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Interoceptive Sensitivity and Self-Reports of Emotional Experience

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Abstract

People differ in the extent to which they emphasize feelings of activation or deactivation in their verbal reports of experienced emotion, termed *arousal focus* (AF). Two multimethod studies indicate that AF is linked to heightened interoceptive sensitivity (as measured by performance on a heartbeat detection task). People who were more sensitive to their heartbeats emphasized feelings of activation and deactivation when reporting their experiences of emotion over time more than did those who were less sensitive. This relationship was not accounted for by several other variables, including simple language effects. Implications for the role of interoception in experienced emotion and the validity of self-reported emotion are discussed.

Arousal is a basic property of all affective judgments (for a recent review, see Russell & Feldman Barrett, 1999) and is ubiquitous in models of emotion (e.g., Berlyne, 1960; Cannon, 1927; Duffy, 1957; Frijda, 1986; Hebb, 1955; Lindsley, 1951; Mandler, 1984; Pribram & McGuiness, 1975; Schachter & Singer, 1962; Thayer, 1989; Zillmann, 1983). Several influential models speculate that explicit, direct access to bodily cues is necessary for the experience of emotion. The purpose of this article is to examine the link between interoceptive access and reports of experienced emotion—specifically, the extent to which people emphasize arousal when reporting their experiences over time, or *arousal focus* (AF; Feldman, 1995;). In doing so, we shed light on the role of interoception in experienced emotion, describe a novel paradigm for the treatment of self-report data, and provide incremental validity for self-reports of experienced emotion.

Arousal as a Property of Affective Judgments

Activation is a ubiquitous property of affective judgments. Usually, when individuals report on their own experiences of emotion, part of what they report is feeling energized and attentive on the one hand versus relaxed and sleepy on the other. Factor analytic studies of self-reported mood repeatedly have found activation or arousal as a descriptive component of such self-reports (Feldman, 1995, Feldman Barrett & Russell, 1998; Mehrabian & Russell, 1974;

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Reisenzein, 1994; Russell, 1978, 1980; Thayer, 1967, 1989, 1996; for a review, see Russell & Feldman Barrett, 1999). Arousal also emerges as a crucial property when judging the emotion of others, such as when judging the emotion in the facial expressions of others (e.g., Bullock & Russell, 1986; Russell & Bullock, 1985, 1986; Schlosberg, 1954; for a recent review, see Russell, Bachorowski, & Fernandez-Dols, 2003). When individuals with amygdala damage make such judgments, part of their deficit involves this perception of activation (Adolphs, Russell, & Tranel, 1999).

Activation is even a component of the language that is used to communicate emotion. Degree of arousal, in part, characterizes the adjectives that make up self-report scales of emotional experience (Feldman Barrett & Fossum, 2001; Kring, Feldman Barrett, & Gard, 2003; Russell, 1980). For example, *nervous* is an adjective that refers to an unpleasant, highly activated state, whereas *sad* is an adjective that refers to an unpleasant, deactivated state. Consistent with the semantic differential work by Osgood, Suci, and Tannenbaum (1957), arousal has been identified as a property of the emotion words found in many cultures (for a review, see Russell, 1991).

Arousal and the Experience of Emotion

In psychological science, it is often assumed that arousal is essential to the experience of emotion: People perceive emotional feelings in their bodies. William James (1884, 1890/1950/1894/1994) proposed what has come to be one of the most compelling ideas in the psychology of emotion: The experience of emotion results from the perception of specific and unique patterns of somatovisceral arousal (see also Damasio, 1993, 1999).[1] Almost a century later, Schachter and Singer (1962) argued that the experience of emotion was due to the direct and explicit experience of a generalized autonomic arousal. Decades of research have suggested, however, that neither of these views is correct in the strong sense.

There is little support for the idea that different categories of emotion are associated with signature visceral sensations (for a meta-analytic review, see Cacioppo, Berntson, Larsen, Poehlmann, & Ito, 2000). The architectures of the central and peripheral nervous systems produce undifferentiated or ambiguous patterns of autonomic and visceral activity (Cacioppo, Berntson, & Klein, 1992; Mandler, 1975; Reed, Harver, & Katkin, 1990) that are not sufficient to produce specific feeling states, suggesting that feelings of anger, fear, and so on do not derive their phenomenological character from specific patterns of somatovisceral activity. Moreover, different measures of autonomic, somatic, or cortical arousal tend not to correlate highly with one another, such that "arousal" is not a unitary phenomenon (Blascovich, 1990, 1992). Obviously, patterns of autonomic and somatic responses relate in some way to feeling active and alert, slowed down and sleepy, or angry or sad, but there is no simple, one-to-one correspondence.

In addition, people do not have automatic, immediate, and explicit access to autonomic and somatic activity as suggested by James (1894/1994) and Schachter and Singer (1962). Internal cues produce feelings of arousal (Blascovich, 1990, 1992) or emotion (Manstead & Wagner,

[1]Although William James is credited with the idea of emotion-specific somatovisceral patterning, James did not appear to hypothesize invariant autonomic nervous system patterns for each category of emotion. With the term *emotion,* James was referring to particular instances of feeling, not to discrete emotion categories. When James suggested that "the emotion ought to be different when the symptoms are different, if the latter *make* the emotion" (James, 1894/1994, p. 206), he was not addressing the differences between categories as much as he was saying that different instances of an emotion, even if within the same category, will feel different if the somatovisceral activations are different. Although James's writings are laced with detailed descriptions of the bodily symptoms that characterize anger, grief, fear, and the like, he explicitly stated in several places that variability within each emotion category, both across individuals and across instances within the individual, is the norm. He explicitly rejected the idea of a single set of bodily symptoms to describe instances of a given emotion category across individuals: "Surely there is no definite affection of 'anger' in an 'entitative' sense" (James, 1894/1994, p. 206)

1981) only when those cues are attended to and perceived. Such perception can be driven by a number of factors, however, and does not necessarily need to be accurate. Misattribution studies make it clear that it is very easy for people to accept false feedback about their internal cues (e.g., Valins, 1966), and such false feedback can in part influence their experience of emotion (e.g., Palomba & Stegagno, 1995).

Although information from the body does not automatically translate into feelings, and people are susceptible to misperception, people can, at times, detect specific information in their bodies, and this sensitivity may be in some way related to the experience of emotion. There is considerable intra- and interindividual variation in the ability to accurately perceive internal bodily states. People are more sensitive to their somatovisceral states in some situations (e.g., during exercise) than in others (e.g., during rest). More importantly for our concerns, some people are more accurate in their ability to detect explicit cues to autonomic arousal, like heartbeats (Blascovich et al., 1992; Katkin, 1985; Katkin, Blascovich, & Goldband, 1981; Pennebaker, 1982). It has been argued that access to such somatovisceral information is the substrate for the subjective experience of feelings in humans (for a review, see Craig, 2002). Afferent information from the body that is needed for homeostasis (like information about temperature, pain, autonomic status, etc.) is re-represented in the anterior insular cortex and other parts of a larger system (including anterior cingulate cortex, limbic motor areas, and orbital frontal cortex) thought to be responsible for the subjective experience of feelings in humans. In particular, right anterior insular cortex seems to mediate attention to and explicit awareness of internal bodily cues. Individuals who are more interoceptively sensitive to their heartbeats show greater insular activation than those who are less sensitive (Critchley, Wiens, Rotshtien, Ohman, & Dolan, 2004). If such explicit representation of bodily cues is one basis for subjective feeling states, then individuals who are more sensitive to their somatovisceral cues will differ in the feelings that they experience and report compared with those who are less sensitive. Even if people perceive only ambiguous or degraded forms of information from their bodies, that information may be useful and usable in people who have sufficient experience with it over time.

Interoception and the Experience of Emotion

In psychology, *interoception* is usually defined as visceroperception or detecting signals arising from the inner organs.[2] General interoceptive sensitivity is typically indexed using performance on a heartbeat detection task, where participants judge whether an external stimulus (a tone) is coincident (or not) with their heartbeats. Such tasks are commonly used because heartbeats are distinct autonomic events that are relatively easy to measure (Whitehead & Drescher, 1980). The ability to detect heartbeats can be correlated with the ability to detect changes in other autonomically innervated organs (Harver, Katkin, & Bloch, 1993;Whitehead & Drescher, 1980), although this is not always the case (Pennebaker, Gonder-Frederick, Cox, & Hoover, 1985). In the typical heartbeat detection task, participants are presented with blocks of 10 tones that are triggered either 200 ms or 500 ms from the R-spike of the QRS complex of the electrocardiogram for each of 10 heartbeats. Participants then decide whether or not the tones were coincident or not with their heartbeats. The only information that distinguishes coincident from noncoincident blocks is the temporal relationship between the tones and the heartbeats. Only participants who detect their heartbeats have the necessary information to distinguish between coincident blocks of trials (with the 200-ms delay) from noncoincident blocks (with the 500-ms delay; Schneider, Ring, & Katkin, 1998;Wiens & Palmer, 2001).

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[2]The term *interoception* is actually much broader than its modal use in social psychology implies. In addition to covering the domain of viscero-perception, it also covers proprioception (or signals from skin, joints, tendons, and muscles). Interoceptive research not only involves studying reactions to sensory information (like sensitivity to visceral cues), but it also includes transduction and encoding (how sensory information like pressure is converted into afferent signals), transmission (how afferent signals are conveyed to the central nervous system), and central nervous system representations (how afferent signals are represented in the brain).

Studies examining the link between interoception and the experience of emotion have generally examined whether better heartbeat detection translates into greater intensity of self-reported emotional experience, with inconsistent results (Critchley et al., 2004; Eichler, Katkin, Blascovich, & Kelsey, 1987; Ferguson & Katkin, 1996; Hantas, Katkin, & Blascovich, 1982; Wiens, Mezzacappa, & Katkin, 2000). In one study, good heartbeat detectors showed greater frequency, intensity, and duration of affect-appropriate facial movements when viewing evocative slides as compared with poor detectors, but the groups did not differ in their verbal reports of experience (Ferguson & Katkin, 1996). In another study, however, good heartbeat detectors reported greater intensity of self-reported positive and negative emotional experiences when viewing film clips as compared with poor detectors (Wiens et al., 2000). In a third study, good heartbeat detectors reported more general levels of intense negative affect as well as more anxiety and depressive symptomatology but not more intense positive affect (Critchley et al., 2004). In most studies, good and poor detectors were not distinguished on any other psychophysiological index (heart rate or skin conductance responses while watching emotionally evocative films), indicating that interoceptive skill was not related to degree of sympathetic activation in those studies (e.g., Ferguson & Katkin, 1996; Hantas et al., 1982; Schandry, 1981; Wiens et al., 2000).

The inconsistent link between interoception and reports of experienced emotion may be due to two factors. The first has to do with the conceptualization and measurement of heartbeat detection performance. Most studies that examine the link between heartbeat detection and the experience of emotion categorize participants into good versus poor heartbeat detectors (defined by whether or not a person performs better than chance on the heartbeat detection task). Not only does dichotomization result in a loss of power (Wiens & Palmer, 2001), but it does not distinguish between correct responses that occur because someone is sensitive to the heartbeats versus those that result from a response tendency to answer one way or the other. This distinction is captured nicely by the signal detection theory concepts of sensitivity and response bias or style (Green & Swets, 1966/1974; Harvey, 1992; McNicol, 1972), which have been fruitfully used in some heartbeat detection studies (e.g., Harver et al., 1993; Jones & Hollandsworth, 1981; Montgomery & Jones, 1984; Violani, Lombardo, DeGennaro, & Devoto, 1996). *Sensitivity* is defined as an observer's ability to accurately detect the presence or absence of target information, here the presence (or absence) of heartbeats, and specifically whether they are coincident (or not) with tones delivered during a heartbeat detection task. Sensitivity varies because of differences in perceptual abilities, among other things. In contrast to sensitivity, *response bias* or *style* is defined as the observer's tendency to merely favor one response ("yes, my heartbeats match the tones") over another ("no, heartbeats do not match the tone"), independent of the base rate for the stimulus. Response style is related to the perceivers' goals (Egan, 1975; Green & Swets, 1966/1974; Healy & Kubovy, 1978) or the perceived costs of making one type of error (e.g., missing a coincident trial) over another (e.g., incorrectly saying "yes" when heartbeats and trials are not coincident; Quigley & Feldman Barrett, 1999). Deriving separate assessments of interoceptive sensitivity and response bias during heartbeat detection may yield a more definitive picture regarding how interoception and emotion experience are related.

The inconsistent link between interoception and reports of experienced emotion may also have resulted from conceptualization and measurement of experienced emotion. Most studies have examined the link between heartbeat detection and explicit ratings of the intensity of emotion experience. For example, respondents rate their experience on a Likert-type scale using a set of adjectives, and those ratings are summed to derive an index of experienced emotion. It is possible, however, that interoceptive sensitivity is better conceptualized as relating to the perception of arousal as a property of experience rather than to the intensity of experience per se. The feelings of activation and deactivation arising from interoceptive cues may be too impoverished to reliably result in direct, consciously available explicit ratings of emotion.

Instead, these background interoceptive cues may manifest in a focus on activation-based aspects of emotional states in a more indirect or nonexplicit way. Presumably, individuals who are more interoceptively sensitive would be more likely to perceive feelings of arousal and would communicate those feelings in self-report process over time, even if such differences are not apparent in the intensity of explicit reports.

In fact, there are individual differences in the extent to which people emphasize the arousal property of their experience and implicitly communicate that property during the self-report process. This individual difference is called AF (see definition above). When rating how well emotion-related adjectives characterize their immediate feeling state, some people emphasize the arousal-related meaning of the words to a large extent, whereas others do so to a lesser extent, perhaps even ignoring that meaning altogether. The purpose of this article is to examine the link between interoception and AF.

Arousal Focus

AF can be thought of as the amount of information about activation and deactivation contained in verbal reports of experienced emotion made over time (Feldman, 1995;). Self-reports characterized by high AF contain a lot of information about activation and deactivation. For example, when rating their immediate feeling state, people high in AF clearly distinguish ratings of nervousness (a high activation state) from ratings of sadness (a low activation state) across every instance in time, such that their self-reports contain a lot of information about feelings of high and low arousal. In contrast, self-reports characterized by low AF contain less of this information. For example, people low in AF rate fear and sadness in a highly similar fashion across every instance in time, communicating what the two have in common—displeasure. AF is a continuous individual difference, ranging from those individuals who emphasize felt activation and deactivation in their self-reports as much as they emphasize other properties (like pleasure–displeasure), to those who basically ignore felt activation and deactivation altogether when generating self-reports of their emotional experience.

Two observations about AF are worth noting. First, AF reflects the patterns of self-report ratings (e.g., the covariance in ratings of “anger” and “sadness”) across multiple occasions and settings and represents the extent to which this pattern is characterized by activation and “deactivation.” In this way, computations of AF treat self-reports as instances of verbal behaviors. The pattern of reporting behaviors is of more interest than the level or magnitude of any single rating. This stands in contrast to the majority of research that uses the explicit content in self-reports of experienced emotion. Respondents rate adjectives like *angry* or *sad* as descriptive (to some extent) of their internal state, and these ratings, or their average over time, are the variables of interest.

Second, AF is an implicit measure by virtue of the way that it is computed. People are not asked, “How much do you attend to feelings of activation and deactivation?” Rather, AF is equivalent to the proportion of variance in each person’s sample of self-report ratings that is accounted for by the arousal-based meanings of the words. AF is estimated by computing the structure of self-report behaviors (the similarity in ratings of different emotional experiences across time), estimating the cognitive structure of emotion language (specifically, the arousal-based meaning of the emotion words used in the rating process), and empirically comparing the two to derive an index of AF for each individual. As such, AF does not refer to whether participants are primarily reporting high or low arousal states per se; that is, AF is not synonymous with the tendency to report distress or enthusiasm. Instead, AF reflects the extent to which participants emphasize the arousal-based meaning of the words when rating those words as descriptive of their emotional experience.

We hypothesized that individual differences in the ability to accurately perceive internal bodily cues may provide one avenue for subjective feelings of activation and deactivation that in turn may lead to AF. Differential sensitivity will lead to differential experience, which in turn will lead to differential endorsement of emotion adjectives during the self-report process. We are not suggesting that items like *aroused* will be endorsed more than items like *calm*. Rather, we are suggesting that when people are sensitive to their interoceptive state, emotion adjectives will be rated in such a way as to take into account their high or low arousal-based meaning. People will use emotion adjectives to emphasize activation and deactivation during the reporting process to the extent that they actually experience feelings of activation and deactivation. If this hypothesis is correct, then we will observe a positive relation between accurate perception of heartbeats (i.e., sensitivity) and AF.

Overview of the Present Studies

In two multimethod studies, we used experience-sampling methods to assess participants' immediate, momentary reports of emotional experience over an extended sampling period. Study 1 used a paper-and-pencil experience-sampling procedure to collect momentary reports of emotional experience across a 60-day period. Study 2 used a computerized experience-sampling procedure across a 28-day period. At each measurement instance, participants were given a set of emotion adjectives (*happy*, *anxious*, *angry*, etc.) and rated on a Likert-type scale the extent to which each adjective described their immediate emotional feeling. We then examined the degree to which these verbal reports contained information about felt activation and deactivation. To do this, we compared the structure of emotion language to each participant's self-report structure to compute an index of AF for each individual. In Study 1 we used a previously published cognitive structure of emotion in the derivation of AF. In Study 2, participants completed similarity ratings of emotion words, which allowed us to estimate their own cognitive structure of emotion language. In both studies, participants completed a heartbeat detection task to assess their sensitivity to interoceptive cues. Judgments were subjected to a signal detection theory analysis to assess sensitivity and response style.

Our primary hypothesis was that heartbeat sensitivity would be positively associated with AF. We predicted that individuals who were more sensitive to their heartbeats would be more highly arousal focused in their self-reports of experienced emotion compared with those who were less sensitive to their heartbeats. If this hypothesis is correct, then it will provide the first validity evidence for an empirical link between interoceptive sensitivity and self-reports of the activation-based aspects of experienced emotion. We expected a weak to moderate relationship given that participants completed the heartbeat detection task under the most difficult conditions (at rest). Because Studies 1 and 2 were highly similar, the effects are meta-analytically combined at the end of the second *Results* section.

We had no specific prediction for the relationship between response style and AF. In these studies, response style was determined by where participants placed the criterion for saying "yes, my heartbeats match the tones." If a participant's tendency to identify the stimulus (answering "yes") matched the base rate of the stimulus (the proportion of trials where tones were synchronous with heartbeats), then the participant would have a zero response bias, or a style to favor neither a "yes" nor "no" response. If a participant was trying to maximize the number of hits (correct identification of synchronous trials) or minimize the number of misses (saying "no" to a synchronous trial), then he or she would use a lax decision criterion for saying that heartbeats matched the tones. This would lead to a situation where the participant answered "yes" more often than is warranted by the objective conditions of the task. Conversely, if the participant was trying to maximize the number of correct rejections (saying "no" to an asynchronous trial) or minimize the number of false alarms (saying "yes" to such trials), he or she would use a more cautious or strict decision criterion. This would lead the participant to answer "no" more often than is warranted by the objective conditions of the task. Because we did not have a strong reason to expect that AF would be linked to how participants set their decision criterion, we made no specific predictions about the relation between AF and response style on the heartbeat detection task.

For the purposes of discriminant validity, we sought to rule out the possibility that interoceptive sensitivity was related to AF merely because it had a broad influence on many indices of emotional experience. A lack of relation between heartbeat sensitivity and these control variables would demonstrate its specific relation to AF. First, we examined the relationship between interoceptive sensitivity and another measure of implicit information contained in self-reports of emotional experience, termed *valence focus* (VF). VF is the tendency to use emotion adjectives to communicate feelings of pleasure and displeasure (Feldman, 1995;). VF and AF are moderately negatively correlated in most samples, so it is important to demonstrate that the two have distinct sets of correlates. We had no reason to expect any relation between interoceptive sensitivity and VF.

Second, we examined the relationship of AF and interoception to a host of explicit emotional experience–related measures. Previous research has shown that interoception is related to the intensity of reported emotional experiences (Wiens et al., 2000), distress in particular (Critchley et al., 2004; Hantas et al., 1982), and negatively related to self-reported levels of affect intensity (Blascovich et al., 1992). As a result, we examined the relationship between heartbeat detection performance and several distress and intensity variables, including scores on neuroticism (individual differences in the tendency to experience negative, high-activation emotions) and extraversion (individual differences in the tendency to experience positive emotions). We also examined its relation to average experience-sampling ratings for negative activation (NA) and positive activation (PA; Watson, Clark, & Tellegen, 1988), and an experience-sampling index of affect intensity (Larsen & Diener, 1987).

Finally, in Study 2, we examined the relationship between interoceptive sensitivity, AF, and *semantic focus*, that is, the attention that people give to the activation-based properties of language, or the arousal-based meanings of the words themselves separate from how the words are being used to communicate feelings. Recent findings () have suggested that AF (the extent to which participants emphasize the arousal-based property of emotion words when rating those words as descriptive of their emotional experience) is related to semantic focus (the extent to which participants attend to the arousal-based properties of emotion words per se, regardless of what the words are used for). In Study 2, we sought to rule out the possibility that interoceptive sensitivity influenced individuals to attend more to the arousal-based meaning of the words themselves, separate from how those words were used to communicate their momentary feelings.

Study 1

Method

Participants—Participants were 55 undergraduate psychology majors (9 men) at Pennsylvania State University.[3] All participants received extra credit for their participation and had an opportunity to partake in a cash lottery.[4]

[3]This sample size reflects the participants available for analysis. One hundred thirty-one potential participants were recruited for Study 1. Sixty-four completed the experience-sampling procedure. Of those, 6 participants (9.4%) were dropped because they reported using memory to complete their momentary emotion ratings more than 30% of the time. Three participants did not complete the heartbeat detection task because of illness (colds) or medical conditions (arrhythmia or asthma), leaving 55 participants (9 men) for analysis. Participants who completed the study did not differ from those who did not in their interoceptive sensitivity and bias estimates.

Procedure—In a first laboratory session (before experience sampling began), participants completed a series of paper-and-pencil questionnaires that included the NEO Five-Factor Inventory (Costa & McCrae, 1992) to measure neuroticism and extraversion. Following completion of the questionnaires, participants completed the heartbeat detection task, after which they immediately began the experience-sampling portion of the study.

Heartbeat detection task.: Our procedure delivered tones only when a participant's heart rate was below 85 beats per minute, thus ensuring that large individual differences in resting heart rate could not influence performance on the heartbeat detection task (although evidence suggests that there is no relationship between resting heart rate and interoceptive ability over a range of heart rates; Ferguson & Katkin, 1996; Hantas et al., 1982; Schandry, 1981; Wiens et al., 2000). If participants had baseline heart rates that regularly exceeded 85 beats per minute, they were excluded from the heartbeat detection task. If heartbeats increased above 85 beats per minute during a trial, the tone for those heartbeats was not presented. This occurred on fewer than 1% of trials.

The session began with a 5-min baseline measure of heart rate followed by administration of a modified Whitehead heartbeat detection procedure (Whitehead, Drescher, Heiman, & Blackwell, 1977). Each trial consisted of 10 tones that were delayed either 200 ms or 500 ms after the R-spike of the QRS complex of the electrocardiogram for 10 consecutive heartbeats. The task consisted of 100 trials, 50 of each type; 200-ms and 500-ms trials were delivered randomly to each participant. After each block of 10 tones, participants were asked to indicate whether the tones were coincident or not with their heartbeats. Only participants who detect their heartbeats have the necessary information to distinguish between coincident blocks of trials (with the 200-ms delay) from noncoincident blocks (with the 500-ms delay; Schneider et al., 1998; Wiens & Palmer, 2001). A *hit* occurred when participants said "yes" to a block of trials where the tones were delivered 200 ms after the R-spikes; a *miss* occurred when participants said "no" to such a block; a *correct rejection* occurred when participants said "no" to a block of trials where the tones were delivered 500 ms after the R-spikes; a *false alarm* occurred when they said "yes" to such a block.

We computed hit rates and false alarm rates from which we then computed nonparametric indices of sensitivity (A′) and response style (B′; Boice & Gardner, 1988). Nonparametric indices were used because parametric indices assume that hit and false alarm rates are normally distributed with equal variance (McNicol, 1972). There is no evidence in the literature to suggest that these assumptions are met in heartbeat detection tasks. Typical values for A′ vary between 0.50 (indicating chance discrimination) and 1.00 (perfect discrimination). A B′ value of zero indicates the absence of bias, with increasing positivity reflecting an increasingly cautious or strict criterion (e.g., tendency to say "no" many times) and increasing negativity indicating an increasingly lax or risky criterion (e.g., tendency to say "yes" many times). In addition, we used the Aaronson and Watts (1987) formulas for computing A′ and B′ whenever participants performed below chance levels for a given category on a given block of trials.[5]

Experience sampling.: Participants completed a rating of their immediate, momentary emotional experiences in the morning (7 a.m.–12 p.m.), afternoon (12 p.m.–5 p.m.), and evening (5 p.m.–12 a.m.) for each of 60 consecutive days. If participants made ratings for more than 60 days, these were included in the analyses. Participants returned completed forms on

[4]The heartbeat detection data were published in a previous study investigating the validity of self-reported somatic amplification (Aronson, Feldman Barrett, & Quigley, 2001). The hypotheses and data analyses contained in that report do not overlap with those presented here.

[5]Traditional signal detection formulas yield nonsensical values for individuals who perform below chance. The Aaronson and Watts (1987) adjustments do not change A′ and B′ values to the point where they reflect above chance performance. Rather, the adjustments modify the magnitude of the initial values to bring them closer to chance performance.

Monday, Wednesday, and Friday of each week. Research assistants contacted participants within 48 hr if they failed to return their ratings and interviewed participants three times during the study to ensure compliance with the research procedures.

At each measurement moment, participants indicated on a 7-point Likert scale the extent to which each of 88 emotion-related adjectives described their current emotional state (0 = *not at all*, 3 = *a moderate amount*, 6 = *a great deal*). Sixty adjectives were taken from the Positive and Negative Affect Schedule—Expanded Form (Watson & Clark, 1994), including 10 items that were summed to measure NA at each moment and 10 to measure PA (Watson et al., 1988), as well as 28 additional items that sampled remaining portions of the affect circumplex (see Larsen & Diener, 1992). An affect intensity score was derived for each participant by taking the sum of PA items (Watson et al., 1988) for moments when PA was the dominant subjective state and of NA items (Watson et al., 1988) on moments when NA was the dominant state (using a procedure like that described in Diener, Larsen, Levine, & Emmons, 1985; Larsen & Diener, 1987).

At the end of the sampling period, experimenters explained the purpose of the study and then asked a number of questions regarding compliance with study procedures. In particular, participants estimated the percentage of time that they used recall to complete their questionnaires and were dropped from the final sample if they reported using memory for more than 30% of the sampling period (as is standard for this type of research). The number of usable measurement moments ranged from 135 to 210, with a mean of 176.76 (*SD* = 11.97).

Results

Estimating Arousal Focus

Step 1: Compute a p-correlation matrix for each participant.: The self-report ratings collected during the experience-sampling procedure were used in this step. Correlations were computed between ratings for all possible pairs of 16 adjectives (*enthusiastic*, *peppy*, *happy*, *satisfied*, *calm*, *relaxed*, *quiet*, *still*, *sleepy*, *sluggish*, *sad*, *disappointed*, *nervous*, *afraid*, *surprised*, and *aroused*) within a participant across all measurement instances, producing one *p*-correlation matrix for each person. These adjectives have been used in previous studies of AF (Feldman, 1995;). The *p*-correlation matrix represents a profile of similarity indicating the relatedness between reported emotional states for a given person. We asked how much of this observed similarity is accounted for by activation and deactivation. To answer this question, we compared each matrix with an external criterion for the arousal-based meaning of the emotion words used in the rating process. This criterion was computed in Step 2.

Step 2: Estimating the cognitive structure of emotion language.: The external criterion that we used to compute AF was based on the cognitive structure of emotion language. The structure used here was derived from a previously published multidimensional scaling (MDS) solution of similarity judgments for the same 16 emotion-related words used to compute the *p*-correlation matrices (Feldman, 1995). Similarity judgments for emotion-related words, when subjected to an MDS analysis, routinely yield valence and arousal dimensions that represent the basic, semantic properties contained in our knowledge about those words and the concepts they represent. This valence–arousal structure of emotion language is highly replicable across item sets, individuals, and languages (for a review, see, e.g., Russell & Feldman Barrett, 1999).

An arousal-based semantic distance matrix was computed by taking the absolute difference between coordinates for all pairs of words along the arousal dimension of the MDS structure. Each word had one coordinate on the arousal dimension, so the result was 120 arousal-based distances. These distances indicate the relatedness between emotion-related words in terms of their level of arousal. The smaller the absolute value between two coordinates, the smaller the distance between two terms on a dimension, the more similar are those terms in terms of arousal. The distance matrix, then, is a profile of similarity for the arousal-based definitions of the emotion-related words. (A similar procedure was followed to compute a valence-based distance matrix to allow us to compute an index of VF.)

Step 3: Correlating each p-correlation matrix to arousal-based semantic distances.: To estimate AF for each person, we correlated the profile of self-reports (the *p*-correlation matrix) to the profile of arousal-based definitions (the arousal-based semantic distance matrix) to determine how much the correlation between ratings of any two emotional experiences was due to the level of arousal that the words share. Each participant's *p*-correlation matrix was correlated with the arousal-based distance matrix across the 120 pairs of affect terms, producing a single correlation coefficient; this correlation represented the correspondence between how a participant used the adjectives to represent emotional experience and how similar the adjectives were in arousal-based meaning. This procedure revealed the proportion of variance in the ratings accounted for by activation and deactivation. The sign of this correlation was reversed to produce AF (such that higher values would represent greater focus). The higher the correlation between the *p*-correlation matrix and the arousal-based similarity of the words, the more activation–deactivation is being emphasized during the self-report process, and the greater the AF.[6] All correlations were subject to Fisher *r*-to-*z* transformations before being used in subsequent analyses. A similar procedure was followed to compute VF for each participant.

Arousal Focus and Interoceptive Sensitivity—The relationships between heartbeat detection performance and all other variables are presented in Table 1. Because of the specific, directional, and a priori nature of our hypothesis that AF is related to interoceptive sensitivity, a one-tailed test was used when evaluating the correlation between AF and heartbeat sensitivity; all other correlations were evaluated using two-tailed tests. As predicted, AF was significantly related to increased heartbeat detection sensitivity ($r = .23$, $p < .05$, 1-tailed), suggesting that individuals who were able to accurately perceive their own interoceptive cues well enough to correctly judge the temporal relationship between the tones and their heartbeats also emphasized feelings of activation and deactivation more when reporting their momentary emotional experience over a 60-day experience-sampling period.

Discriminant Validity for the Link Between AF and Interoceptive Sensitivity— Unexpectedly, greater AF was related to greater B′ values. We considered the AF–response style effect marginally significant in this study because even though it is similar in magnitude to the AF–sensitivity correlation, we did not predict it beforehand. Individuals with greater AF had larger B′ values, reflecting that they were more cautious or strict in their threshold for saying that their heartbeats matched the tones. Sensitivity and bias were uncorrelated with one another, so that when both were entered into a regression analysis (with AF as the criterion variable and sensitivity and bias as the predictors), the relationship between heartbeat sensitivity and AF remained identical to that reported in Table 1.

As is clear from a quick scan down the first data column of Table 1, none of the other variables related to the experience of emotion had a positive relationship with accurate heartbeat performance, indicating that interoceptive sensitivity did not have its effect on AF merely

[6]There is another way to compute VF and AF. Each participant's *p*-correlation matrix can be factor analyzed; the first two unrotated factors extracted are typically valence and arousal, and the size of each factor represents the variance in the self-report ratings accounted for by each property. These factor-analytic estimates of VF and AF, although strongly related to the more externally based estimates (Feldman, 1995;), are less optimal because they contain the usual ambiguities associated with factor analysis (such as factor identification).

because of a broad influence on emotional experience. Thus, these results represent important discriminant validity evidence for the specificity of the interoception–AF link. Nonetheless, there are some potentially interesting findings here. In particular, individuals who evidenced more intense reports of experienced emotion on a moment-to-moment basis during the experience-sampling procedure were less sensitive during the heartbeat detection task than were those who gave less intense reports. In addition, individuals with greater affect intensity also evidenced lower B′ values. They set a more lax criterion for their responses, suggesting that they were more willing to false alarm during the heartbeat detection task. These findings are generally consistent with Blascovich et al.'s (1992) findings that self-reported affect intensity was negatively related to the accuracy with which individuals perceived their own heartbeats. In addition, individuals who reported greater PA on average across the 60 days of experience sampling, and to a lesser extent greater NA across that period, also evidenced lower B′ values.

Study 2

Given the small size of the interoceptive sensitivity–AF link, the unexpected relationship observed between AF and response style during heartbeat detection, and the general instability that can be observed in the interoception literature, a replication study was needed. The purpose of Study 2 was to replicate Study 1, with a few exceptions. First, heartbeat detection was performed at the end rather than at the beginning of the study. This was done to ensure that the interoception–AF link was not dependent on the order of measurement. Second, a computerized experience-sampling procedure was used. Computerized procedures have various advantages over the paper-and-pencil method used in Study 1, including better tracking of participants' compliance (Feldman Barrett & Barrett, 2001). As in Study 1, we predicted that interoceptive sensitivity would be related to increased AF. On the basis of Study 1, we further explored the relationship between AF and interoceptive response style. We did not elevate this to an a priori prediction, however, because there is no real theoretical reason to assume this link.

Third, we sought to extend the discriminant validity findings from Study 1 by examining the possibility that interoceptive sensitivity influenced how much attention people paid to the arousal-based meanings of the words themselves, separate from whether people rated those words as descriptive of their momentary feelings. Some researchers have argued that self-report ratings of emotional experience tell us more about emotion language (i.e., the words used in the rating process) than they do about subjective experiences per se (e.g., Frijda, Markam, Sako, & Wiers, 1995; Ortony, Clore, & Collins, 1988). So perhaps interoceptive sensitivity has its effect on how people attend to the properties of language rather than on attention to the properties of experience. In Study 2, we examined the relationship between interoceptive sensitivity and semantic focus (the degree to which people believe emotion words convey information about activation or deactivation). In addition to using emotion adjectives to rate their emotional experiences, participants completed similarity ratings of the same adjectives, allowing us to estimate their cognitive structure of emotion language. These ratings were subjected to an individual difference multidimensional scaling procedure (INDSCAL; Carroll & Chang, 1970) to produce a group MDS solution; this group solution provided the semantic structure of the words to allow computation of AF as was done in Study 1. In addition, the INDSCAL procedure produced a set of dimension weights for each participant. INDSCAL weights represent the extent to which each participant used arousal (and valence) properties of the words when judging their similarity (see Arabie, Carroll, & DeSarbo, 1987), which, in turn, is a measure of attention to arousal-based (and valence-based) meaning of the words (for a discussion, see Nosofsky, 1992). Thus, we had measures of the extent to which participants paid attention to the arousal-based semantic properties of words (the INDSCAL weights representing semantic focus), the extent to which they focused on that meaning when reporting their experience (AF), and an estimate of their interoceptive sensitivity. Comparing the three would allow us to rule out the possibility that interoceptive sensitivity was related to differential attention to the semantic properties of language, that is, the meanings of the words themselves, separate from how the words were used to represent feelings. In addition to measuring semantic focus, we also measured the same control variables as in Study 1 to determine whether interoception had a broad influence on self-report indices of experienced emotion or whether it had a specific relationship to AF.

Method

Participants—Participants were 54 undergraduate students (24 men) at Boston College who completed an experience-sampling procedure (described below).[7] All participants received $80 for participating in the experience-sampling portion of the study and another $30 for completing the heartbeat detection procedure.[8]

Procedure—Participants visited the laboratory six times during the course of 7 weeks. During the first laboratory session, participants completed a series of paper-and-pencil questionnaires that included the Big Five Inventory (John, Donahue, & Kentle, 1991) to measure neuroticism and extraversion. Next, they were assigned a palm-top computer (Hewlett-Packard 360 LX; Hewlett-Packard USA, Houston, TX) and received instructions regarding the experience-sampling portion of the study. The experience-sampling procedure lasted for a 28-day period, during which participants carried their palm-top and recorded their emotional experiences. During the next four lab sessions, an experimenter uploaded participants' emotional experience data to a desktop computer; participants were given immediate feedback regarding their level of trial completion (using a companion program called ESPCount; Barrett & Feldman Barrett, 1999). Participants also completed a series of laboratory tasks, including the similarity judgment task described below (Lab Session 2). Once the experience-sampling procedure was over, participants were called back 2 weeks later to complete the heartbeat detection task (Lab Session 6). The details of the heartbeat detection task were identical to those in Study 1, with the exception that participants rested for a 20-min period before beginning the procedure.

Experience-sampling procedure.: The palm-top computers used for the experience-sampling procedure ran on custom software (Experience Sampling Program [ESP]; Barrett & Feldman Barrett, 1999). Participants were beeped randomly 10 times per day for a 28-day period and asked about their momentary affective experience (potentially resulting in 280 affect measurement moments per participant).

At each measurement instance, they reported their experience at the time of the beep using 29 emotion-related terms. Affect terms were presented in a random order at each trial. Participants made their ratings on a 7-point Likert scale (0 = *not at all*, 3 = *a moderate amount*, 6 = *a great deal*) recorded by pressing numbers on the keyboard of the palm-top computer. Participants were told to rate as quickly as possible without compromising accuracy (the extent to which they felt each emotional experience at each measurement instance). They were told that if they did not respond to the first prompt, they would be beeped again several minutes later. If they failed to respond to that prompt as well, then the trial was recorded as missing data. Participants completed a practice trial of ESP and were given written instructions about the experience-sampling procedure before leaving the lab. Both ratings of experience and latencies to make

[7]Ninety-three participants began the experience-sampling procedure. Five (5% of the sample) were dismissed for noncompliance, leaving 88 who completed the experience-sampling procedure. Of those, 66 (75% of the remaining sample) agreed to return to the lab for the heartbeat detection task after experience-sampling was completed; 12 (19%) were ineligible for heartbeat detection because of illness (colds) or medical conditions (arrhythmia or asthma). Participants who completed the heartbeat detection procedure (and who are included in this report) did not differ in AF or VF from those who did not complete the procedure.

[8]Some of the self-report and similarity-rating data reported in Study 2 were used to examine the link between VF and perception of affective expressions (Feldman Barrett & Niedenthal, 2004). The specific hypotheses tested in that article do not overlap with those presented here.

those ratings were recorded, although latencies are not discussed in this report. The number of usable measurement instances per person ranged from 111 to 243, with a mean of 171.19 (*SD* = 16.62). The number of usable measurement instances was not related to AF or heartbeat performance.

AF and VF indices were computed from these experience-sampling data. Of the 29 terms included in the experience-sampling procedure, 16 (the same as in Study 1) were used to compute a *p*-correlation matrix. AF and VF were computed as in Study 1, with the exception that the group MDS solution derived from participants' own similarity ratings was used to generate the arousal-based semantic distance matrix. Descriptive statistics are presented in Table 2.

An intensity score was derived from the experience-sampling ratings for each participant. This was done by taking the average of pleasant experiences (*happy*, *enthusiastic*, *joyful*, *amused*) for moments when positive affect was the dominant subjective state and of unpleasant experiences (*sadness*, *afraid*, *angry*, and *guilty*) for moments when negative affect was the dominant state (e.g., Diener, Larsen, Levine, & Emmons, 1985; Larsen & Diener, 1987).

Finally, each participant received an average PA and NA score by averaging their ratings for the adjectives *active*, *enthusiastic*, and *peppy* to make a PA index for each measurement moment; a similar procedure was followed for *afraid*, *nervous*, and *angry* to make an NA index. These adjectives were chosen either because they all had very high factor loadings on the original Positive and Negative Affect Schedule scales (Watson et al., 1988) or because they semantically anchor those high activation, valenced octants of affective space. These were then averaged across all measurement moments to derive a single NA and PA index for each participant.

Similarity ratings.: Participants were seated in front of a Macintosh computer (either a G3 or a PowerMac 7600/120) and were asked to judge the similarity for all pairs of the 16 emotion-related adjectives used in the AF computation (120 pairs in all). For a given pair, each term served either as the referent or as the comparison. Pairs were presented in a different random order for each participant. The intertrial interval was 1,000 ms (1 s). Participants made their ratings on a 7-point Likert-type scale (1 = *extremely dissimilar*, 4 = *unrelated*, 7 = *extremely similar*) by pressing numbers on the keyboard of the Macintosh. Participants were told to respond as quickly as possible without compromising their accuracy. Both similarity judgments and latencies to make those judgments were recorded, although only judgments are relevant to this report.

The similarity ratings were subjected to an INDSCAL analysis using the ALSCAL procedure (Takane, Young, & DeLeeuw, 1976). A Stress × Dimension plot revealed a clear elbow at the two-dimensional solution in both cases, suggesting the suitability of the two-dimensional MDS solution (stress= .21, R^2 = .75).[9] An inspection of the solution suggested that one axis corresponded to the arousal denoted by the affect terms, and the other corresponded to valence. The congruence coefficients for this solution and those used in Study 1 (taken from Feldman, 1995) were .94 for the arousal dimension and .92 for the valence dimension. This group solution produced the arousal-based semantic distance matrix used to compute AF. The arousal dimension subject weights served as the index of semantic focus. In absolute terms, weights could range from 0 to 1, where 0 indicates that the participant ignored arousal when judging the similarity of affect words, such that the arousal dimension was unimportant to his or her structure, and 1 indicates that arousal was attended to and was very important (Young & Harts,

[9]Fit of the MDS solution was determined by procedures outlined in Davison (1983) and used in and Kring et al. (2003).

1994). Descriptive statistics for the subject weights are presented in the final data columns of Table 2.

Results

The relationships between heartbeat detection performance and all measured and derived variables are presented in Table 2. Most notably, as predicted, we observed AF to have a positive, small, but statistically significant relationship to increased heartbeat detection sensitivity, replicating the findings from Study 1. No other relationships even came close to reaching conventional levels of statistical significance. In particular, it is important that individuals who accurately attended to the information afforded by their own heartbeats did not seem to attend to all arousal-related information equally—that is, they did not show an increased tendency to attend to the arousal-based properties of emotion language per se. Rather, it is in the way that they used that language to describe how they felt (i.e., their degree of AF) where we see small but consistent effects. Furthermore, in a regression analysis (with AF as the criterion variable and sensitivity and semantic focus as the predictors), the relationship between heartbeat sensitivity and AF remained identical to that reported in Table 2, indicating that interoceptive sensitivity did not have its effect by influencing attention to emotion language.

Meta-Analytic Summary

Both Studies 1 and 2 tested the relationships between heartbeat detection performance and a host of emotional experience–related variables—most importantly, the relationship to AF. For all analyses except those involving semantic focus (which were only included in Study 2), it was possible, using meta-analytic techniques, to summarize the results across both studies. This analytic strategy was advantageous, because it allowed us to estimate the probability that we would have obtained the observed results in both Studies 1 and 2 if the null hypothesis of no relation between AF and interoceptive sensitivity were true. We used the procedures for combining effect sizes and significance tests discussed in chapter 4 of Rosenthal (1984).

Typically, it is most justifiable to combine effects across studies when their effect sizes and p values do not significantly vary from one another, so our first step was to compare corresponding effects across Studies 1 and 2 using the formulae offered in Rosenthal (1984, pp. 65–67). As expected by simply looking at the estimates contained in Tables 1 and 2, the AF–interoceptive sensitivity effects did not differ statistically from one another in their size ($z = .03$, $p < .49$) or in their p values ($z = .04$, $p < .48$). Somewhat unexpectedly, the same was true for AF–bias effects; they did not differ statistically from one another in their size ($z = .04$, $p < .48$) or in their p values ($z = .27$, $p < .61$) when compared across Studies 1 and 2. The meta-analytic combination of AF–sensitivity and AF–bias effects are presented in Table 3. Individuals who emphasized feelings of activation and deactivation implicitly in their self-reports of emotional experience performed more accurately and with more stringent criteria during heartbeat detection than those who placed less emphasis on those feelings. The effects were small but consistent and statistically significant. It is particularly notable that the replicated interoceptive–AF link that we observed would have occurred only 9 in 1,000 times ($p < .01$ for a one-tailed test) if the null hypothesis of no relationship between AF and interoceptive sensitivity were true.

The rest of the comparisons and combined effects are presented in Table 3. When compared across Studies 1 and 2, some effects were heterogeneous in size or p values or both, and these are presented in italics. These combined effects across both studies are presented for completeness' sake, although they cannot really be interpreted. Only the PA–bias effect was consistent across studies, similar in magnitude to the AF effects, and statistically significant; individuals who reported more momentary PA during experience-sampling had lower B′

statistics, indicating an increasingly lax or risky criterion (e.g., tendency to say "yes, the tones matched my heartbeats" many times). This effect was not predicted and has not been documented in the literature before, so it bears further investigation before it is interpreted.

General Discussion

Several of the most influential emotion theories of the past century have assumed that direct and explicit detection of arousal cues plays a crucial role in the experience of emotion. Although there is growing evidence that somatovisceral information from the body influences thoughts, feelings, and behaviors in a bottom-up way (Berntson, Sarter, & Cacioppo, 2003), empirical evidence consistently linking interoception to the experience of emotion has remained elusive. In this article, we report a consistent link between one form of interoceptive access (heartbeat detection sensitivity) and feelings of activation and deactivation as they are implicitly communicated in self-reports of experienced emotion (that is, AF indices computed on data compiled during several weeks of experience sampling). In our studies, participants described their moment-to-moment feelings by rating a series of emotion-related adjectives on standard Likert-type scales, and their ratings were treated as behaviors from which implicit information was extracted. In doing so, some were focusing on arousal as a property of experience more than were others, and some were basically ignoring this aspect of their experience altogether. This emphasis on arousal-related experience was related to participants' interoceptive sensitivity as indexed by their performance on a heartbeat detection task across two studies: The more that an individual was able to accurately perceive his or her own heartbeat well enough to correctly judge the temporal relationship between them and a set of delivered tones, the more that individual emphasized feelings of activation and deactivation in emotion reports during the experience-sampling procedure. This relation held regardless of whether heartbeat detection was performed before experience sampling (Study 1) or 2 weeks after it had ceased (Study 2). These findings, then, present important evidence that interoceptive sensitivity is related to the experience of emotion. Moreover, they provide the first evidence that heartbeat sensitivity is related to experienced emotion as reported in the context of everyday life over time. This contributes to the existing literature, which to date has focused on self-reports obtained during laboratory procedures.

The relation that we observed between AF and heartbeat detection sensitivity was specific and precise. It was not the case that interoceptive sensitivity was broadly related to many facets of emotional experience and was related to AF as a consequence. Interoceptive sensitivity displayed a specific relationship to AF. Of particular importance, we observed that individuals who were more sensitive to their heartbeats did not attend to the arousal-based properties of emotion words in general when compared with those who were less interoceptively sensitive. Rather, they showed a specific attention or emphasis to the arousal-based properties of words only when reporting on their own subjective emotional states. In addition, AF was related to heartbeat detection performance, but VF (an implicit measure of hedonic information contained in self-reports of experienced emotion) was not. This report, along with others (Feldman Barrett & Niedenthal, 2004) provides accumulating evidence that VF and AF have separate sets of correlates.

Although we found a link between AF and accurate performance on the heartbeat detection task, the effect sizes were small. As a result, it might be argued that the effect is not very strong and, by implication, not very important. However, it is important to note that participants made detection judgments at rest, when it is most difficult to be sensitive to interoceptive cues. In a sense, then, our findings might be considered a lower limit on the AF–interoceptive relationship. Moreover, we believe that these findings offer a host of important insights related both to the experience of emotion and interoception.

Interoception and the Experience of Emotion

Over the last several decades, failure to find strong support for Jamesian (see James, 1884see James, 1890/1950/1894/1994) and Schachter and Singer (1962) assumptions of automatic, direct, and explicit access to somatovisceral cues has led to an ongoing debate over the relative importance of bodily states in determining an experience of emotion. Our findings suggest the intriguing hypothesis that direct and explicit attention to and representation of interoceptive cues is more important to the emotional experiences of some individuals than to the experiences of others. Some individuals incorporated feelings of activation and deactivation into their reports of experienced emotion, whereas others did so to a lesser extent. Everyone reported conscious feelings, but the properties of those feelings differed in a way that was related to their heartbeat detection performance. The implication, then, is that one static, nomothetic theory of emotional experience may not apply equally to everyone. A weak version of James's basic assumption (that the experience of emotion is the perception of bodily states) may hold only for some people.

Incremental Validity for Self-Reports of Emotional Experience

Our findings not only provide validity for the link between interoceptive sensitivity and experienced emotion, then, but they also provide much-needed incremental validity (Sechrest, 1963) for self-reports of emotional experience. First, these are some of the first findings to show that information implicitly contained in self-report ratings (i.e., the extent to which people focus on a property of their experience when reporting it) is associated with a behavioral variable (heartbeat sensitivity). This is a different sort of validity than showing that the levels of self-reported emotional experience (e.g., participants' ratings of anger, pleasure, etc.) correlate with behavioral or psychophysiological measurements. Second, many of the studies that provide validity evidence for self-reports of emotional experience have examined concurrent relationships between self-reports and validity variables. In the present studies, we demonstrated predictive relationships in both directions and across several weeks. The heartbeat detection behavior was assessed prior to experience sampling in Study 1 and was assessed 2 weeks after experience sampling had finished in Study 2. So even though the effect sizes between AF and heartbeat sensitivity are small, the incremental validity conferred is substantial.

Construct Validity of AF

Our findings also provide evidence for the validity of AF as a new individual difference variable. When verbally reporting their feeling states, people can use the same emotion words very differently. For example, *anxious* is characterized as an activated, unpleasant state. Yet, the word *anxious* can be used to communicate a feeling of anticipation, emphasizing high activation (as in "I am anxious to do this"); a feeling of nervousness, emphasizing both activation and displeasure; or a feeling of displeasure (as in "I am upset"). Our findings suggest that people's use of such words is linked to their perception of internal cues. Of course, we cannot prove this directly. There is no way to directly measure what a person is "really" feeling and compare it with his or her report of that experience. Nonetheless, we have provided a plausible explanation for why greater sensitivity to heartbeats is related to an emphasis on activation and deactivation in self-reports: Feelings drive the verbal report such that self-reports of emotional experience contain information about how people feel.

Unexpectedly, AF was related to the response style that participants used during the heartbeat detection task. Specifically, individuals who emphasized activation and deactivation more during the self-report process had an increasingly cautious or strict criterion for saying "yes, the tones match my heartbeats." Without additional research, it is difficult to interpret this finding or understand its relevance for AF. For the moment, however, it suggests that individuals with higher AF seemed to be using a judgment strategy designed to decrease false alarms and increase correct rejections, although it is not clear why they would do so. In general, a respondent's judgment criterion is influenced by three factors: (a) his or her beliefs about the base rates of the event, (b) the goals that she or he has when making a judgment about the event (Egan, 1975; Green & Swets, 1966/1974; Healy & Kubovy, 1978), and (c) the perceived severity and consequences of a miss or false alarm (Quigley & Feldman Barrett, 1999). This suggests that future research should examine whether AF is somehow linked to beliefs about how often synchronous trials were delivered during the heartbeat detection task, the goals that direct judgments during the task, and the perceived consequences of each type of judgment error.

The Scientific Value of Interoception

Finally, our results suggest that there is scientific value in studying interoception. We found that interoceptive sensitivity was related to real-world reports of experience. This counters the concern, raised by Dworkin (2000), that conscious visceral perception is nothing more than a fragile laboratory curiosity. It also quells the concern that sensitivity is rarely meaningful in relation to other psychological variables (cf. Vaitl, 1996).

Caveats

Two caveats are worth noting. First, our findings do not speak directly to the issue of causation, although some of our data can be brought to bear on this question. It may be, as we have suggested, that individuals who are more sensitive to their heartbeats experience more varied and nuanced feelings of activation and deactivation and adjust their use of emotion-related adjectives to reflect these experiences. The findings are equally consistent with the possibility that emphasizing felt activation–deactivation in reports of emotional experience can somehow lead people to be more interoceptively sensitive, although this possibility seems implausible for two reasons. If the process of self-report influenced participants' sensitivity to their heartbeats, then the magnitude of the interoceptive–AF link would have been larger for Study 2 (heartbeat sensitivity measured after AF) than for Study 1 (sensitivity measured before AF); this was not the case. Also, there is no reason to believe that participants would have learned anything about interoception from the experience-sampling procedure (used to measure AF). Improving someone's sensitivity to his or her heartbeats requires immediate, unambiguous feedback about heart rate after each judgment, and our experience-sampling procedure offered no such feedback.

Second, the mechanisms that link interoceptive sensitivity to AF are not known. Several articles have recently been published addressing how afferent information is represented in the central nervous system and re-represented for the purposes of interoception (e.g., Cameron, 2000; Cameron & Minoshima, 2002; Craig, 2002; Critchley et al., 2004). Although it seems clear that the right anterior insular cortex is involved, we still have much to learn about the psychological mechanisms by which people become aware of bodily information. Compared with poor heartbeat detectors, good detectors have larger cardiovascular responses to active coping situations (Eichler & Katkin, 1994; Eichler, Katkin, Blascovich, & Kelsey, 1987; Eichler, Kelsey, Guethlein, & Katkin, 1988; but see Ferguson & Katkin, 1996). The cardiovascular response to active coping tasks is generally associated with sympathetic activation, suggesting the possibility that increases in sympathetic activation or associated hemodynamic changes may aid heartbeat detection (Eichler & Katkin, 1994). It may be that individuals who have more exposure to intense cardiovascular activity become more interoceptively sensitive (at least to their heartbeats), in turn leading to greater AF. Intense cardiovascular activity might expose people to increased myocardial contractility (which is driven prominently by sympathetic activity and by changes in venous return to the heart) or stroke volume, such that individuals who have stronger contractility or greater stroke volume may be more sensitive to their heartbeats (Eichler & Katkin, 1994; Schandry & Bestler, 1995), thereby producing more change in feelings of activation and deactivation, which in turn leads to greater AF. These would be questions for further research.

Conclusions

Although future research is needed to identify mechanisms that relate heartbeat sensitivity and representations of arousal information in self-reports, this report has made an important advance in our understanding and measurement of experienced emotion. By relying on what people tell us about their experiences and analyzing those phenomenological reports for information that they implicitly contain, we have established an important link between interoceptive sensitivity and reports of experienced emotion. This, in turn, leads to a number of interesting points. First, our findings suggest the intriguing hypothesis that interoceptive cues may be more important to the experience of emotion for some individuals than for others. Second, our findings provide bounded incremental validity for self-reports of emotional experience. They offer important empirical evidence to support those who already believe that self-reports are valid and to challenge skeptics who are quick to dismiss self-reports as unscientific. Psychological measures are not inherently valid or invalid—it is how they are used that matters. We observed a relation between interoceptive sensitivity and self-reports using performance-based measures. None of the findings reported here were based on participants' beliefs about their own abilities. Interoceptive sensitivity was indexed by an objective heartbeat detection procedure. Ratings of emotional experience were generated by the participants, but they were treated as behaviors that implicitly contain psychological information (in contrast to, e.g., asking people explicitly if they are aware of feelings of activation or deactivation). Self-reports are rarely used in this way in psychological science, but to do so can yield important findings about the topic under investigation (in this case, emotional experience) as well as provide a foundation for the scientific study of self-reports. Finally, our findings contribute to a developing research program that attempts to leverage verbal reports of experienced emotion to learn something about the processes related to the experiences themselves. They suggest that it may be possible to offer evidence for what people feel by examining how they represent their feelings. Simply observing the patterns in what people say about their feelings over time may provide an empirical basis to begin understanding the processes by which people come to verbally represent their feelings and, perhaps someday, how they generate those feelings in the first place.

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Table 1

Zero-Order Correlations Between Heartbeat Detection Performance and Emotional Experience Variables: Study 1

	A′		B′			
Variable	***r***	***p***	***r***	***p***	***M***	***SD***
AF	.23	.05[a]	.24	.08	0.24	0.15
VF	−.19	.17	−.04	.78	0.61	0.13
N	−.16	.25	−.01	.94	2.78	0.63
NA	−.16	.23	−.24	.07	6.42	4.90
E	.05	.74	−.17	.23	3.69	0.56
PA	−.22	.10	−.30	.03	17.13	8.50
AI	−.29	.03	−.38	.01	18.04	7.54
A′	—				0.56	0.23
B′	−.01	.47	—		0.08	0.33

Note. Means and standard deviations are reported for the Fisher transformed AF (arousal focus) and VF (valence focus) indices. *N* = 55. A′ = sensitivity; B′ = response bias; N = neuroticism; E = extraversion; NA = average negative activation Positive and Negative Affect Schedule—Expanded Form (PANAS-X) score computed from 60 days of experience-sampling ratings; PA = average positive activation PANAS-X scale score computed from 60 days of experience-sampling; AI = affect intensity computed from experience-sampling ratings.

[a] One-tailed test.

Table 2

Zero-Order Correlations Between Heartbeat Detection Performance and Emotional Experience Variables: Study 2

	A′		B′			
Variable	***r***	***p***	***r***	***p***	***M***	***SD***
AF	.23	.05[a]	.19	.18	0.38	0.19
VF	−.02	.90	−.17	.21	0.54	0.21
N	−.10	.47	−.11	.42	2.82	0.81
NA	−.06	.66	.11	.42	2.39	0.81
E	.13	.34	−.09	.52	3.51	0.75
PA	.03	.86	−.09	.51	3.16	0.74
AI	.01	.94	−.00	.99	3.80	0.75
A weight	−.10	.46	.01	.96	0.64	0.14
A′	—				0.61	0.16
B′	.17	.22	—		−0.02	0.28

Note. Means and standard deviations are reported for the Fisher transformed AF (arousal focus) and VF (valence focus) indices. $N = 54$. A′ = sensitivity; B′ = response bias; N = neuroticism; E = extraversion; NA = average negative activation score computed from 60 days of experience-sampling ratings; PA = average positive activation score computed from 60 days of experience sampling; AI = affect intensity computed from experience-sampling ratings. A weight = individual difference multidimensional scaling procedure weight for arousal dimension.

[a] One-tailed test.

Table 3

Meta-Analytic Combination of Effects From Studies 1 and 2

	A′		B′	
Variable	**Effect**	***p***	**Effect**	***p***
AF	.23	.02	.21	.03
VF	.10	.29	−.11	.29
N	.13	.18	−.06	.54
NA	.12	.24	*−.07*	*.07*
E	.09	.36	−.12	.19
PA	*.10*	*.19*	−.20	.05
AI	*−.14*	*.11*	*−.20*	*.05*

Note. Statistics reported in italics represent combined results where effect sizes or *p* values or both were heterogeneous. A′ = sensitivity; B′ = response bias; AF = arousal focus; VF = valence focus; N = neuroticism; E = extraversion; NA = negative activation; PA = positive activation; AI = affect intensity.