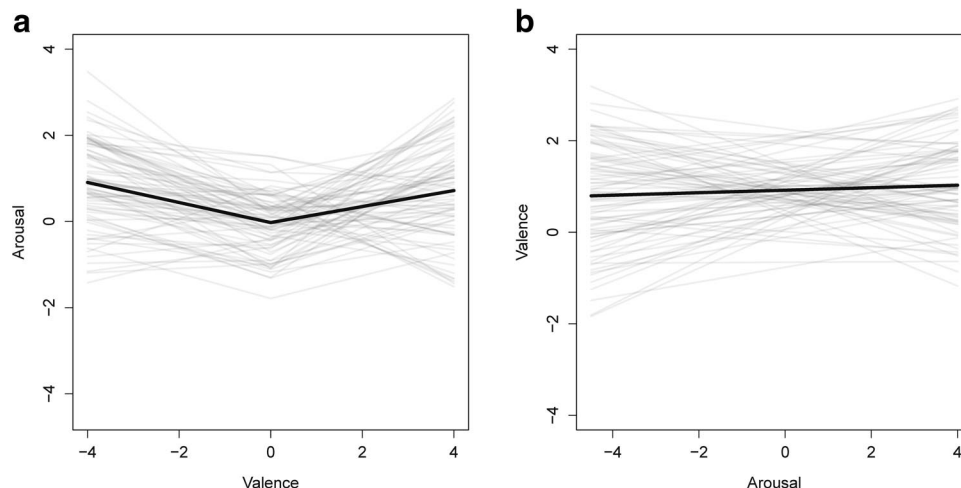


Figure 8. Relation in European daily life between (a) valence and arousal according to Model 5 (asymmetric V-shaped relation) and (b) arousal and valence according to Model 2 (linear relation). The bold line represents the average relation. The individual gray lines represent the relation for each participant separately (Study 2d).

differences in the relation between valence and arousal (which is also the reason why Model 5 is favored above Model 3, despite the lack of significance of the negativity bias parameter). From the VfA models (see Table 3), the results pointed to a nomothetic linear relation between arousal and valence with a positive slope that was not significant (Model 2; $\beta_1(\text{Model 2}) = 0.03, p = .34$). Yet, the relation showed considerable variation at the individual level (see Figure 8b).

A possible limitation of Study 2d is that pleasure and arousal, although frequently assessed, were measured with a single item. This can limit reliability and increase the possibility of response bias. In Study 2e we therefore analyzed data from a second experience sampling study in which valence and arousal were measured with multiple adjectives.

Study 2e: Affective Experiences in American Daily Life

The data for this study were taken from Barrett (2004). In these data, the experience of an extended list of affective experiences was assessed during daily life with a computerized experience sampling technique.

Method. Participants were given palmtop computers loaded with the Experience Sampling Program (ESP; Barrett & Barrett, 2001) and programmed to randomly beep an average of 10 times a day for an average of 30 days. Participants carried their palmtops during their normal daytime routine, and at each beep they were asked to report how much their current feeling corresponded to a list of in total 29 adjectives. Part of this list included affective words that correspond theoretically to the four quadrants of the affective space defined by valence and arousal: *active, enthusiastic,* and *peppy* (positive valence and high arousal), *afraid, nervous,* and *angry* (negative valence and high arousal), *calm* and *relaxed* (positive valence and low arousal), and *bored, sleepy, sluggish,* and *tired* (negative valence and low arousal). For each measurement occasion, an aggregate score was calculated for each quadrant item set. Next, scores for valence and arousal were calculated

by subtracting the sum of the negative aggregate scores from the sum of the positive aggregate scores and by subtracting the sum of the low arousal aggregate scores from the sum of the high arousal aggregate scores, respectively (with multilevel analyses indicating negative relations between opposite subscales, $p_s < .001$). On average, participants recorded their responses on 201 of the programmed beeps.

Results and discussion. The AfV model selection parameters clearly favor a V-shaped asymmetrical relation between valence and arousal at the nomothetic level (Model 6 in Table 2; $\beta_1(\text{Model 6}) = 0.16, p < .001$). Contrary to what would be expected on the basis of positivity offset and negativity bias, however, the relation involves a lower (instead of higher, see also Study 1c) intercept ($\beta_2(\text{Model 6}) = -0.23, p < .001$) and a steeper (instead of less steep, see also Studies 1b, 1c, 2a, and 2c) slope ($\beta_3(\text{Model 6}) = 0.11, p < .001$) for the positive valence–arousal than for the negative valence–arousal function. As is clear from Figure 9a, large individual differences variability characterized the observed relations at the idiographic level. In terms of VfA, finally, the data favored a positive linear relation (Model 2, see Table 3; $\beta_1(\text{Model 2}) = 0.12, p < .001$) with, again, considerable individual differences (see Figure 9b).

Studies 2a–2e: Are the Observed Individual Differences Meaningful? Preliminary Evidence

The repeatedly observed substantial individual differences in the valence–arousal relation raises the important question of the extent to which this idiographic variation is meaningful: Can the variation be explained in terms of relations with well-established, independently defined sources of individual differences? An answer to this question would contribute to building a nomological network that explains the observed idiographic variation. In two preliminary studies (Kuppens, Tuerlinckx, Koval, Yik, & Russell, 2012), we therefore examined how individual differences in the relation between valence and arousal are a function of five-factor model of personality dimensions and culture (comparing data from Canada,

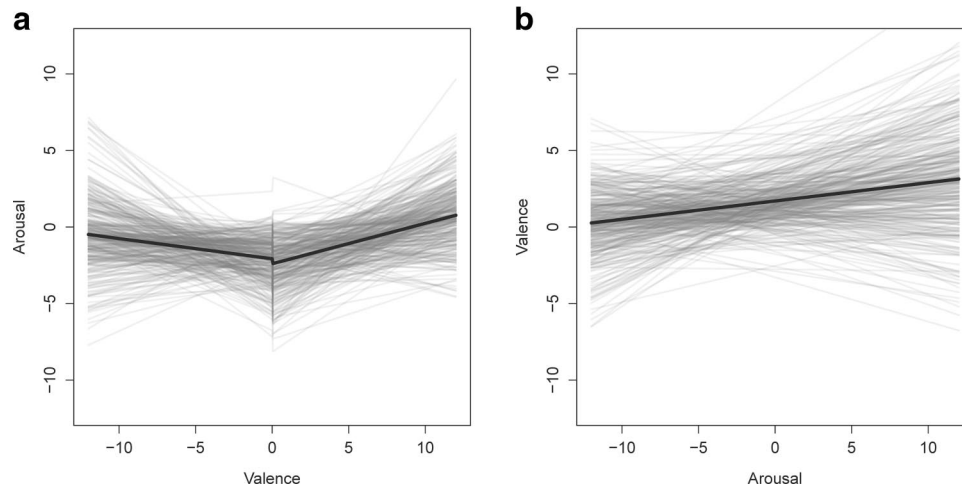


Figure 9. Relation in American daily life between (a) valence and arousal according to Model 6 (asymmetric V-shaped relation) and (b) arousal and valence according to Model 2 (linear relation). The bold line represents the average relation. The individual gray lines represent the relation for each participant separately (Study 2e).

Hong Kong, Japan, Korea, and Spain). In these studies, we consistently replicated the V-shaped relation between valence and arousal and individual differences in that relation. More important, we found evidence that the individual differences are related to both standard personality dimensions and to culture.

In a first study, participants were asked to recall recent events of positive and negative valence, high and low arousal, and were asked to report their feelings with multiple formats. We found that individual differences in experiencing particular valence–arousal combinations were meaningfully related to broad personality dimensions in ways consistent with existing literature (e.g., Kuppens et al., 2007; Larsen & Ketelaar, 1991; Tellegen, 1985; Watson & Clark, 1984). In particular, we found that extraverts gravitate toward positive feelings when they are experiencing high arousal and likewise gravitate toward feeling active when they are feeling positive or negative. Neurotics, in contrast, gravitate to negative feelings when they are experiencing low arousal and gravitate toward experiencing high arousal when they experience negative feelings. In addition, we found that agreeableness was related to experiencing high arousal in combination with positive valence and low arousal in combination with negative valence.

In a second study (using methods comparable to those used in Study 1b), we observed cultural differences in the valence–arousal relation. Although this relation was consistently characterized by a symmetric V shape in each culture, the slope of this V shape was steepest for western cultures (Canada, Spain) but less steep (Japan, Korea) to almost flat (Hong Kong) for eastern cultures. In other words, at the group level, positive and negative valence come with increased arousal in western nations, and valence and arousal are experienced relatively independently from each other in eastern cultures. These findings strongly resonate with the documented preference for high arousal positive affect in western cultures and lower arousal positive affect in eastern cultures (Tsai et al., 2006). They moreover suggest that these preferences for high and low arousal extend to negative affect.

General Discussion

The Relation Between Valence and Arousal at the Group (Nomothetic) Level

Table 4 provides an overview of the findings when arousal is considered as a function of valence. From this overview, it is clear that the majority of the studies (all but one) pointed toward a V-shaped, asymmetric relation at the nomothetic level. This means that as people feel more positive or negative, they tend to experience higher levels of arousal on average. Likewise, feelings of arousal are more likely to be accompanied by valenced feelings, positive or negative. This phenomenon was observed in people's experience in reaction to pictorial stimuli (Studies 1a, 2a, and 2c), in people's current (Study 1b) and remembered affect (Study 1c), and throughout their daily life (Studies 2d and 2e). This finding is robust because it holds across different stimuli, measurement methods, and scales, limiting the possibility that the obtained relation is due to particular measurement bias.

Table 5 summarizes the findings when valence was modeled as a function of arousal. The results point to a positive linear relation (the only exception occurs in Study 1a, which differs from the other studies in the important respect that the nomothetic relation describes the stimuli, not participants). When analyzed this way, the data clearly did not provide any consistent support for an inverse V-shaped relation (corresponding to the notion of optimal medium arousal). In addition, a comparison of the final columns of Tables 2 and 3 reveals that best fitting AfV models clearly outperform VfA models in terms of explained variance. Moreover, the graphs show a clear misfit in many cases because of the tilted V-shaped pattern in the data (which cannot be captured by a functional model). In sum, the dominant pattern characterizing observed valence and arousal is identified in the AfV analyses, leading to the conclusion that the nomothetic relation between valence and arousal conforms to a weak V shape with arousal as a function of valence.

Table 4
Overview of the Observed Relation When Arousal Is Modeled as a Function of Valence (A|V) Across Studies

Study	Best model	Relation	Offset ^a	Bias ^b
Studies on nomothetic relation				
Study 1a: IAPS data	Models 5/7	Asymmetric V-shaped/nonparametric	No	Negativity bias
Study 1b: Current affect	Model 5	Asymmetric V-shaped	No	Positivity bias
Study 1c: Remembered affect	Model 6	Asymmetric V-shaped	Negativity offset	Positivity bias
Studies on nomothetic and idiographic relation				
Study 2a: Idiographic IAPS	Model 6	Asymmetric V-shaped	Positivity offset	Positivity bias
Study 2b: Balanced IAPS	Model 2	Linear	No	No
Study 2c: Modern art paintings	Model 5	Asymmetric V-shaped	No	Positivity bias
Study 2d: Experience sampling study, Europe	Model 5	Asymmetric V-shaped	No	Negativity bias
Study 2e: Experience sampling study, U.S.	Model 6	Asymmetric V-shaped	Negativity offset	Positivity bias

Note. IAPS = International Affective Picture System.

^a Offset refers to the presence of a difference in intercept between the positive valence-arousal function and the negative valence-arousal function. ^b Bias refers to the presence of a difference in slope between the positive valence-arousal function and the negative valence-arousal function.

The nomothetic positive linear VfA relation supports the same conclusion. Such a relation is indeed expected when (a) there is a V-shaped relation with arousal as a function of valence (keeping in mind that a function implies that each valence value can be associated with only one arousal value) and (b) more data points are observed for positive than for negative valence (meaning that people on average experience more pleasant than unpleasant valence). The latter was the case in all studies (except in Study 1a, due to the study design) and is consistent with what is known about the distribution of affect (e.g., Diener & Diener, 1996; Kahneman, Krueger, Schkade, Schwarz, & Stone, 2004; Zelenski & Larsen, 2000).

Our data point out two crucial qualifications of the V-shaped nomothetic relation, however. First, the variance accounted for is low, as can be inferred from the very low to moderate R^2 values reported in the final columns of Tables 2 and 3. In other words, the degree to which we can predict a person's level of arousal based on his or her level of positive or negative valence is limited, and any combination between the two can in principle occur (to illustrate this point, we refer to the plotted data or individual lines in Figures 2–9). Therefore, the nomothetic relation should be interpreted in a

weakly probabilistic rather than in a deterministic manner. On average, the probability is higher that when people experience more arousal they will also experience increasing pleasure or displeasure and that highly aroused states will more likely be valenced than not. Yet, affective experiences of all combinations of valence and arousal can occur (e.g., low arousal but highly positive or negative affect states do occur, although less frequently). We therefore conclude that the average individual will feel slightly increased arousal in combination with increasing pleasure and displeasure.

The Relation Between Valence and Arousal at the Idiographic Level

The finding of a weak V-shaped relation between valence and arousal at the nomothetic level should be held against the background of the large individual differences that were observed in the relation between valence and arousal at the idiographic level. In all data sets pertaining to within-person relations (Study 2), large individual differences were observed in the idiographic relations between valence and arousal (see Figures 5–9). These findings make the important point that the relation between valence and arousal does not show one lawful, universal form and appears to be sculpted quite differently from one person to the other. Our findings show that the valence–arousal relation can take almost any form, underscoring Gordon Allport's observation many years ago that what may hold for the average person or across persons may differ dramatically from what holds for each individual. How people's feelings are structured and, consequently, how they help to constitute the mind varies from one person to the next.

The consequences of this conclusion are far from trivial. The affective properties of people's emotional experiences are not identical across individuals. This implication puts serious boundary conditions on, for instance, the quest for universal correlates (neural, behavioral, etc.) of affect and suggests that such correlates are significantly moderated by individual differences. Importantly, the idiographic variation in the valence–arousal relation also implies that valence and arousal most likely do not have invariant contributions to other psychological phenomena. With affect being in the spotlight of many research areas, either as the predictor or as the criterion, our findings point toward a course correction for the science of psychology in understanding the affective contributions

Table 5
Overview of the Observed Relation When Valence Is Modeled as a Function of Arousal (V|A) Across Studies

Study	Best model	Relation
Studies on nomothetic relation		
Study 1a: IAPS data	Models 2/4	Negative linear/nonparametric
Study 1b: Current affect	Model 2	Positive linear
Study 1c: Remembered affect	Model 2	Positive linear
Studies on nomothetic and idiographic relation		
Study 2a: Idiographic IAPS	Models 2/4	Positive linear/nonparametric
Study 2b: Balanced IAPS	Model 2	Positive linear
Study 2c: Modern art paintings	Model 2	Positive linear
Study 2d: Experience sampling study, Europe	Model 2	Linear (not positive or negative)
Study 2e: Experience sampling study, U.S.	Model 2	Positive linear

Note. IAPS = International Affective Picture System.

to emotion, well-being, personality, attitudes, moral judgment, memory, perception, and so on. In the paragraphs below, we explore the implications in more detail.

Does a Lawful Relation Between Valence and Arousal Exist?

Previous proposals on the relation between valence and arousal were guided by the desire to postulate statements about how valence and arousal are universally related in all individuals. Doing so is valuable because psychology as a science has often searched for the nomothetic laws of the human mind. In contrast, our findings showed that although on average the relation between valence and arousal gravitates toward a V shape, more fundamentally there is no universal architecture that adequately describes the relation between valence and arousal in subjective experience for everyone.

Although our results clearly support the finding of a V-shaped relation as obtained from research on affective pictures, our results also clearly show that it is misguided to argue that arousal forms the intensity of positive and negative valence because the low power of this relation at the nomothetic level as well as the large idiographic variability clearly do not support a strong V-shaped relation. As a consequence, our findings do not support a general arousal = intensity hypothesis (although there may be just such a relation for some individuals). For many, however, there is more to the intensity of valence than arousal level and vice versa. The arousal that people report as an element of their affective experiences has a quality that goes beyond simply the intensity of pleasure or displeasure. On the basis of the evidence presented here, it can be concluded that a conceptual distinction between arousal and intensity of valence is necessary and that an arousal dimension independent of valence is needed to describe affective experience.

Our results also did not provide consistent evidence for a particular type of asymmetry in the relation between valence and arousal (see Table 4). It is possible, however, that the type of asymmetry depends at least partly on the stimuli or contexts in which valence and arousal were assessed. This caveat implies that the relation between valence and arousal varies not only across individuals but also across contexts or domains.

The fact that the V-shaped relation between valence and arousal was consistently characterized by asymmetry—both in general and for most specific individuals—does however signal that arousal does not uniformly covary with pleasant and unpleasant feelings. In the context of the debate of the bipolarity of affect, this finding suggests that at least to some extent positive and negative affect are separable and have bivariate instead of bipolar properties, at least in terms of their relation to arousal. Future research could take this finding as a starting point to further clarify in which respects or contexts positive and negative valence are bipolar or bivariate (such as in their relations with other psychological dimensions).

Understanding Individual Differences in the Structure of Affect

We know that there are profound individual differences in the structure of affect (Feldman, 1995b), and in this article we have shown that one of the basic elements of that structure—the relation between valence and arousal—differs across individuals. For some (in fact a majority of our participants), feeling bad means

feeling stress, anxiety, irritation, or other high-arousal negative states and feeling good means feeling excited and upbeat, whereas for others feeling good means feeling relaxed or content and feeling bad means feeling down or sad. Yet for others, the two are independent, and feeling good or bad can come with high or low experienced arousal.

We expect that such individual differences in affect structure are not trivial variations but are meaningful and important for understanding differences in people's affective lives and how they respond to events. Indeed, preliminary evidence indicates that individual differences in the experience of particular valence–arousal combinations are meaningfully related to dimensions from the five-factor model of personality, particularly neuroticism, extraversion, and agreeableness, and to cultural differences, particularly East–West differences in ways lining up with preferences for ideal affect (Kuppens et al., 2012). As such, we believe that idiographic information on the relation between valence and arousal can contribute to understanding the ways people habitually respond to the world. An important step for further research is therefore to examine the factors that are implicated in shaping individual differences in valence–arousal relations and how they are related to emotion, personality, and culture-bound processes.

Implications for Research Involving Affect

Subjective experience provides a window on affect, which, in turn, influences processes involved in emotion, judgment, perception, decision making, and so on at the level of the individual. Consideration of people's idiographic affect structure is therefore essential in research that examines the role of affect in other areas of psychological functioning.

Our findings argue for caution among researchers who attempt to assess valence while ignoring arousal, to assess arousal while ignoring valence, or even to assess the two independently of each other. Given the assumption of independence, researchers might attempt to manipulate valence independently from arousal, but the present findings suggest that this may be difficult to achieve in a uniform way across participants. Researchers should be aware of the possibility of nonindependence of valence and arousal in many individuals and should take this possibility into account when performing manipulation checks and interpreting results.

Our findings highlight the importance of considering how the impact of valence or arousal on other areas may be moderated by individual differences in the valence–arousal relation. Valence and arousal can most likely not be expected to have invariant correlates with or influence on other phenomena. This lack of invariant correlation may play a role in some of the difficulties researchers face pinning down the exact substrates of valence or arousal or their link to other phenomena. For instance, there is considerable disagreement and inconsistency in findings about if and how the amygdala processes valence or arousal information (e.g., Anders, Eippert, Weiskopf, & Veit, 2008; Barrett, Bliss-Moreau, Duncan, Rauch, & Wright, 2007; Berntson, Bechara, Damasio, Tranel, & Cacioppo, 2007; Kensinger & Corkin, 2004; Lewis, Critchley, Rotshtein, & Dolan, 2007). Yet, if these dimensions covary differently in different people, researchers will have to change their experimental paradigms and sample more broadly to arrive at solid conclusions. Any studies that do not take idiographic variation into account will run the risk of being obsolete.

A similar cautionary implication holds for the burgeoning research that examines the impact of affect on other phenomena. Advance in such research domains not infrequently is impeded or complicated because there remain significant inconsistencies about whether valence or arousal is underlying affect's impact and in what form. For instance, despite a wealth of research, it remains unclear whether mainly valence (e.g., Kensinger & Schacter, 2008) or arousal (e.g., Mather, 2007) affect memory and even whether they facilitate or impede it (e.g., Cook, Marsh, Clark-Foos, & Meeks, 2007; Mather & Nesmith, 2008). Similar observations have been made regarding the influence of affect on vision (e.g., Lane, Chua, & Dolan, 1999), judgment and decision making (Blanchette & Richards, 2010), and so forth. Yet, if arousal covaries positively, negatively, or not at all with valence depending on the individual, it is clear that a true account of these effects should take idiographic variation into consideration.

As another example, a large area of research has shown that positive affect broadens attention (Fredrickson, 2001). Yet, recent research suggests that broadening may only hold for low arousal positive affect and that the inverse is true for high arousal positive affect (Gable & Harmon-Jones, 2008). The broadening (vs. narrowing) effect of positive affect on attention may therefore be moderated by the particular type of relation between positive valence and arousal that characterizes the individual.

In sum, if there is one important take-home message from our findings for research involving affect, it is to take seriously the existence of individual differences in the structural architecture of affect for developing studies and hypotheses about the origins, nature, and consequences of this basic feature of the mind.

Limitations

Our current investigation is limited to the relation between valence and arousal in subjective experience, as assessed through self-reports, and our results and implications should be restricted to that topic. Although self-report certainly has its weaknesses, there are currently no other means available that reliably measure how people subjectively feel (cf. Barrett, 2006). An important avenue for future research and review efforts would consist of examining whether our conclusions also hold for other (behavioral, psychophysiological, neurophysiological, or other) measures of emotion or where these may diverge and what such divergence would imply for the multicomponential nature of emotions.

Finally, aside from the limitations already noted for each data set, one clear limitation of our findings is that they come from data that were collected exclusively in a Western cultural context. Although we would expect similar amounts of variability in the relation between valence and arousal in people of other cultures, research on ideal affect (Tsai et al., 2006) and preliminary findings from our own research (Kuppens et al., 2012) give reason to suspect that the observed average or nomothetic relation between valence and arousal might take a different shape in cultures that are characterized by a preference for lower arousal positive feelings. Clearly, more research on the relation between valence and arousal in non-Western cultures is needed to explore such questions.

Conclusions

In conclusion, in this article we reported the results of a systematic and comprehensive analysis of the relation between two of

the most fundamental dimensions underlying subjective affective experience. We formulate the following three general conclusions. First, the modal, nomothetic relation between valence and arousal takes the form of a weak asymmetric V shape, with arousal increasing as a function of both positive and negative valence. Second, at the level of specific individuals, however, our findings showed large individual differences variability in the relation between valence and arousal. This is evidence of a large idiographic malleability of the structure of affect. The observed weak nomothetic relation and the large idiographic variability clearly indicate that it is not informative to postulate a strong universal valence-arousal relation and thus preclude equating arousal with affect intensity. Therefore, we strongly encourage psychology to withhold from making universal claims but to instead take individual differences seriously when examining the structure of affect and its role in other psychological phenomena.

References

- Allport, G. W. (1937). *Personality: A psychological interpretation*. New York, NY: Holt.
- Anders, S., Eippert, F., Weiskopf, N., & Veit, R. (2008). The human amygdala is sensitive to the valence of pictures and sounds irrespective of arousal: An fMRI study. *Social Cognitive and Affective Neuroscience*, 3, 233–243. doi:10.1093/scan/nsn017
- Averill, J. R. (1975). A semantic atlas of emotional concepts. *JSAS: Catalog of Selected Documents in Psychology*, 5 (MS. No. 1103). doi:10.1207/s15327965pli0603_3
- Barrett, L. F. (1997). The relation among momentary emotional experiences, personality descriptions, and retrospective ratings of emotion. *Personality and Social Psychology Bulletin*, 23, 1100–1110. doi:10.1177/01461672972310010
- Barrett, L. F. (1998). Discrete emotions or dimensions? The role of valence focus and arousal focus. *Cognition & Emotion*, 12, 579–599. doi:10.1080/026999398379574
- Barrett, L. F. (2004). Feelings or words? Understanding the content in self-report ratings of emotional experience. *Journal of Personality and Social Psychology*, 87, 266–281. doi:10.1037/0022-3514.87.2.266
- Barrett, L. F. (2006). Solving the emotion paradox: Categorization and the experience of emotion. *Personality and Social Psychology Review*, 10, 20–46. doi:10.1207/s15327957pspr1001_2
- Barrett, L. F. (2009). Variety is the spice of life: A psychological constructionist approach to understanding variability in emotion. *Cognition & Emotion*, 23, 1284–1306. doi:10.1080/02699930902985894
- Barrett, L. F., & Barrett, D. J. (2001). An introduction to computerized experience sampling in psychology. *Social Science Computer Review*, 19, 175–185. doi:10.1177/089443930101900204
- Barrett, L. F., & Bliss-Moreau, E. (2009). Affect as a psychological primitive. *Advances in Experimental Social Psychology*, 41, 167–218. doi:10.1016/S0065-2601(08)00404-8
- Barrett, L. F., Bliss-Moreau, E., Duncan, S. L., Rauch, S. L., & Wright, C. I. (2007). The amygdala and the experience of affect. *Social Cognitive and Affective Neuroscience*, 2, 73–83. doi:10.1093/scan/nsl042
- Barrett, L. F., & Fossium, T. (2001). Mental representations of affect knowledge. *Cognition & Emotion*, 15, 333–363. doi:10.1080/02699930125711
- Barrett, L. F., Mesquita, B., Ochsner, K. N., & Gross, J. J. (2007). The experience of emotion. *Annual Review of Psychology*, 58, 373–403. doi:10.1146/annurev.psych.58.110405.085709
- Barrett, L. F., & Russell, J. A. (1998). Independence and bipolarity in the structure of current affect. *Journal of Personality and Social Psychology*, 74, 967–984. doi:10.1037/0022-3514.74.4.967

- Barrett, L. F., & Russell, J. A. (1999). The structure of current affect: Controversies and emerging consensus. *Current Directions in Psychological Science*, 8, 10–14. doi:10.1111/1467.00003
- Baumeister, R. F., Bratslavsky, E., Finkenauer, C., & Vohs, K. D. (2001). Bad is stronger than good. *Review of General Psychology*, 5, 323–370. doi:10.1037/1089-2680.5.4.323
- Berlyne, D. E. (1960). *Conflict, arousal and curiosity*. New York, NY: McGraw-Hill.
- Bernat, E., Patrick, C. J., Benning, S. D., & Tellegen, A. (2006). Effects of picture content and intensity on affective physiological responses. *Psychophysiology*, 43, 93–103. doi:10.1111/j.1469-8986.2006.00380.x
- Berntson, G. G., Bechara, A., Damasio, H., Tranel, D., & Cacioppo, J. T. (2007). Amygdala contribution to selective dimensions of emotion. *Social Cognitive and Affective Neuroscience*, 2, 123–129. doi:10.1093/scan/nsm008
- Blanchette, I., & Richards, A. (2010). The influence of affect on higher level cognition: A review of research on interpretation, judgment, decision making and reasoning. *Cognition & Emotion*, 24, 561–595. doi:10.1080/02699930903132496
- Bolger, N., Davis, A., & Rafaeli, E. (2003). Diary methods: Capturing life as it is lived. *Annual Review of Psychology*, 54, 579–616. doi:10.1146/annurev.psych.54.101601.145030
- 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. doi:10.1037/1528-3542.1.3.276
- Bradley, M. M., Cuthbert, B. N., & Lang, P. J. (1990). Startle reflex modification: Emotion or attention? *Psychophysiology*, 27, 513–522. doi:10.1111/j.1469-8986.1990.tb01966.x
- Bradley, M. M., & Lang, P. J. (2007). The international affective picture system (IAPS) in the study of emotion and attention. In J. A. Coan & J. J. B. Allen (Eds.), *Handbook of emotion elicitation and assessment* (pp. 29–46). New York, NY: Oxford University Press.
- Bullock, M., & Russell, J. A. (1984). Preschool children's interpretation of facial expressions of emotion. *International Journal of Behavioral Development*, 7, 193–214. doi:10.1177/016502548400700207
- Bush, L. E., II. (1973). Individual differences multidimensional scaling of adjectives denoting feelings. *Journal of Personality and Social Psychology*, 25, 50–57. doi:10.1037/h0034274
- Cacioppo, J. T., & Berntson, G. G. (1994). Relation between attitudes and evaluative space: A critical review, with emphasis on the separability of positive and negative substrates. *Psychological Bulletin*, 115, 401–423. doi:10.1037/0033-2909.115.3.401
- Cacioppo, J. T., Berntson, G. G., Norris, C. J., & Gollan, J. K. (2012). The evaluative space model. In P. Van Lange, A. Kruglanski, & E. T. Higgins (Eds.), *Handbook of theories of social psychology* (Vol. 1, pp. 50–72). Thousand Oaks, CA: Sage Press.
- Cacioppo, J. T., & Gardner, W. L. (1999). Emotion. *Annual Review of Psychology*, 50, 191–214. doi:10.1146/annurev.psych.50.1.191.2
- Cacioppo, J. T., Gardner, W. L., & Berntson, G. G. (1997). Beyond bipolar conceptualizations and measures: The case of attitudes and evaluative space. *Personality and Social Psychology Review*, 1, 3–25. doi:10.1207/s15327957pspr0101_2
- Cacioppo, J. T., Gardner, W. L., & Berntson, G. G. (1999). The affect system has parallel and integrative processing components: Form follows function. *Journal of Personality and Social Psychology*, 76, 839–855. doi:10.1037/0022-3514.76.5.839
- Cahill, L., & McGaugh, J. L. (1998). Mechanisms of emotional arousal and lasting declarative memory. *Trends in Neurosciences*, 21, 294–299. doi:10.1016/S0166-2236(97)01214-9
- Carroll, J. M., Yik, M. S. M., Russell, J. A., & Barrett, L. F. (1999). On the psychometric principles of affect. *Review of General Psychology*, 3, 14–22. doi:10.1037/1089-2680.3.1.14
- Carver, C. S., & Scheier, M. F. (1990). Origins and functions of positive and negative affect: A control-process view. *Psychological Review*, 97, 19–35. doi:10.1037/0033-295X.97.1.19
- Carver, C. S., & White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: The BIS/BAS scales. *Journal of Personality and Social Psychology*, 67, 319–333. doi:10.1037/0022-3514.67.2.319
- Clore, G. L., & Ortony, A. (2008). Appraisal theories: How cognition shapes affect into emotion. In M. Lewis, J. M. Haviland-Jones, & L. F. Barrett (Eds.), *Handbook of emotions* (3rd ed., pp. 628–642). New York, NY: Guilford Press.
- Clore, G. L., Ortony, A., & Foss, M. A. (1987). The psychological foundations of the affective lexicon. *Journal of Personality and Social Psychology*, 53, 751–766. doi:10.1037/0022-3514.53.4.751
- Conner, T. S., Tennen, H., Fleeson, W., & Barrett, L. F. (2009). Experience sampling methods: A modern idiographic approach to personality. *Social and Personality Psychology Compass*, 3, 292–313. doi:10.1111/j.1751-9004.2009.00170.x
- Cook, G. I., Marsh, R. L., Clark-Foos, A., & Meeks, J. T. (2007). Learning is impaired by activated intentions. *Psychonomic Bulletin & Review*, 14, 101–106. doi:10.3758/BF03194035
- Cuthbert, B. N., Bradley, M. M., & Lang, P. J. (1996). Probing picture perception: Activation and emotion. *Psychophysiology*, 33, 103–111. doi:10.1111/j.1469-8986.1996.tb02114.x
- Davidson, R. J. (2000). Affective style, psychopathology, and resilience: Brain mechanisms and plasticity. *American Psychologist*, 55, 1196–1214. doi:10.1037/0003-066X.55.11.1196
- Davidson, R. J. (2004). Affective style: Causes and consequences. In J. T. Cacioppo & G. C. Berntson (Eds.), *Essays in social neuroscience* (pp. 77–91). Cambridge, MA: MIT Press.
- Davidson, R. J., Pizzagalli, D., Nitschke, J. B., & Putnam, K. (2002). Depression: Perspectives from affective neuroscience. *Annual Review of Psychology*, 53, 545–574. doi:10.1146/annurev.psych.53.100901.135148
- Depue, R. A., & Iacono, W. G. (1989). Neurobehavioral aspects of affective disorders. *Annual Review of Psychology*, 40, 457–492. doi:10.1146/annurev.ps.40.020189.002325
- Diener, E., & Diener, C. (1996). Most people are happy. *Psychological Science*, 7, 181–185. doi:10.1111/j.1467-9280.1996.tb00354.x
- Duffy, E. (1957). The psychological significance of the concept of arousal or activation. *Psychological Review*, 64, 265–275. doi:10.1037/h0048837
- Eagly, A. H., & Chaiken, S. (1998). Attitude structure and function. In D. T. Gilbert, S. T. Fiske, & G. Lindzey (Eds.), *The handbook of social psychology* (4th ed., pp. 269–322). New York, NY: McGraw-Hill.
- Elliot, A. J., & Thrash, T. M. (2002). Approach-avoidance motivation in personality: Approach and avoidance temperaments and goals. *Journal of Personality and Social Psychology*, 82, 804–818. doi:10.1037/0022-3514.82.5.804
- Faraway, J. J. (2006). *Extending the linear model with R: Generalized linear, mixed effects, and non-parametric regression models*. Boca Raton, FL: Chapman & Hall.
- Feldman, L. A. (1995a). Valence focus and arousal focus: Individual differences in the structure of affective experience. *Journal of Personality and Social Psychology*, 69, 153–166. doi:10.1037/0022-3514.69.1.153
- Feldman, L. A. (1995b). Variations in the circumplex structure of emotion. *Personality and Social Psychology Bulletin*, 21, 806–817. doi:10.1177/0146167295218003
- Fontaine, J. R. J., Scherer, K. R., Roesch, E. B., & Ellsworth, P. C. (2007). The world of emotions is not two-dimensional. *Psychological Science*, 18, 1050–1057. doi:10.1111/j.1467-9280.2007.02024.x

- Fowles, D. C. (1987). Application of a behavioral theory of motivation to the concepts of anxiety and impulsivity. *Journal of Research in Personality, 21*, 417–435. doi:10.1016/0092-6566(87)90030-4
- Fredrickson, B. L. (2001). The role of positive emotions in positive psychology: The broaden-and-build theory of positive emotions. *American Psychologist, 56*, 218–226. doi:10.1037/0003-066X.56.3.218
- Freud, S. (1957). The unconscious. In J. Strachey (Ed. & Trans.), *The standard edition of the complete psychological works of Sigmund Freud* (Vol. 14, pp. 166–204). London, England: Hogarth Press. (Original work published 1915)
- Frijda, N. H. (1986). *The emotions*. Cambridge, England: Cambridge University Press.
- Gable, P. A., & Harmon-Jones, E. (2008). Approach-motivated positive affect reduces breadth of attention. *Psychological Science, 19*, 476–482. doi:10.1111/j.1467-9280.2008.02112.x
- Gray, J. A. (1987). *The psychology of fear and stress*. Cambridge, England: Cambridge University Press.
- Gray, J. A. (1990). Brain systems that mediate both emotion and cognition. *Cognition & Emotion, 4*, 269–288. doi:10.1080/02699939008410799
- Greene, J. D., Sommerville, R. B., Nystrom, L. E., Darley, J. M., & Cohen, J. D. (2001, September 14). An fMRI investigation of emotional engagement in moral judgment. *Science, 293*, 2105–2108. doi:10.1126/science.1062872
- Greenwald, M. K., Cook, E. W., & Lang, P. J. (1989). Affective judgment and psychophysiological response: Dimensional covariation in the evaluation of pictorial stimuli. *Journal of Psychophysiology, 3*, 51–64.
- Haidt, J. (2001). The emotional dog and its rational tail: A social intuitionist approach to moral judgment. *Psychological Review, 108*, 814–834. doi:10.1037/0033-295X.108.4.814
- Hebb, D. O. (1955). Drives and the CNS (conceptual nervous system). *Psychological Review, 62*, 243–254. doi:10.1037/h0041823
- Higgins, E. T., Shah, J., & Friedman, R. (1997). Emotional responses to goal attainment: Strength of regulatory focus as moderator. *Journal of Personality and Social Psychology, 72*, 515–525. doi:10.1037/0022-3514.72.3.515
- Hull, C. (1943). *Principles of behavior*. New York, NY: Appleton-Century-Crofts.
- Ito, T. A., & Cacioppo, J. T. (2001). Affect and attitudes: A social neuroscience approach. In J. P. Forgas (Ed.), *Handbook of affect and social cognition* (pp. 50–74). Mahwah, NJ: Erlbaum.
- Ito, T. A., & Cacioppo, J. T. (2005). Variations on a human universal: Individual differences in positivity offset and negativity bias. *Cognition & Emotion, 19*, 1–26. doi:10.1080/02699930441000120
- 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. doi:10.1177/0146167298248006
- Jennings, P. D., McGinnis, D., Lovejoy, S., & Stirling, J. (2000). Valence and arousal ratings for Velten mood induction statements. *Motivation and Emotion, 24*, 285–297. doi:10.1023/A:1010745016868
- Kahneman, D., Krueger, A. B., Schkade, D. A., Schwarz, N., & Stone, A. A. (2004, December 3). A survey method for characterizing daily life experience: The day reconstruction method. *Science, 306*, 1776–1780. doi:10.1126/science.1103572
- Kensinger, E. A., & Corkin, S. (2004). Two routes to emotional memory: Distinct processes for valence and arousal. *Proceedings of the National Academy of Sciences, USA, 101*, 3310–3315. doi:10.1073/pnas.0306408101
- Kensinger, E. A., & Schacter, D. L. (2008). Memory and emotion. In M. Lewis, J. M. Haviland-Jones, & L. F. Barrett (Eds.), *Handbook of emotions* (pp. 601–617). New York, NY: Guilford Press.
- Konorski, J. (1967). *Integrative activity of the brain: An interdisciplinary approach*. Chicago, IL: University of Chicago Press.
- Kringelbach, M. L., & Rolls, E. T. (2004). The functional neuroanatomy of the human orbitofrontal cortex: Evidence from neuroimaging and neuropsychology. *Progress in Neurobiology, 72*, 341–372. doi:10.1016/j.pneurobio.2004.03.006
- Kuppens, P. (2008). Individual differences in the relation between pleasure and arousal. *Journal of Research in Personality, 42*, 1053–1059. doi:10.1016/j.jrp.2007.10.007
- Kuppens, P., Oravecz, Z., & Tuerlinckx, F. (2010). Feelings change: Accounting for individual differences in the temporal dynamics of affect. *Journal of Personality and Social Psychology, 99*, 1042–1060. doi:10.1037/a0020962
- Kuppens, P., Stouten, J., & Mesquita, B. (2009). Individual differences in emotion components and dynamics: Introduction to the special issue. *Cognition & Emotion, 23*, 1249–1258. doi:10.1080/02699930902985605
- Kuppens, P., Tuerlinckx, F., Koval, P., Yik, M. S. M., & Russell, J. A. (2012). *Individual differences in the valence–arousal relation as a function of personality and culture*. Manuscript in preparation.
- Kuppens, P., Van Mechelen, I., Nezlek, J. B., Dossche, D., & Timmermans, T. (2007). Individual differences in core affect variability and their relation to personality and psychological adjustment. *Emotion, 7*, 262–274. doi:10.1037/1528-3542.7.2.262
- Lane, R. D., Chua, P. M., & Dolan, R. J. (1999). Common effects of emotional valence, arousal and attention on neural activation during visual processing of pictures. *Neuropsychologia, 37*, 989–997. doi:10.1016/S0028-3932(99)00017-2
- Lang, P. J. (1994). The motivational organization of emotion: Affect–reflex connections. In S. H. M. van Goozen & N. E. Van de Poll (Eds.), *Emotions: Essays on emotion theory* (pp. 61–93). Hillsdale, NJ: Erlbaum.
- Lang, P. J. (1995). The emotion probe: Studies of motivation and emotion. *American Psychologist, 50*, 372–385. doi:10.1037/0003-066X.50.5.372
- Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1992). A motivational analysis of emotion: Reflex–cortex connections. *Psychological Science, 3*, 44–49. doi:10.1111/j.1467-9280.1992.tb00255.x
- Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1998). Emotion, motivation, and anxiety: Brain mechanism and psychophysiology. *Biological Psychiatry, 44*, 1248–1263. doi:10.1016/S0006-3223(98)00275-3
- Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). *International affective picture system (IAPS): Affective ratings of pictures and instruction manual* (Tech. Rep. A-8). Gainesville: University of Florida.
- Larsen, J. T., & McGraw, A. P. (2011). Further evidence for mixed emotions. *Journal of Personality and Social Psychology, 100*, 1095–1110. doi:10.1037/a0021846
- Larsen, J. T., To, Y. M., & Fireman, G. (2007). Children’s understanding and experience of mixed emotions. *Psychological Science, 18*, 186–191. doi:10.1111/j.1467-9280.2007.01870.x
- Larsen, R. J., & Diener, E. (1992). Promises and problems with the circumplex model of emotion. In M. S. Clark (Ed.), *Review of personality and social psychology* (Vol. 13, pp. 25–59). Newbury Park, CA: Sage.
- Larsen, R. J., & Ketelaar, T. (1991). Personality and susceptibility to positive and negative states. *Journal of Personality and Social Psychology, 61*, 132–140. doi:10.1037/0022-3514.61.1.132
- Lewis, P. A., Critchley, H. D., Rotshtein, P., & Dolan, R. J. (2007). Neural correlates of processing valence and arousal in affective words. *Cerebral Cortex, 17*, 742–748. doi:10.1093/cercor/bhk024
- Lindquist, K. A., Wager, T. D., Kober, H., Bliss-Moreau, E., & Barrett, L. F. (2012). The brain basis of emotion: A meta-analytic review. *Behavioral and Brain Sciences, 35*, 121–143. doi:10.1017/S0140525X11000446
- Mandler, G. (1984). *Mind and body: Psychology of emotion and stress*. New York, NY: Norton.
- Mather, M. (2007). Emotional arousal and memory binding: An object-based framework. *Perspectives on Psychological Science, 2*, 33–52. doi:10.1111/j.1745-6916.2007.00028.x

- Mather, M., & Nesmith, K. (2008). Arousal-enhanced location memory for pictures. *Journal of Memory and Language*, *58*, 449–464. doi:10.1016/j.jml.2007.01.004
- Mehrabian, A., & Russell, J. A. (1974). *An approach to environmental psychology*. Cambridge, MA: MIT Press.
- Miller, N., & Dollard, J. (1941). *Social learning and imitation*. New Haven, CT: Yale University Press.
- Molenaar, P. C. M., & Campbell, C. G. (2009). The new person-specific paradigm in psychology. *Current Directions in Psychological Science*, *18*, 112–117. doi:10.1111/j.1467-8721.2009.01619.x
- Myung, I. J., Forster, M. R., & Browne, M. W. (Eds.). (2000). Model selection [Special issue]. *Journal of Mathematical Psychology*, *44*(1). doi:10.1006/jmps.1999.1283
- Nezlek, J. B. (2005). Distinguishing affective and non-affective reactions to daily events. *Journal of Personality*, *73*, 1539–1568. doi:10.1111/j.1467-6494.2005.00358.x
- Osgood, C. E. (1969). On the whys and wherefores of E, P, and A. *Journal of Personality and Social Psychology*, *12*, 194–199. doi:10.1037/h0027715
- Osgood, C. E., May, W. H., & Mirron, M. S. (1975). *Cross-cultural universals of affective meanings*. Urbana: University of Illinois Press.
- Peeters, G., & Czapinski, J. (1990). Positive-negative asymmetry in evaluations: The distinction between affective and informational negativity effects. *European Review of Social Psychology*, *1*, 33–60. doi:10.1080/14792779108401856
- Pettinelli, M. (2008). *The psychology of emotions, feelings, and thoughts* (4th ed.). Retrieved from <http://cnx.org/content/col10447/1.11/>
- Phelps, E. A. (2006). Emotion and cognition: Insights from studies of the human amygdala. *Annual Review of Psychology*, *57*, 27–53. doi:10.1146/annurev.psych.56.091103.070234
- Phelps, E. A., Ling, S., & Carrasco, M. (2006). Emotion facilitates perception and potentiates the perceptual benefits of attention. *Psychological Science*, *17*, 292–299. doi:10.1111/j.1467-9280.2006.01701.x
- Pittam, J., & Scherer, K. R. (1993). Vocal expression and communication of emotion. In M. Lewis & J. M. Haviland (Eds.), *Handbook of emotions* (pp. 185–197). New York, NY: Guilford Press.
- Posner, J., Russell, J. A., Gerber, A., Gorman, D., Colibazzi, T., Yu, S., . . . Peterson, B. S. (2009). The neurophysiological basis of emotion: An fMRI study of the affective circumplex using emotion-denoting words. *Human Brain Mapping*, *30*, 883–895. doi:10.1002/hbm.20553
- Radloff, L. S. (1977). The CES-D scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement*, *1*, 385–401. doi:10.1177/014662167700100306
- Raftery, A. E. (1995). Bayesian model selection in social research. *Sociological Methodology*, *25*, 111–163. doi:10.2307/271063
- Ramsey, F. L., & Schafer, D. W. (2002). *The statistical sleuth: A course in methods in data analysis* (2nd ed.). Pacific Grove, CA: Duxbury.
- Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods* (2nd ed.). Newbury Park, CA: Sage.
- Reisenzein, R. (1994). Pleasure-arousal theory and the intensity of emotions. *Journal of Personality and Social Psychology*, *67*, 525–539. doi:10.1037/0022-3514.67.3.525
- Robinson, M. D., & Clore, G. L. (2002a). Belief and feeling: An accessibility model of emotional self-report. *Psychological Bulletin*, *128*, 934–960. doi:10.1037/0033-2909.128.6.934
- Robinson, M. D., & Clore, G. L. (2002b). Episodic and semantic knowledge in emotional self-report: Evidence for two judgment processes. *Journal of Personality and Social Psychology*, *83*, 198–215. doi:10.1037/0022-3514.83.1.198
- Robinson, W. S. (1950). Ecological correlations and the behavior of individuals. *American Sociological Review*, *15*, 351–357. doi:10.2307/2087176
- Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, *39*, 1161–1178. doi:10.1037/h0077714
- Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological Review*, *110*, 145–172. doi:10.1037/0033-295X.110.1.145
- Russell, J. A., & Carroll, J. M. (1999). On the bipolarity of positive and negative affect. *Psychological Bulletin*, *125*, 3–30. doi:10.1037/0033-2909.125.1.3
- Russell, J. A., Weiss, A., & Mendelsohn, G. A. (1989). Affect Grid: A single-item scale of pleasure and arousal. *Journal of Personality and Social Psychology*, *57*, 493–502. doi:10.1037/0022-3514.57.3.493
- Schachter, S., & Singer, J. E. (1962). Cognitive, social and physiological determinants of emotional state. *Psychological Review*, *69*, 379–399. doi:10.1037/h0046234
- Schlosberg, H. (1952). The description of facial expression in terms of two dimensions. *Journal of Experimental Psychology*, *44*, 229–237. doi:10.1037/h0055778
- Schlosberg, H. (1954). Three dimensions of emotion. *Psychological Review*, *61*, 81–88. doi:10.1037/h0054570
- Schwarz, G. (1978). Estimating the dimensions of a model. *Annals of Statistics*, *6*, 461–464. doi:10.1214/aos/1176344136
- Snijders, T. A. B., & Bosker, R. J. (2011). *Multilevel analysis: An introduction to basic and advanced multilevel modeling* (2nd ed.). London, England: Sage.
- Spencer, H. (1855). *Principles of psychology*. London, England: Longman, Brown, & Green. doi:10.1037/14065-000
- Spielberger, C. D., & Sydeman, S. J. (1994). State-Trait Anxiety Inventory and State-Trait Anger Expression Inventory. In M. E. Maruish (Ed.), *The use of psychological tests for treatment planning and outcome assessment* (pp. 292–321). Hillsdale, NJ: Erlbaum.
- Stone, A. A., Schwartz, J. E., Neale, J. M., Shiffman, S., Marco, C. A., Hickcox, M., . . . Cruise, L. J. (1998). A comparison of coping assessed by ecologic momentary assessment and retrospective recall. *Journal of Personality and Social Psychology*, *74*, 1670–1680. doi:10.1037/0022-3514.74.6.1670
- Sully, J. (1892). *Outlines of psychology* (Vol. 2). New York, NY: Appleton.
- Taylor, S. E. (1991). Asymmetrical effects of positive and negative events: The mobilization-minimization hypothesis. *Psychological Bulletin*, *110*, 67–85. doi:10.1037/0033-2909.110.1.67
- Tellegen, A. (1985). Structures of mood and personality and their relevance to assessing anxiety, with an emphasis on self-report. In A. H. Tuma & J. D. Maser (Eds.), *Anxiety and the anxiety disorders* (pp. 681–706). Hillsdale, NJ: Erlbaum.
- Thayer, R. E. (1967). Measurement of activation through self-report. *Psychological Reports*, *20*, 663–678. doi:10.2466/pr0.1967.20.2.663
- Thayer, R. E. (1989). *The biopsychology of mood and arousal*. New York, NY: Oxford University Press.
- Thayer, R. E. (1996). *The origin of everyday moods: Managing energy, tension, and stress*. New York, NY: Oxford University Press.
- Timmermans, T., Van Mechelen, I., & Nezlek, J. B. (2009). Individual differences in core affect reactivity. *Personality and Individual Differences*, *47*, 510–515. doi:10.1016/j.paid.2009.05.002
- Tsai, J. L., Knutson, B., & Fung, H. H. (2006). Cultural variation in affect valuation. *Journal of Personality and Social Psychology*, *90*, 288–307. doi:10.1037/0022-3514.90.2.288
- Vuilleumier, P. (2005). How brains beware: Neural mechanisms of emotional attention. *Trends in Cognitive Sciences*, *9*, 585–594. doi:10.1016/j.tics.2005.10.011
- Wagenmakers, E. J. (2007). A practical solution to the pervasive problems of p values. *Psychonomic Bulletin & Review*, *14*, 779–804. doi:10.3758/BF03194105
- Wager, T. D., Barrett, L. F., Bliss-Moreau, E., Lindquist, K. A., Duncan, S., Kober, H., . . . Mize, J. (2008). The neuroimaging of emotion. In M. Lewis, J. M. Haviland-Jones, & L. F. Barrett (Eds.), *Handbook of emotions* (3rd ed., pp. 249–271). New York, NY: Guilford Press.

- Waldorp, L., & Wagenmakers, E. J. (Eds.). (2006). Model selection: Theoretical developments and applications [Special issue]. *Journal of Mathematical Psychology, 50*(2).
- Watson, D., & Clark, L. A. (1984). Negative affectivity: The disposition to experience aversive emotional states. *Psychological Bulletin, 96*, 465–490. doi:10.1037/0033-2909.96.3.465
- Watson, D., & Clark, L. A. (1997). Measurement and mismeasurement of mood: Recurrent and emergent issues. *Journal of Personality Assessment, 68*, 267–296. doi:10.1207/s15327752jpa6802_4
- Watson, D., & Tellegen, A. (1985). Toward a consensual structure of mood. *Psychological Bulletin, 98*, 219–235. doi:10.1037/0033-2909.98.2.219
- Watson, D., Wiese, D., Vaidya, J., & Tellegen, A. (1999). The two general activation systems of affect: Structural findings, evolutionary considerations, and psychobiological evidence. *Journal of Personality and Social Psychology, 76*, 820–838. doi:10.1037/0022-3514.76.5.820
- Wood, S. (2006). *Generalized additive models: An introduction with R*. Boca Raton, FL: Chapman & Hall.
- Wundt, W. M. (1924). *An introduction to psychology* (R. Pintner, Trans.). London, England: Allen & Unwin. (Original work published 1912)
- Wundt, W. M. (1998). *Outlines of psychology* (C. H. Judd, Trans.). Bristol, England: Thoemmes Press. (Original work published 1897)
- Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology, 18*, 459–482. doi:10.1002/cne.920180503
- Yik, M. S. M., Russell, J. A., & Barrett, L. F. (1999). Structure of self-reported current affect: Integration and beyond. *Journal of Personality and Social Psychology, 77*, 600–619. doi:10.1037/0022-3514.77.3.600
- Yik, M., Russell, J. A., & Steiger, J. H. (2011). A 12-point circumplex model of core affect. *Emotion, 11*, 705–731. doi:10.1037/a0023980
- Zelenski, J. M., & Larsen, R. J. (2000). The distribution of emotions in everyday life: A state and trait perspective from experience sampling data. *Journal of Research in Personality, 34*, 178–197. doi:10.1006/jrpe.1999.2275

Appendix

Multilevel Regression Models for Nested or Crossed Data

In Studies 2a–e, the data conform to a nested (between-person; Studies 2a, 2d, 2e) or fully crossed data structure (within-person; Studies 2b, 2c). Nested and fully crossed data structures require the use of multilevel or hierarchical models (or mixed models; e.g., Snijders & Bosker, 2011). The advantage is that person-specific effects (for nested data) or both person- and stimulus-specific effects (for fully crossed data) can be modeled with multilevel or hierarchical models, yielding information on what the relation between valence and arousal looks like in the population (i.e., averaged across persons; the nomothetic level) as well as for each person individually (the idiographic level). Below we present an overview of the used multilevel or hierarchical models. In essence, they are analogous to the traditional regression models outlined in the main part of this article, with the additional complexity that they involve person-specific or person- and stimulus-specific random effects. Note that we discuss the models for the most complicated case (involving both person- and stimulus-specific random effects). In the case of measurements (or situations or stimuli) nested within persons, the models are the same but without the stimulus-specific random effects.

Model 1: Independence

A first model implies independence between valence and arousal:

$$Arousal_{ij} = \beta_0 + \gamma_{0i} + \delta_{0j} + \varepsilon_{ij}, \quad (\text{Model 1})$$

where i denotes the i th participant and j the j th stimulus. This model includes a person-specific deviation γ_{0i} from the overall intercept. This is consistent with the notion that the average experienced arousal level may vary across individuals (e.g., Kuppens et al., 2007). Similarly, there is a stimulus-specific deviation δ_{0j} from the overall intercept. It is assumed that both γ_{0i} and δ_{0j} are drawn from their own population distributions (presumed to be normal with zero mean and an unknown variance; see the final paragraph of this Appendix). Note that Model 1 corresponds to a classic unconditional mixed model (e.g., Snijders & Bosker, 2011) but with the additional complexity that there are two random intercept effects (one from the person and one from the stimulus; such a model is called a crossed random effects model).

Model 2: Linear Relation

A second model implies a linear relation between valence and arousal:

$$Arousal_{ij} = (\beta_0 + \gamma_{0i} + \delta_{0j}) + (\beta_1 + \gamma_{1i})Valence_{ij} + \varepsilon_{ij}. \quad (\text{Model 2})$$

(Appendix continues)

The model includes next to a person-specific and stimulus-specific deviation from the general intercept (γ_{0i} and δ_{0j} , respectively) a person-specific deviation γ_{1i} from the general slope β_1 , consistent with the notion that the linear relation between valence and arousal can vary across individuals (Kuppens, 2008). Note that Model 2 corresponds to a classic mixed or multilevel model with random intercept and slope (Snijders & Bosker, 2011; but with an additional stimulus-specific intercept). The reason that we do not include a stimulus-specific slope is that in several cases an abundance of stimulus random effects leads to a hard to estimate model. Yet, for the models where additional random stimulus effects could be included without technical problems, the conclusions remained the same as the ones presented in the article (paradoxically, for some cases, the additional complexity resulted in a model that could be estimated more easily; see footnote 4). For the population of persons and stimuli, the interpretation of Model 2 is as follows: For an average individual who responds to an average stimulus, one expects on the basis of Model 2 that arousal is a linear function of valence with intercept β_0 and slope β_1 .

Model 3: Symmetric V-Shaped Relation

A third model allows for a symmetric V-shaped relation, again allowing for person-specific intercept and slope values (and a stimulus-specific intercept):

$$Arousal_{ij} = (\beta_0 + \gamma_{0i} + \delta_{0j}) + (\beta_1 + \gamma_{1i})|Valence_{ij}| + \varepsilon_{ij}. \quad (\text{Model 3})$$

Similar to the basic model, a positive value of β_1 implies a symmetric V-shaped relation between valence and arousal, for the average individual in response to the average stimulus.

Models 4–6: Asymmetric Relation Between Valence and Arousal

Fourth, three different models evaluate the different possible instantiations of an asymmetric V-shaped relation between valence and arousal:

$$Arousal_{ij} = (\beta_0 + \gamma_{0i} + \delta_{0j}) + (\beta_1 + \gamma_{1i})|Valence_{ij}| + (\beta_2 + \gamma_{2i})I_{ij} + \varepsilon_{ij}. \quad (\text{Model 4})$$

$$Arousal_{ij} = (\beta_0 + \gamma_{0i} + \delta_{0j}) + (\beta_1 + \gamma_{1i})|Valence_{ij}| + (\beta_3 + \gamma_{3i})|Valence_{ij}|I_{ij} + \varepsilon_{ij}. \quad (\text{Model 5})$$

$$Arousal_{ij} = (\beta_0 + \gamma_{0i} + \delta_{0j}) + (\beta_1 + \gamma_{1i})|Valence_{ij}| + (\beta_2 + \gamma_{2i})I_{ij} + (\beta_3 + \gamma_{3i})|Valence_{ij}|I_{ij} + \varepsilon_{ij}. \quad (\text{Model 6})$$

In Models 3–6, I_{ij} again denotes a dummy variable that indicates whether $Valence_{ij}$ is positive ($I_{ij} = 1$) or negative ($I_{ij} = 0$). These models allow for person-specific intercept and slope values, separately for positive and negative valence, consistent with the possibility of individual differences in positivity offset and negativity bias. The interpretation of the fixed regression parameters (i.e., β_0 , β_1 , β_2 , and β_3) is analogous to that in the basic models but with the caveat that it holds for an average individual responding to an average stimulus (or for a randomly sampled individual and a randomly sampled stimulus).

Model 7: Nonparametric Relation

Finally, we consider a nonparametric regression curve:

$$Arousal_{ij} = (\beta_0 + \gamma_{0i} + \delta_{0j}) + f(Valence_{ij}) + \gamma_{1i}|Valence_{ij}| + (\beta_2 + \gamma_{2i})I_{ij} + \gamma_{3i}|Valence_{ij}|I_{ij} + \varepsilon_{ij}, \quad (\text{Model 7})$$

where f is again an arbitrary smooth function. (Because of presence of the nonparametric and parametric regression effects in an additive way together with random effects, this model is also called a linear additive mixed model; see Faraway, 2006; Wood, 2006.) In Model 7, the expected relation between arousal and valence for an average person and stimulus is such as in the basic Model 7:

$$E(Arousal_{ij}) = \beta_0 + f(Valence_{ij}) + \beta_2 I_{ij}.$$

To account for possible interindividual and interstimulus differences, we add the person and stimulus random effects (note that the random effects are added to the model in a very restricted manner: It is hard to allow for random effect such that the nonparametric function f is different from person to person, and therefore we have a random effects structure equal to the previous models). Such a model extension also enhances comparability across models, as only the mean structure—the relation between expected arousal and valence—is changed and the structure of between-person and between-stimulus differences remains constant. All random effects are assumed to be normally distributed with a mean of 0 and a to-be-estimated standard deviation, to be independent from each other and from all other random components of the model: $\gamma_{0i} \sim N(0, \sigma_{\gamma_0}^2)$ and $\delta_{0j} \sim N(0, \sigma_{\delta_0}^2)$. For the residual ε_{ij} , we make a similar assumption as in Study 1: $\varepsilon_{ij} \sim N(0, \sigma_{\varepsilon}^2)$.

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