The Immutability of Valence and Arousal in the Foundation of Emotion

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Abstract

Over the past century, great debate has ensued regarding the fundamental properties of emotions. The idea that two properties—valence and arousal—are critical for emotion and psychologically irreducible has had substantial staying power in the literature. In the present report, we examine whether a third dimension – reflecting the social properties of emotion – might arise if stimuli high in that dimension (i.e., "theoretically social emotions") were included in the task and, or, if social information was primed. We used a similarity-rating task to evaluate whether a dimension representing the "socialness" of emotion – the extent to which emotions are associated with social contexts – might arise as the result of inclusion of emotion words that are theorized to represent "social emotions". In Study 1, we assessed the dimensional structure of 41 different emotion terms (of which 41% were "social emotions") based on pair-wise similarity ratings of a subset of the emotion terms. In Study 2, we tested whether priming social information before and during the similarity rating task would shift the emergent dimensional structure of emotion words. Results of multidimensional scaling across both studies indicated that the structure of emotion is best described by two dimensions – valence and arousal – and was not influenced by the priming of social information. Contrary to predictions, evidence did not emerge for a third dimension corresponding to socialness, nor any other property.

Keywords: structure of emotion, social emotion, valence, arousal

Over the last century, much ink has been spilled regarding what constitutes the most basic or fundamental, psychologically irreducible properties of emotions – the joints beyond which emotions cannot be further carved. Despite robust debate, the idea that affect forms the foundation of emotions and is characterized by two such fundamental properties – valence and arousal – has had substantial staying power in the literature. Whether regarded as explicit dimensions (Russell, 1980) or properties implied by the presence of other dimensions (Thayer, 1989; Watson & Tellegen, 1985), valence (hedonicity) and arousal (activation) are consistently discussed as properties affect, and thus as properties of emotions. Concurrent investigations have focused on the social nature of emotions, proposing that "social emotions" may be a special class that serve social functions (e.g., K. C. Barrett & Campos, 1987; Hareli & Parkinson, 2008) or that "socialness" may reflect a property of emotion (e.g., Boiger & Mesquita, 2012; Lutz & White, 1986). Notably, studies that have explicitly evaluated the structure of affect or emotion (e.g., Feldman, 1995; Fontaine, Scherer, Roesch, & Ellsworth, 2007; Russell, 1980; Russell & Mehrabian, 1977; Thayer, 1989; Russell, 1980; Watson & Tellegen, 1985; Thayer, 1989; Feldman, 1995; Fontaine, Scherer, Roesch, & Ellsworth, 2007) typically lack emotion exemplars that would be considered highly social (but see Condon & Barrett, 2013; Fontaine, Poortinga, Setiadi, & Markam, 2002; Fontaine, Scherer, Roesch, & Ellsworth, 2007). As such, they potentially fail to identify a property of emotion related, globally, to social nature of emotion, which we term socialness. In the present report we investigate whether socialness might emerge as a property of emotion across two studies. We explored whether a social dimension might emerge, in addition to or instead of valence or arousal, as a result of expanding the stimuli set to include emotion words theorized to be particularly social in nature (Studies 1) or by priming social information (Study 2, Samples a and b).

Many assessments of the properties of emotion have highlighted the importance of valence and arousal in the experience and perception of affect and emotion (for reviews, see

Barrett & Bliss-Moreau, 2009; Barrett & Russell, 1999; Fontaine et al., 2007; Kuppens, Tuerlinckx, Russell, & Barrett, 2013; Mattek, Woldford, & Whalen, 2017; Russell, 1980). If grounded theoretically, studies of this nature are typically grounded in one of two perspectives. The first perspective is that affect is the foundation of emotion (e.g., Barrett & Russell, 1999; Russell & Barrett, 1999, Russell, 1980; Russell, 2003). In this view, discrete emotions such as happiness, sadness, and excitement emerge from affect (characterized by pleasantness/unpleasantness (valence) and activation/calmness (arousal)) and other psychological ingredients. Affect is required for emotions, though emotions are not reducible to affect (Bliss-Moreau, 2018). Thus, valence and arousal represent fundamental properties of both affect and emotion. The second perspective is adopted by scholars who typically focus on discrete emotions where the claim is that valence and arousal represent fundamental properties of discrete emotions themselves – often leading to discussions of 'dimensional theories of emotion' (e.g., Harmon-Jones, Harmon-Jones, & Summerell, 2017). Regardless of theoretical perspective, valence and arousal consistently emerge when affect or emotion stimuli are perceived or evaluated or when people report on their current experience. Thus, for simplicity, refer to the dimensional space created by evaluations of affect or emotion stimuli and experiences as *affective space*.

Debate has ensued regarding whether valence and arousal constitute the only fundamental properties of affective space and whether valence and arousal dimensions are bipolar in nature (Barrett & Russell, 1998; Diener & Emmons, 1984; Fontaine et al., 2007; Kron, Pilkiw, Banaei, Goldstein, & Anderson, 2015; Norris, Gollan, Berntson, & Cacioppo, 2010; Russell & Carroll, 1999). A substantial literature supports the idea, however, that when the properties of affective space are derived from similarity ratings of emotion words, valence and arousal are the predominant dimensions (for reviews, see Barrett & Bliss-Moreau, 2009; Barrett & Russell, 1999; Kuppens et al., 2013). This finding holds across cultures (Russell, Lewicka, & Niit, 1989) suggesting that the importance of valence and arousal is not culturally

bound. Evidence from developmental studies document the emergence of both valence and arousal dimensions in such ratings (Russell & Bullock, 1985; Nook et al., 2017). The arousal dimension appears to expand with age (Nook et al., 2017), suggesting that while neither dimension is developmentally bound, the relative importance of arousal increases across childhood into adulthood. Valence and arousal also emerge as organizing dimensions of affective space in patient populations with compromised affective processing (i.e., individuals with schizophrenia or schizoaffective disorder), leading researchers to conclude that they are universally important for emotion (Kring, Barrett, & Gard, 2003).

While valence and arousal may be the most consistent properties to emerge in studies of the structure of affective space, other dimensions do emerge in some analyses. When it arises, the third dimension has been argued to reflect a number of different qualities, including potency (Fontaine et al., 2007; Veirman & Fontaine, 2015; Osgood, 1969) and dominance-submission (Russell & Mehrabian, 1977). In studies evaluating ratings of affect and emotion words, Fontaine and colleagues (2007, 2015) identified a third potency-control dimension. A fourth predictability dimension also emerged in one of these studies (Fontaine et al., 2007). Fourth and fifth dimensions related to power and novelty emerged in a more recent study (Veirman & Fontaine, 2015), though the scree plots did not clearly indicate the number of dimensions that best fit the data. The emergence of valence, arousal, power, and novelty dimensions was replicated when words were rated on their features (including appraisals, bodily reactions, expressions, action tendencies, etc.) rather than their similarity (Gentsch et al., 2018). An important feature of these most recent studies is that they did include many different affect and emotion words, including those theorized to be social in nature (Veirman & Fontaine, 2015; Gentsch et al., 2018). Moreover, power and dominance are indeed inherently related to social life, but do not comprehensively capture all aspects of sociality. Further, power and dominance alone do not map precisely to what is meant by

socialness by theorists who postulate that there is a special class of emotions, called "social emotions" that are uniquely social.

Considerable literature exists focused on the nature of what are termed "social emotions", which are often discussed as a special class of emotions (K. C. Barrett & Campos, 1987; Bennett & Matthews, 2000; Hareli & Parkinson, 2008; Leary, 2000; Oatley & Johnson-Laird, 1987). According to these perspectives, some emotions are thought to be particularly "social" (for a review, Williams & Bliss-Moreau, 2018). Other views draw distinctions around "self-conscious" (for reviews, Lewis, 2008; Tracy, Robins, & Tangney, 2007) or "moral" (for a review, Tangney, Stuewig, & Mashek, 2007) emotions, with both strongly drawing on social information. Social emotions purportedly serve uniquely social functions (e.g., promoting social bonding or social status), occur preferentially in social contexts, are felt about social others, and/or rely upon specialized neuroanatomical processes that support processing of social information (for a review, see Williams & Bliss-Moreau, 2018; Bliss-Moreau, Williams, & Karaskiewicz, 2018). A number of emotions have been consistently labeled as social (e.g., gratitude, compassion, jealousy; Hareli & Parkinson, 2008). For the purposes of this report, we term these emotions "theoretically social".

The "social emotion" perspective, while perhaps the dominant view to discuss the social nature of emotions in the emotion literature writ large, is not the only one that postulates that the social experience and social functions are critical for emotions. Social constructivist views (e.g., Boiger & Mesquita, 2012; Lutz & White, 1986) make a different argument about the social nature of emotions: all emotions are social by nature and would not exist in the absence of the social environment. These views do not recognize theoretically social emotions as a special class, but allow for the possibility that emotions may vary in terms of the extent to which they rely on or support social processes (what we call "socialness").

If socialness is a fundamental property of emotion, why has a corresponding dimension not been consistently identified in previous work? It is the case that dimensions related to social-processing, like dominance-submission or power, appear in some studies of the structure of affective space (Russell & Mehrabian, 1977; Veirman & Fontaine, 2015; Gentsch et al., 2018). However, as noted above, human social life is characterized by features other than dominance (e.g., balancing getting along with others versus getting ahead; for a review see Williams, 2018). Further, theorizing about what makes "social emotions" a special class often relies on constructs that are not related to dominance, such as fairness or morality (Hareli & Parkinson, 2008). Finally, dimensions capturing socialness are not consistently present across studies.

One possibility is that extant studies of the structure of emotion may be biased with regards to the stimuli that they utilize. With few exceptions, many exemplars of social emotions have never before been subjected to similarity ratings (but see Condon & Barrett, 2013 who included compassionate, grateful, proud, guilty, and sympathetic among a total set of 15 words judged in a similarity task; Veirman & Fontaine, 2015 who included 85 words (in Dutch) including emotion terms typically thought to be "social" such as jealous, compassion, and ashamed). It may be the case that limited numbers of stimuli are used in such similarity-rating tasks because, typically, all participants evaluate all stimuli in a pair-wise fashion. This design results in a large number of judgments. For example, a stimulus set of 16 words results in each participant making 120 judgments (e.g., Feldman, 1995). One option that allows for large stimulus sets to be judged is to have participants complete ratings of subsets of words (as was done in Veirman & Fontaine, 2015). Such an approach allows many more items to be evaluated (i.e., 85 as in Veirman & Fontaine, 2015), allowing for the inclusion of a more diverse set of affect and emotion terms.

The goal of the present studies was to test whether socialness emerges as a fundamental dimension of emotion using a similarity-rating task – first by including words

that represent theoretically social emotions, then by priming social information. We reasoned that the task needed to include a substantial number of theoretically social emotions in addition to affect and emotion terms that have not been identified as theoretically social (i.e., those used in the majority of past structure of emotion research). To that end, in both studies, we utilized a set of 41 words that included 17 theoretically social emotions (41%), many of which have not been included in past research on the structure of emotion.

Study 1 deployed a novel analytic procedure by subjecting similarity ratings of a subset of the total possible pairings to multidimensional scaling in a method that, even with substantial amounts of missing data, accounts for between-subject heterogeneity in the relative importance of each dimension when evaluating stimulus similarity. This represents an advance over approaches that derive an averaged matrix to account for missing data (Veirman & Fontaine, 2015), which ignore between-subject heterogeneity and have been shown to yield solutions which have artificially good fits to data (Ashby, Maddox, & Lee, 1994). As a result of this approach, participants in the studies reported here completed 123 similarity judgments rather than the 820 judgments that would have been required if each participant had judged all pairwise combinations – an unreasonable number of judgments for a single session. In Study 2, we primed social information by having participants watch and then describe brief video clips that included people (in the social priming condition) or did not include people (in the control condition). Trials of the video task were interspersed throughout the emotion word similarity-rating task.

Together, these two studies enabled evaluation of whether a third dimension might emerge that a) explained a substantial amount of variance, and b) was interpretable relative to the theoretically-proposed social nature of emotions. Study methodologies and plans for sampling, data collection, data exclusions, and analysis for both studies were pre-registered (https://osf.io/g2qbr/). All procedures were approved by the UNSW Sydney Human Research Ethics Advisory Panel.

Study 1

Study 1 represented an initial test of the emergence of a social dimension in the structure of emotion as a function of increasing the stimulus set to include broad representation of theoretically social emotions. In Study 1, we deployed a subset procedure alongside an analytic approach that was robust to the amount of missing data that accompanies subset procedures in similarity rating tasks.

Method

Participants. Participants were 326 U.S.-based users of Amazon.com's Mechanical Turk reimbursed monetarily for their time ($1.50, based on at a rate of $10/hour with average duration determined via pretesting in the first and second authors' laboratories). Per preregistered exclusion criteria, data from a total of 20 participants were excluded from analysis because of incomplete data (n = 1), because they finished the study in less than 5 minutes (n = 11), because of technical difficulties during the study (n = 5), and because they reported learning English as a second language and being fluent in English after the age of 8 (n = 3). Data were checked to ensure that no participant had 0 variance in ratings. The majority of the analyzed sample of 306 participants (gender: 162 female, 143 male, 1 other; age: M = 37.56, SD = 11.68) self-identified as White/Caucasian (n = 240), with other ethnicities reported by fewer than 10% of the sample. This sample size exceeded the pre-determined minimum of 280, which ensured that no fewer than 20 participants completed each of the 14-word subsets, thus providing sufficient coverage of all word pairs.

Procedure. The study was deployed using Inquisit 4 Web (v4.0.2). Word stimuli were 41 affect and emotion words (asterisks denote theoretically social emotions): admiration*, afraid, amused, angry, appreciated*, aroused, ashamed*, awe, calm, compassionate*, contempt*, content, disappointed, disgusted, embarrassed*, energized, enthusiastic, envious*, grateful*, grief*, guilty*, happy, hopeful, indebted*, interested, jealous*, joyful, love*,

morally disgusted*, morally elevated*, nervous, proud*, quiet, relaxed, sad, satisfied, sleepy, sluggish, still, surprised, and vengeful*.

Our list of emotions was selected on the following bases. First, we started with the 16 terms classically used in studies of the structure of affective space (e.g., Feldman, 1995): aroused, surprised, peppy, enthusiastic, happy, satisfied, calm, relaxed, quiet, still, sleepy, sluggish, sad, disappointed, nervous, afraid. We replaced the term 'peppy' with 'energized' due to earlier work in our labs revealing confusion about this term. We added several additional commonly studied discrete positive emotions not typically cited as being social: amused (Giuliani, McCrae, & Gross, 2008), awed (Keltner & Haidt, 2003), content (Cordaro, Brackett, Glass, & Anderson, 2016), hopeful (Bruininks & Malle, 2005) interested (Silvia, 2008), joyful (Watkins, Emmons, Greaves, & Bell, 2018). We also added two discrete negative emotions classically treated as 'basic emotions' (angry, disgusted; Ekman, 1992).

For the selection of theoretically social emotions, we selected four self-conscious emotions (proud, embarrassed, guilty, ashamed; e.g., Tracy & Robins, 2004), three 'other praising' emotions (grateful, admiration, morally elevated; Algoe & Haidt, 2009), two negatively-valenced moral emotions (contemptuous, morally disgusted; Rozin, Lowery, Imada, & Haidt, 1999), indebted (Mathews & Green, 2010), envious (Hill, DelPriore, & Vaughan, 2011), jealous (DeSteno, Valdesolo, & Bartlett, 2006), grieving (Jakoby, 2012), loving (Averill, 1985), compassionate (Goetz, Keltner, & Simon-Thomas, 2010). We included two less-classically studied states (appreciated, vengeful) to raise the number of theoretically social terms, with the logic that feeling appreciated (the counterpart to gratitude) and feeling vengeful (a strongly socially-oriented version of anger) are social in nature.

Pairwise combination of these 41 words resulted in 820 unique pairs. We divided the 820 unique pairs into 20 sets of 41 pairs and allocated those sets into 14 experimental conditions of 3 sets each, ensuring that each set, and thus each pair, was represented in at

least two experimental conditions. Each experimental condition thus included 123 pairs. Each participant was randomly assigned to one of the 14 experimental conditions.

On each trial, a pair of words appeared on the screen. Position of the word on the right or left of the screen was randomized. Participants rated the similarity of the two words in each pair on a 7-point scale anchored by *extremely dissimilar* (1) and *extremely similar* (7). After completing the similarity-rating task, participants then rated their familiarity with the meaning of each word stimulus (1 = *I do not know the meaning of the word,* 4 = *I am certain I know the meaning of the word*), and reported their gender, age, and ethnicity among other demographic details.

Data Analysis Strategy. Prior to data analysis, 38 trials from 16 unique participants were removed from the data set because of participants' low familiarity with the words. Of these participants, 9 were unfamiliar with one word, 5 were unfamiliar with two words, 1 was unfamiliar with three words, and 1 was unfamiliar with 16 words. When those trials were removed, the mean rated familiarity with the words was 6.69 (SD = 0.91), with a median of 7 and an IQR of 0, indicating high familiarity with the stimuli. All analyses were computed on the whole dataset and thus represent group-level solutions.

Data analysis was completed using the multidimensional scaling procedure (PROC MDS) in SAS (v9.4), which is capable of handling the volume of missing data produced by the subset procedure (85% of the total matrix for each subject). We used a Weighted Euclidean procedure to compute individual-level solutions that preserve participant-level variability (similar to INDSCAL in SPSS), representing an advance over procedures that average across all data points for a given matrix cell and subject those averaged data points to MDS (such as ALSCAL and PROXSCAL in SPSS). Tied data were untied. Solutions were computed at each level of dimensionality (e.g., 1 dimension, 2 dimensions). A stress-by-dimensionality plot was attained for each solution. We determined the number of appropriate

dimensions by first identifying the elbow in the stress-by-dimensionality plot and then assessing the interpretability of the solution.

We fit two models using two different procedures for minimizing stress: *S-stress*, which minimizes squared distances (similar to ALSCAL in SPSS), and *Stress-1*, which minimizes absolute distances (similar to PROXSCAL in SPSS).[1] S-Stress minimizes the sum of the normalized, squared difference between the squared observed distances and the squared fitted distances, thus weighting the ratings of dissimilar pairs more heavily than similar pairs in the same solution. Critically, because of this calculation, positioning of the points on the solution may not reflect their relative positioning in psychological space. For example, if S-Stress is used to create a two-dimensional plot, and one pair of points (say, A and B) are 1 unit apart and a second pair (say, B and C) are 5 units apart, it does not mean that A and B are 5 times more similar than B and C. In contrast, Stress-1 minimizes the sum of the normalized, squared difference between directly-observed distances and fitted differences, thus weighting the ratings of dissimilar and similar pairs equally. As a result, distances between pairs can be interpreted as reflecting distance in conceptual space. That is, pairs that are closer together are more similar than pairs that are farther apart.

Results and Discussion

Regardless of whether stress was calculated by minimizing squared distances (S-Stress; Figure 1a) or absolute distances (Stress-1; Figure 1b), the stress-by-dimensionality plots indicated solutions with two dimensions. In both solutions, ordering of the words indicated that one dimension corresponded with “valence” (the first, represented horizontally in Figure 1c and 1d,) and another with “arousal” (the second, represented vertically in Figure 1c and 1d). RSQ values, which correspond to variance explained, for the 2-dimension solutions were 0.92 (Stress-S) and 0.96 (Stress-1).

It is important to note that using a common stress calculation (*S-stress*) utilized in the affect circumplex literature (e.g., Feldman, 1995) produced a circular ordering of terms

around an open central space (Figure 1c). By modifying the stress calculation (to *Stress-1*) so that the space between points can be interpreted as conceptual distance, words spread over the circular structure, filling all but the most central dimensional space (Figure 1d). While readers are likely more familiar with S-Stress calculations and the structures that they produce, we believe that the use of Stress-1 calculations provides a more readily interpretable solution. Further, it suggests that the strict "circumplex" model of affect – in which terms are arranged around the outside of an empty circle – may be a statistical artifact and that, instead, affective space may be better thought of as a continuous two-dimensional space. When applied to the study of emotional experience, rather than the definitions of emotion words (as in the present study), this finding calls into question the idea that each word's distance from the origin ($x = 0$ and $y = 0$) reflects the intensity of the affective state or emotion as suggested by Russell and Barrett (1999).

For the sake of completeness, we inspected the third dimension for interpretability. The third dimension was largely non-interpretable and did not appear to capture the socialness of emotion nor any other dimension observed in prior research (see Table 1). Notably, theoretically social emotions were distributed across this third dimension in both solutions.

It is possible that a third interpretable dimension did not emerge because judgments of words in Study 1 were made in the absence of contextual information. Given that context shapes the meaning of affective stimuli (for a review Barrett, Mesquita, & Gendron, 2011), we reasoned that providing socially-relevant contextual cues might facilitate emergence of a dimension representing the social nature of emotions. To that end, we conducted a second study that introduced an experimental manipulation of social information.

Study 2

Study 2 served two aims. First, we sought to replicate the two-dimensional structure identified in Study 1 with the expanded set of word stimuli and evaluate whether use of a

novel statistical procedure produced a similarly densely populated circular representation of affect. Second, we sought to establish whether priming social information would impact the derived structure. Participants were randomly assigned to a social information priming condition in which they watched short videos that either included people or not. The priming task occurred before and then interspersed amongst word similarity ratings. Study 2 utilized two samples: a university student sample (Sample 2a) and a much larger sample from an online community (Sample 2b). This approach was adopted to amplify the generalizability of findings. Prior to collecting Samples 2a and 2b, we first carried out a pre-test of our priming procedure.

Priming Pretest

Prior to using the priming method in the context of similarity ratings, a separate sample of participants watched a set of videos that either included people or did not and described the content of the videos. Our goal was to ensure that videos in the social condition primed social information, namely other people, and that videos in the control condition did not.

Participants were 65 students at the University of New South Wales (gender: 46 female, 19 male; age: $M = 19.15$, $SD = 2.13$) who were remunerated with course credit for their participation. The majority of the sample self-identified as North East Asian ($n = 22$), White/Caucasian ($n = 16$), South East Asian ($n = 9$), or multiple ethnicities ($n = 7$), with other ethnicities reported by fewer than 10% of the sample. Participants were randomly assigned to either the social condition ($n = 32$) or the control condition ($n = 35$). In each condition, participants viewed nine brief videos 19-23 s in duration sourced from www.pixabay.com. Videos in the social condition featured people engaged in every-day activities (e.g., people riding bikes on a nature trail; a person sitting on a bench reading a newspaper). Videos in the control condition did not feature people (e.g., koi swimming in a pond; grass blowing in the wind). Following each video, participants described what happened in the video and rated how the video made them feel on 9-point scales assessing valence (anchors: *extremely*

negative and *extremely positive*) and arousal (anchors: *extremely relaxed/unactivated* and *extremely stimulated/activated*). Once participants viewed all videos, they completed a rating task in which they indicated how familiar they were with each of the 41 emotion words used in Study 1, data which were obtained in order to assess potential trial-by-trial exclusion rates in Sample 2a and not reported here.

Narratives were coded by two research assistants blind to condition. Each noted the presence or absence of references to people. High inter-coder reliability (94.1%) was achieved. In cases where the two coders did not agree, the first author read the narratives, assigned a code, and then verified that code with the second author. These data, in combination with the valence and arousal ratings, were used to select the set of videos used in Studies 2a and 2b.

In the social condition, the narratives provided by all 32 participants for all nine videos included social information. In the control condition, the narratives of three videos included social information (one video prompted a description that included social information from one participant, another video from two participants, and a third from seven participants). These three videos were excluded. The nine videos in the social condition were rated higher in arousal than the remaining six videos in the control condition, $t(13) = 2.65$, $p = .20$, $d = 1.40$ 95% CI [0.21, 2.54],[2] ($M_{social} = 4.50$, $SD_{social} = 0.36$; $M_{control} = 3.89$, $SD_{control} = 0.53$). We therefore excluded the three social videos with the highest arousal ratings, yielding six social and six control videos. The valence and arousal ratings did not differ significantly across these sets; valence: $t(10) = 0.39$, $p = .71$, $d = 0.23$ 95%CI [-0.92, 1.36], ($M_{social} = 5.87$, $SD_{social} = 0.33$; $M_{control} = 5.74$, $SD_{control} = 0.29$); arousal: $t(10) = 1.74$, $p = .11$, $d = 1.01$ 95%CI [-0.23, 2.20], ($M_{social} = 4.32$, $SD_{social} = 0.27$; $M_{control} = 3.89$, $SD_{control} = 0.53$).

Method

Participants. Study 2 utilized two samples. Sample 2a comprised 166 students at the University of New South Wales who were remunerated with course credit for their

participation. Per preregistered exclusion criteria, data from a total of 29 participants were excluded from analysis – one due to technical difficulties during the session, 25 because they reported learning English as a second language and being fluent in English after the age of 8, and 3 due to narratives that included social information in the control condition, did not include social information in the social condition, or were blank or task-irrelevant.[3] The majority of the analyzed sample of 137 participants (gender: 89 female, 48 male; age: M = 19.20, SD = 1.91) self-identified as White/Caucasian (n = 55), North East Asian (n = 32), or multiple ethnicities (n = 16), with other ethnicities reported by fewer than 10% of the sample.

Sample 2b comprised 641 U.S.-based users of Amazon.com's Mechanical Turk reimbursed monetarily for their time ($2.50, based on at a rate of $10/hour with average duration determined via pretesting in the first and second authors' laboratories). Per preregistered exclusion criteria, data from a total of 77 participants were removed from analysis – 14 because their data were incomplete, 7 because they finished in less than 7.5 minutes, 8 because they of technical difficulties during the session, 1 because of 0 variance in the ratings, 8 because they reported learning English as a second language and being fluent in English after the age of 8, and 39 due to narratives that did not include social information in the social condition, included social information in the control condition, or were blank or task-irrelevant. The majority of the analyzed sample of 564 participants (gender: 268 female, 296 male; age: M = 35.41, SD = 10.54) self-identified as White/Caucasian (n = 425), with other ethnicities reported by fewer than 10% of the sample. Per the rationale in Study 1, our aim was to obtain a sample of 280 participants per condition. Though time constraints limited the size of Sample 2a, we achieved this target for the Sample 2b control condition and very nearly did so for the Sample 2b social condition.

Procedure. Participants were randomly assigned to the social (Sample 2a: n = 58, Sample 2b: n = 271) or control (Sample 2a: n = 79, Sample 2b: n = 293) conditions. Participants completed the same similarity-rating task used in Study 1 with one modification.

Interspersed throughout the similarity-rating task (prior to the initial word judgment and then after every 20th-21st trial), participants completed six trials of a video task in which they viewed the short videos selected based on the pretest reported above. After viewing each video, participants wrote short narratives describing the content of the video. Narratives were coded as in the pretest by a research assistant. As noted above, data from 3 participants in Sample 2a and 39 in Sample 2b were excluded on the basis of narratives. As such, all analysis was carried out on data for which the social videos were effective in priming social information and the control videos did not prime social information.

Data Analysis Strategy. The analysis strategy for Study 2 mirrored that of Study 1. In Sample 2a, 17 trials from 14 participants were removed because of participants' low familiarity with the words; of these, 11 participants were unfamiliar with one word and 3 were unfamiliar with two words. In Sample 2b, 40 trials from 24 participants were removed based on this criterion. Of these participants, 15 were unfamiliar with one word, 5 were unfamiliar with two words, 1 was unfamiliar with three words, and 3 were unfamiliar with four words. When those trials were removed, familiarity ratings indicated high familiarity with the stimuli (Sample 2a: $M = 6.60$, $SD = 0.90$, median = 7, IQR = 0; Sample 2b: $M = 6.65$, $SD = 0.73$, median = 7, IQR = 0).

Analyses were implemented in SAS (v9.4) using PROC MDS. MDS solutions were computed for the social and control conditions separately using the raw data matrices (i.e., individual level) and both the S-Stress and Stress-1 calculations. While readers may be more familiar with S-Stress calculations, given that the Stress-1 calculations allow for the distance between points to be interpreted as reflecting the extent to which two points are conceptually related (with smaller distances reflecting greater similarity), we present only Stress-1 figures here. S-Stress figures are available in the Supplementary Materials. Stress-by-dimensionality plots were inspected to determine the number of dimensions present.

Results and Discussion

Regardless of whether stress was calculated by absolute distances (Stress-1) or minimizing squared distances (S-Stress, see Supplemental Figure S1), the stress-by-dimensionality plots for both Samples 2a and 2b indicated solutions with two dimensions for both the social and control conditions (Figures 2). For both samples, across both conditions, and in both solutions, ordering of the emotions indicated that one dimension corresponded with "valence" (the first, represented horizontally) and another with "arousal" (the second, represented vertically) (see Figure 3; and Supplementary Figures S2). RSQ values for the two dimension solutions were high: 0.95 for both conditions in Sample 2a and 0.96 for the social condition and 0.97 for the control condition in Sample 2b (Stress-1). The ordering of words across the derived two-dimensional spaces was highly consistent across the social and control conditions. As in Study 1, we inspected the third dimensions of the social and control condition solutions for interpretability (see Table 2). Once again, the third dimensions were largely non-interpretable and did not appear to capture the socialness of emotions nor other dimensions observed in past research.

General Discussion

Across two studies, we demonstrated that valence and arousal are the organizing dimensions of affective space, even when terms representing theoretically social emotions were included (Studies 1 and 2) and when social information was primed (Study 2). Studies evaluating the fundamental properties of emotion are only as valid as the stimuli that are included in them—for example, if a study included only negative emotions, a valence dimension might not emerge. In this view, we posited that a dimension representing the social nature of emotion has not emerged in previous analyses of the structure of affective space because social emotion terms were not evaluated (but see, Condon & Barrett, 2013; Kgantsi, Fontaine, & Temane, 2015; Veirman & Fontaine, 2015). The goal of the social priming task deployed in Study 2, as articulated, was to orient participants to think about other people by watching a brief video and writing about it. We excluded data from the few participants in the

social priming condition who did not mention people and from the few participants in the control condition who did mention people (Study 2a: 1.8%; Study 2b: 6.1%). There is no doubt that there are many different varieties of social experience, and thus many ways to prime socialness, but our priming manipulation worked as designed – to ensure that the concept of people was activated in the minds of participants in the social condition.

Inclusion of terms thought to capture highly social emotions did not result in the emergence of another dimension (representing socialness) or a reorganization of the primary two dimensions observed. Rather, we replicated evidence from the literature suggesting that the structure of affective space is best captured by two dimensions (for reviews, see Barrett & Bliss-Moreau, 2009; Barrett & Russell, 1999; Fontaine et al., 2007; Kuppens, Tuerlinckx, Russell, & Barrett, 2013; Mattek, Woldford, & Whalen, 2017; Russell, 1980). Further, and perhaps a more robust of this hypothesis, we found that activating social information did not lead to the emergence of a socialness dimension – or even a substantial reorganization of emotions in valence-based and arousal-based affective space. Instead, as per a long history of extant studies, valence and arousal – and only valence and arousal – were identified as the fundamental properties of affective space and the organization of terms in that affective space was highly consistent across studies and statistical solutions.

While our results suggest that valence and arousal are the fundamental properties of affective space, other dimensions have emerged in other studies (e.g., potency, dominance, and power: Fontaine et al., 2002; 2007; Jonker et al., 2011; Osgood, 1969; Russell & Mehrabian, 1977; Veirman & Fontaine, 2015; Gentsch et al., 2018; predictability: Fontaine et al., 2007; Veirman & Fontaine, 2015; novelty: Gentsch et al., 2018; Veirman & Fontaine, 2015). Dimensions relating to dominance may capture variance related to social life, although the failure for dominance dimensions to emerge consistently across the studies reported here suggests that it may not be a fundamental or universal property of affect or emotion. Additionally, human social life includes potent social features other than dominance (e.g.,

affiliation) and, as mentioned above, arguments about what makes theoretically social emotions "social" include many social processes other than dominance (e.g., fairness; Hareli & Parkinson, 2008).

Work documenting other dimensions of affective space has deployed a wide variety of tasks (e.g., similarity ratings, similarity sorting, feature ratings, relevance ratings) with a variety of samples (e.g., children, adolescents, adults, university students, community samples) who speak a variety of languages (e.g., English, Indonesian, Dutch, French, Afrikaans). Any of these methodological features could plausibly lead to differences in the emergence of higher-order dimensions beyond valence and arousal. Of note, in all but one study (Kgantsi et al., 2015), valence and arousal emerged as dimensions – suggesting that valence and arousal are likely universal, with other dimensions emerging based on the methodological approaches or the cultural contexts in which the work was conducted. Consistent with the impervious nature of valence and arousal in organizing affective space is the finding that priming social information in Study 2 did not result in the emergence of an additional dimension, nor a shift in the relative placement of words within the identified affective space. These findings are therefore consistent with the idea that similarity ratings that produce two-dimensional affective space reflect prototypical definitions of emotion, which are impervious to momentary manipulation (Condon & Barrett, 2013; Gentsch et al., 2018), but may be bound by culture and language. Understanding the conditions under which different dimensions of affective space emerge will help shed light on the mechanism that drives variation across samples and methodologies.

Valence and arousal may be important for organizing psychological phenomena other than emotions, as well. Evidence exists that the neural basis of mind perception organizes along three dimensions (Tamir et al., 2016). The authors call these dimensions *rationality* (capturing variance in mental states that reflect plan-full cognitive activities at one end of the dimension and emotive activities at the other), *valence* (capturing variance in mental states

that reflect negative states at one end of the dimension and positive states at the other) and *social impact* (capturing variance in mental states that reflects highly arousing social mental states at one end of the continuum and neutral arousal nonsocial states at the other). Tamir and colleagues' social impact dimension therefore reflects a blend of arousal and social information. While the theoretically social emotions in our study did not map onto the arousal dimension in a way that is suggestive of a similar blend, one possibility for which we are accumulating evidence is that the perception of social others (as was required in Tamir et al., 2016) is never truly neutral (Bliss-Moreau, Bauman, & Amaral, 2011; Bliss-Moreau, Moadab, & Machado, 2017). In this view, social others engaged in behavior that is not indicative of valence or arousal are cause for further processing or vigilance, rather than being ignored as would be predicted if they were neutral in valence or arousal (i.e., not relevant for allostasis; Bliss-Moreau et al., 2017). This is consistent with the present findings that, in the pretest prior to paring, social prime stimuli were rated, overall, to be more arousing than nonsocial prime stimuli.

By using two different measures of stress when conducting the MDS analysis we also demonstrated that the classically observed circumplex – with emotions distributed around the outside of a circle and open space around the axes intersection – may be a confound of the method rather than the organization of affective space per se. Using a stress calculation (*S-stress*) commonly utilized in the affect circumplex literature (e.g., Feldman, 1995) produced a circular ordering of terms around an open central space. By modifying the stress calculation (to *Stress-1*) so that the space between points can be interpreted as distance in conceptual space, emotion words spread across the entire circumplex structure, filling all but the most central dimensional space. The fact that different structures emerged as a result of varying the statistical approach suggests that the circular structure of affect so ubiquitous in the literature (see Russell, 1980; Barrett & Bliss-Moreau, 2009 for reviews) may reflect mathematical rather than psychological reality. This finding may be particularly important for interpreting

reports of emotional experience. While similarity judgments such as those made by participants in the studies reported here provide information about how participants conceptualize emotion words, affect dimensions can also be extracted from reports of emotional experience. Typically, distance from the axis intersection (i.e., the vector length to the emotion term) is interpreted as the intensity of the emotional experience (Russell & Barrett, 1999). That interpretation only makes sense of the central space of the circumplex is not populated with other terms as is the case in the Stress-1 solutions. Researchers interested in the structure of affective space should therefore be careful to ensure that their theoretical conclusions are not biased by the methodological tools they employ.

We also evaluated a novel analytical approach in this field of research: subjecting subsets of similarity ratings directly to MDS analysis despite large amounts of missing data. This approach represents an advance over those that submit average ratings for each comparison to MDS (as per Veirman & Fontaine, 2015), as this latter approach can produce artificially good fitting solutions (Ashby, Maddox, & Lee, 1994). Despite the large amount of missing data per participant in our dataset, the ordering of words on the two dimensions was essentially identical to previous studies in which structures were derived from complete matrices obtained from each participant (e.g., Russell, 1980; for reviews, Barrett & Bliss-Moreau, 2009; Barrett & Russell, 1998). Critically, we replicated this effect in two studies utilizing samples of both university students and community members recruited online – that is to say, we both replicated existing studies and replicated our own findings in two different sample types, even though each participant only completed 123-word pair judgments out of a total of 820 (15%). This suggests that the circumplex solution is not heavily influenced by the large number of missing data points in each participant's matrix.

Of note, many evaluations of the structure of affective space compute participant-level structures using individual-level analyses (such as the Weighted Euclidean procedure in SAS or INDSCAL in SPSS) in order to evaluate individual differences (e.g., Kring et al., 2003; see

also Barrett, 2004)—that is, the extent to which people are oriented to one over the other dimension. Such analyses may not be appropriate using the method deployed in this study because not all participants evaluated the same stimuli. We are currently investigating statistical methods that would allow for the preservation of individual difference qualities from partial datasets.

In conclusion, the studies reported here build upon prior examinations of the structure of affective space by explicitly evaluating the possibility that a third dimension, or further additional dimensions, might emerge as a result of inclusion of words thought to represent emotions highly social in nature (Studies 1 and 2) or as a result of priming social information (Study 2). We demonstrated that two dimensions, valence and arousal, organize affective space even when a broader set of emotional stimuli are considered and that the structure of the circumplex is consistent regardless of whether social information is primed or not. These findings underscore the importance of valence and arousal in the experience and perception of emotion. Further, our results suggest that classic conceptions of the topography of affective space may result from the statistical approach used, rather than reflect psychological organization per se. Nevertheless, given the importance of emotions for social life, future research should investigate how daily life is influenced by the interplay between valence, arousal, and socialness. Future research should examine the extent to which emotions rely on and support social processes, including occurring preferentially in social contexts (with conspecifics present), being felt about or experienced with social others, and relying on neuroanatomical and psychological processes that ground social processing (such as mind perception).

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Footnotes

[1] The formulae for Stress-S is: $\sum_{i<j}\left(d_{ij}^2 - \hat{d}_{ij}^2\right)^2 / \sum_{i<j} \hat{d}_{ij}^4$ and Stress-1 is: $\sqrt{\sum_{i<j}\left(d_{ij} - \hat{d}_{ij}\right)^2 / \sum_{i<j} \hat{d}_{ij}^2}$. d_{ij} is the observed distance between stimuli i,j and $\hat{d}_{ij}$ is the fitted distance between stimuli i,j.

[2] For this and the remaining *t*-test results, confidence interval values represent 95% confidence intervals based on the noncentral *t* distribution (Smithson, 2003), using guidelines outlined by Wuensch (2012).

[3] We unexpectedly found several cases in which participants did not write anything or the content of their narrative was task irrelevant. Despite not preregistering this, we opted to exclude data from participants for whom this was the case in addition to the preregistered criteria regarding the content of the narratives. In Sample 2a, data from one participant in the social priming condition was excluded on this basis. In Sample 2b, data from 11 participants in the social priming condition and 13 in the control condition were excluded on this basis.

Table 1
Distribution of Emotions across the Third Dimension in Study 1

Dimension Weights			
S-Stress		*Stress-1*	
***envious**	-1.37	***jealous**	-1.49
***contemptuous**	-1.32	***envious**	-1.46
***jealous**	-1.32	***contemptuous**	-1.24
amused	-1.12	***proud**	-1.16
***vengeful**	-1.1	***morally elevated**	-1.06
***proud**	-0.97	***admiring**	-1.05
***admiring**	-0.78	***vengeful**	-0.93
***morally elevated**	-0.68	still	-0.57
interested	-0.61	calm	-0.56
content	-0.58	disappointed	-0.51
angry	-0.57	energized	-0.51
sleepy	-0.53	disgusted	-0.49
calm	-0.48	satisfied	-0.48
disgusted	-0.45	interested	-0.47
relaxed	-0.43	content	-0.44
disappointed	-0.38	angry	-0.43
satisfied	-0.38	***morally disgusted**	-0.31
***morally disgusted**	-0.35	sluggish	-0.3
sluggish	-0.28	enthusiastic	-0.24
enthusiastic	-0.1	happy	-0.04
still	-0.09	aroused	0.02
energized	0.05	joyful	0.05
happy	0.09	relaxed	0.12
quiet	0.13	sleepy	0.14
sad	0.18	sad	0.17
joyful	0.22	***appreciated**	0.22
aroused	0.33	***loving**	0.23
***appreciated**	0.35	quiet	0.61
***grieving**	0.6	amused	0.62
***loving**	0.6	***grieving**	0.69
surprised	0.69	***guilty**	0.73
***guilty**	0.74	***grateful**	0.83
***ashamed**	0.8	awed	0.88
hopeful	0.88	***indebted**	0.88
***grateful**	0.9	***ashamed**	0.91
awed	0.92	surprised	0.95
***compassionate**	1.01	afraid	0.99
***embarrassed**	1.24	hopeful	0.99
nervous	1.28	***compassionate**	1.14
afraid	1.34	nervous	1.16
***indebted**	1.51	***embarrassed**	1.41

Note. Theoretically social emotions are denoted by bold font and an asterisk.

Table 2
Distribution of Emotions Across the Third Dimension of the Stress-1 Solution in Study 2

Sample 2a				Sample 2b			
Social Condition		Control Condition		Social Condition		Control Condition	
***envious**	-1.37	***contemptuous**	-1.46	***vengeful**	-1.51	***envious**	-1.49
***jealous**	-1.33	amused	-1.33	angry	-1.26	amused	-1.45
***admiring**	-1.31	***proud**	-1.2	surprised	-1.21	***morally disgusted**	-1.13
awed	-1.22	disgusted	-1.14	energized	-1.2	***morally elevated**	-1.06
***compassionate**	-1.12	***jealous**	-1.1	amused	-1.12	***jealous**	-1.05
***proud**	-1.01	***morally elevated**	-0.95	joyful	-0.89	***proud**	-0.99
interested	-0.85	sleepy	-0.95	happy	-0.88	sleepy	-0.94
***vengeful**	-0.81	angry	-0.93	***contemptuous**	-0.85	angry	-0.81
disappointed	-0.76	***morally disgusted**	-0.84	enthusiastic	-0.78	***vengeful**	-0.81
***loving**	-0.74	aroused	-0.71	aroused	-0.72	energized	-0.73
sleepy	-0.69	satisfied	-0.69	sleepy	-0.7	relaxed	-0.59
enthusiastic	-0.58	***vengeful**	-0.66	satisfied	-0.61	joyful	-0.49
energized	-0.52	sluggish	-0.6	sluggish	-0.61	***contemptuous**	-0.48
angry	-0.43	disappointed	-0.4	***morally disgusted**	-0.57	***admiring**	-0.47
sad	-0.37	joyful	-0.34	content	-0.34	disappointed	-0.41
***grateful**	-0.25	content	-0.3	disgusted	-0.24	content	-0.35
sluggish	-0.19	energized	-0.3	***grieving**	-0.18	aroused	-0.31
***morally disgusted**	-0.17	enthusiastic	-0.3	hopeful	-0.18	sluggish	-0.31
aroused	-0.12	happy	-0.26	***jealous**	-0.14	happy	-0.13
calm	0	surprised	-0.1	afraid	-0.11	satisfied	-0.11
***morally elevated**	0	relaxed	-0.09	interested	-0.09	disgusted	0
happy	0.18	hopeful	-0.02	awed	-0.06	enthusiastic	0.07
***grieving**	0.23	calm	0.08	nervous	0.04	calm	0.14
surprised	0.25	quiet	0.22	calm	0.11	interested	0.14
disgusted	0.32	***ashamed**	0.27	***proud**	0.19	***guilty**	0.22
joyful	0.38	***envious**	0.34	disappointed	0.33	sad	0.3
***ashamed**	0.39	still	0.35	relaxed	0.38	***grateful**	0.34
***appreciated**	0.47	sad	0.39	quiet	0.41	quiet	0.39
relaxed	0.48	interested	0.56	***morally elevated**	0.5	***loving**	0.45
content	0.53	***embarrassed**	0.75	***compassionate**	0.66	surprised	0.55
still	0.54	***appreciated**	0.76	sad	0.66	still	0.64
quiet	0.64	***admiring**	0.79	***admiring**	0.68	***ashamed**	0.67
satisfied	0.66	***grateful**	0.81	***loving**	0.71	hopeful	0.75
nervous	0.82	***loving**	0.82	still	0.91	***grieving**	0.88
afraid	0.85	***guilty**	0.97	***grateful**	0.99	nervous	0.95
***guilty**	0.96	awed	1.01	***guilty**	1.09	awed	0.97
hopeful	1.09	***grieving**	1.02	***embarrassed**	1.13	***appreciated**	1.03
amused	1.12	***compassionate**	1.24	***ashamed**	1.22	***compassionate**	1.28
***indebted**	1.21	afraid	1.29	***appreciated**	1.25	afraid	1.32
***embarrassed**	1.29	nervous	1.29	***envious**	1.28	***embarrassed**	1.35
***contemptuous**	1.42	***indebted**	1.72	***indebted**	1.71	***indebted**	1.72

Note. Theoretically social emotions are denoted by bold font and an asterisk.

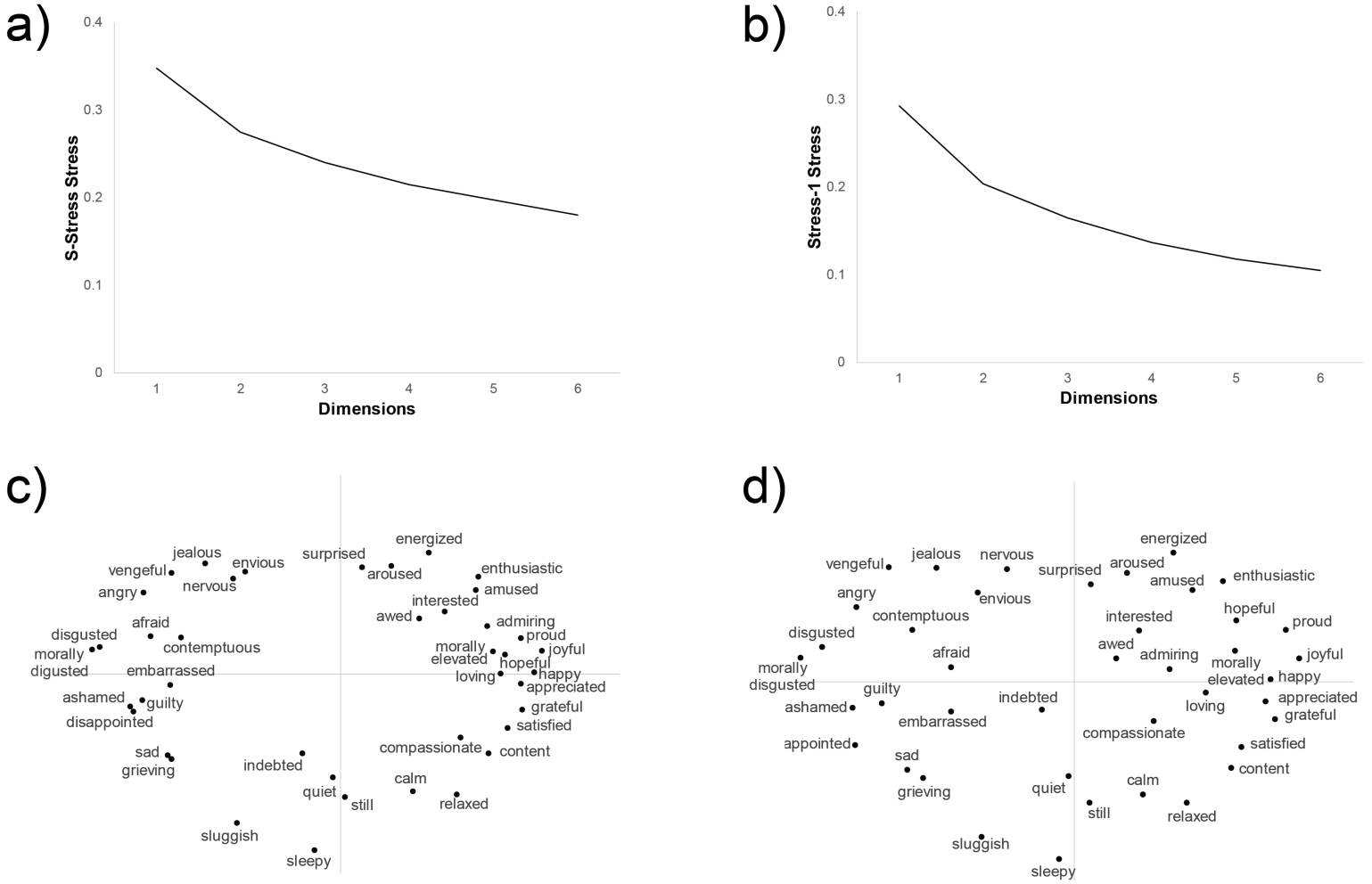

Figure 1. Two-dimension solutions in Study 1. a) *S-Stress*-by-dimensionality plot; b) *Stress-1*-by-dimensionality plot; c) Two-dimensional solution computed with S-Stress; d) Two-dimensional solution computed with Stress-1. *x*- and *y*-axes in c and d are equal length.

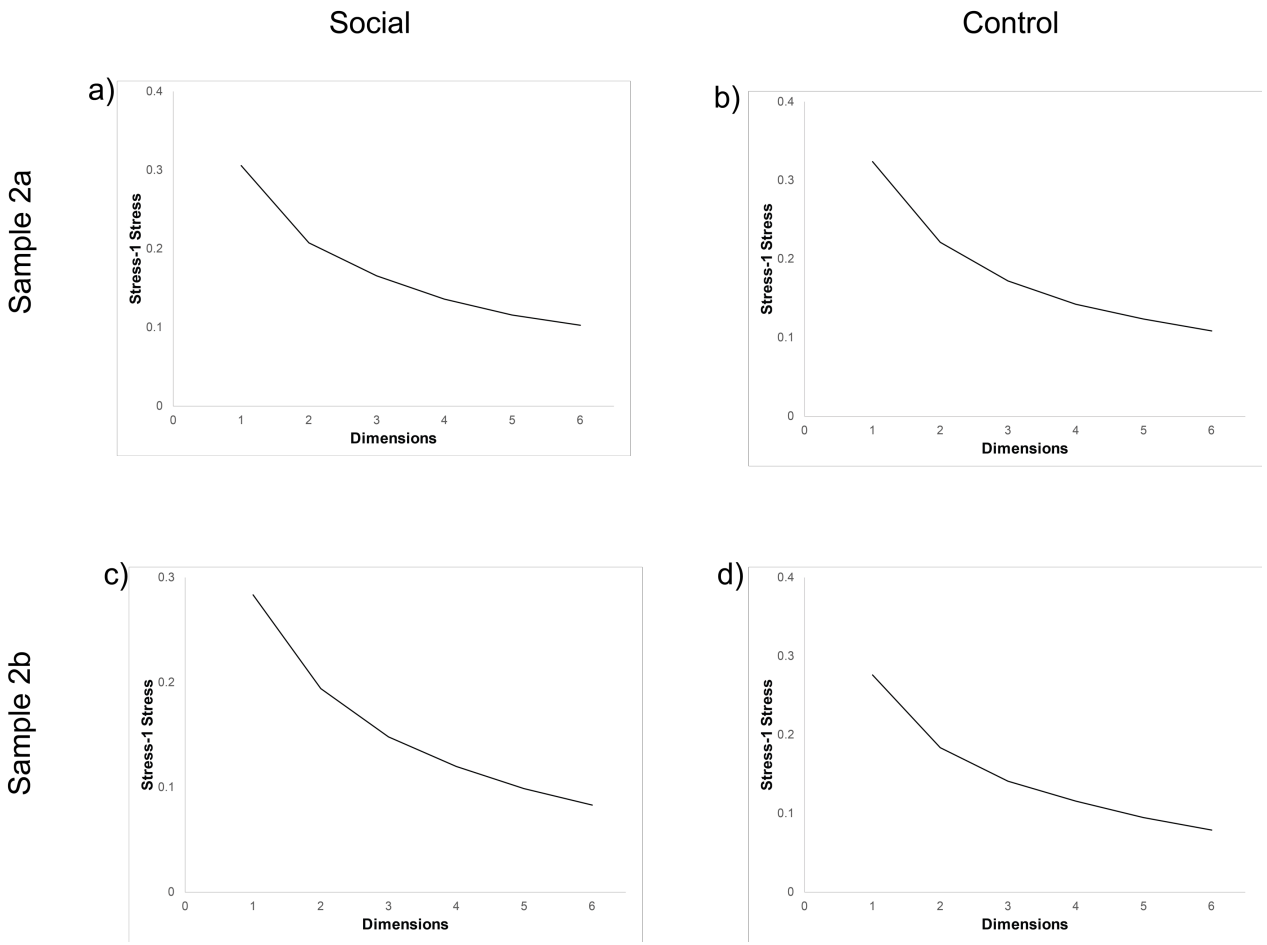

Figure 2. Stress-by-dimensionality plots using Stress-1 for the social (left) and control (right) conditions, for Sample 2a (top, a and b) and Sample 2b (bottom, c and d) in Study 2.

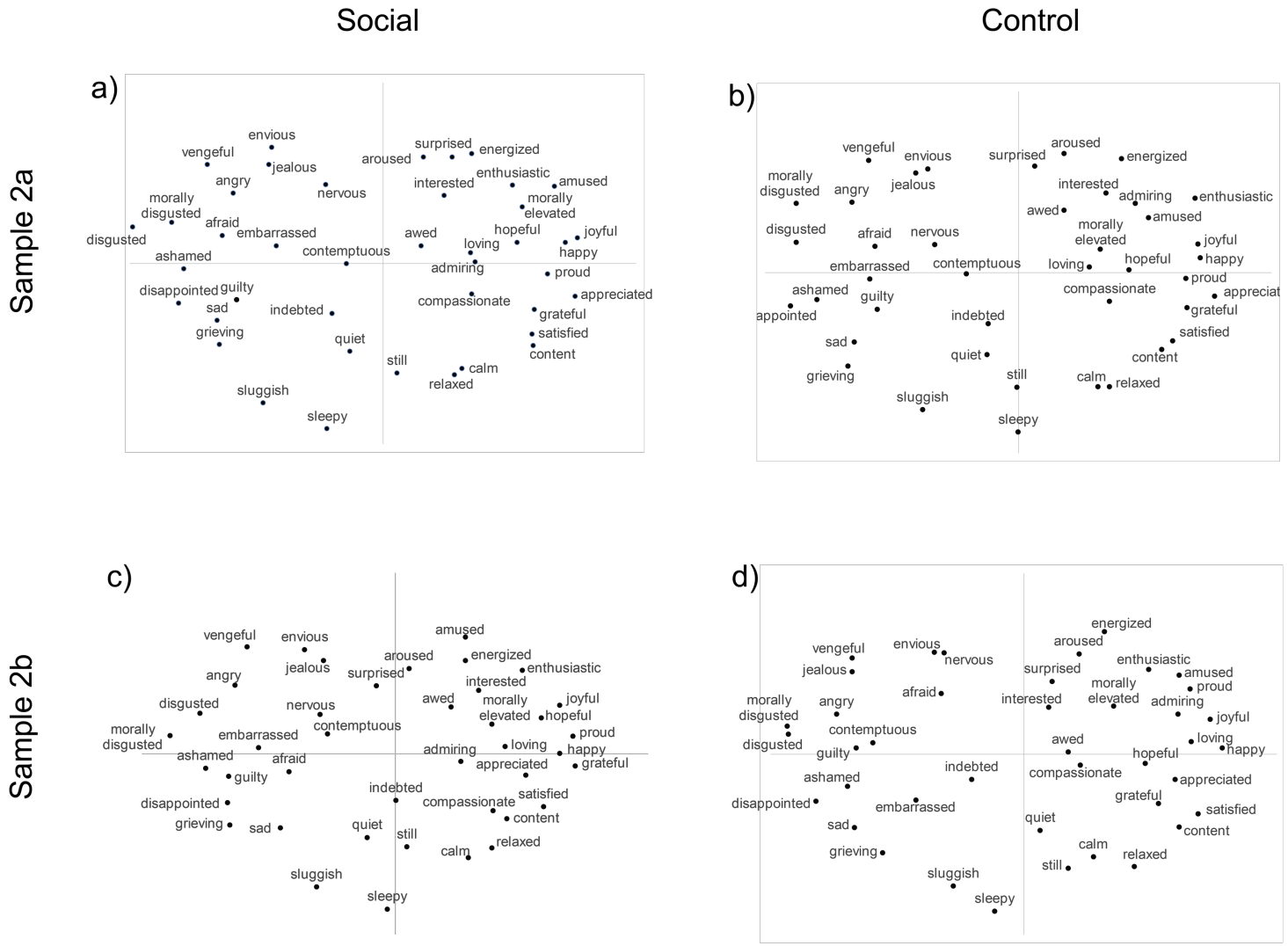

Figure 3. Two-dimensional solutions computed with Stress-1 for the social (left) and control (right) conditions, and for Sample 2a (top, a and b) and Sample 2b (bottom, c and d), in Study 2.

Supplementary Materials

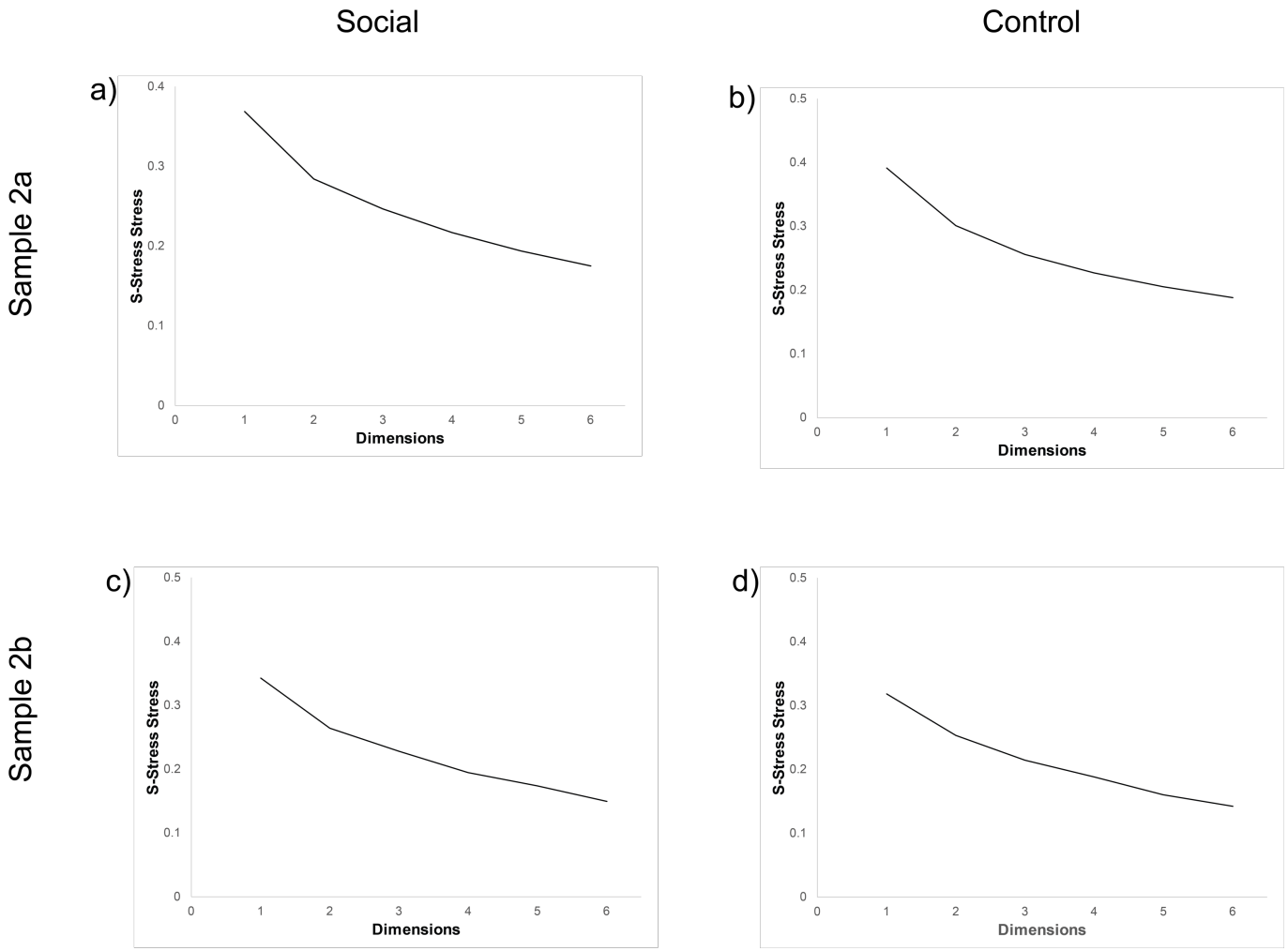

Figure S1. S-Stress x Dimension plots for Sample 2a (top, a and b) and Sample 2b (bottom, c and d). Social conditions are plotted on the right (a and c) and control conditions are plotted on the left (b and d)

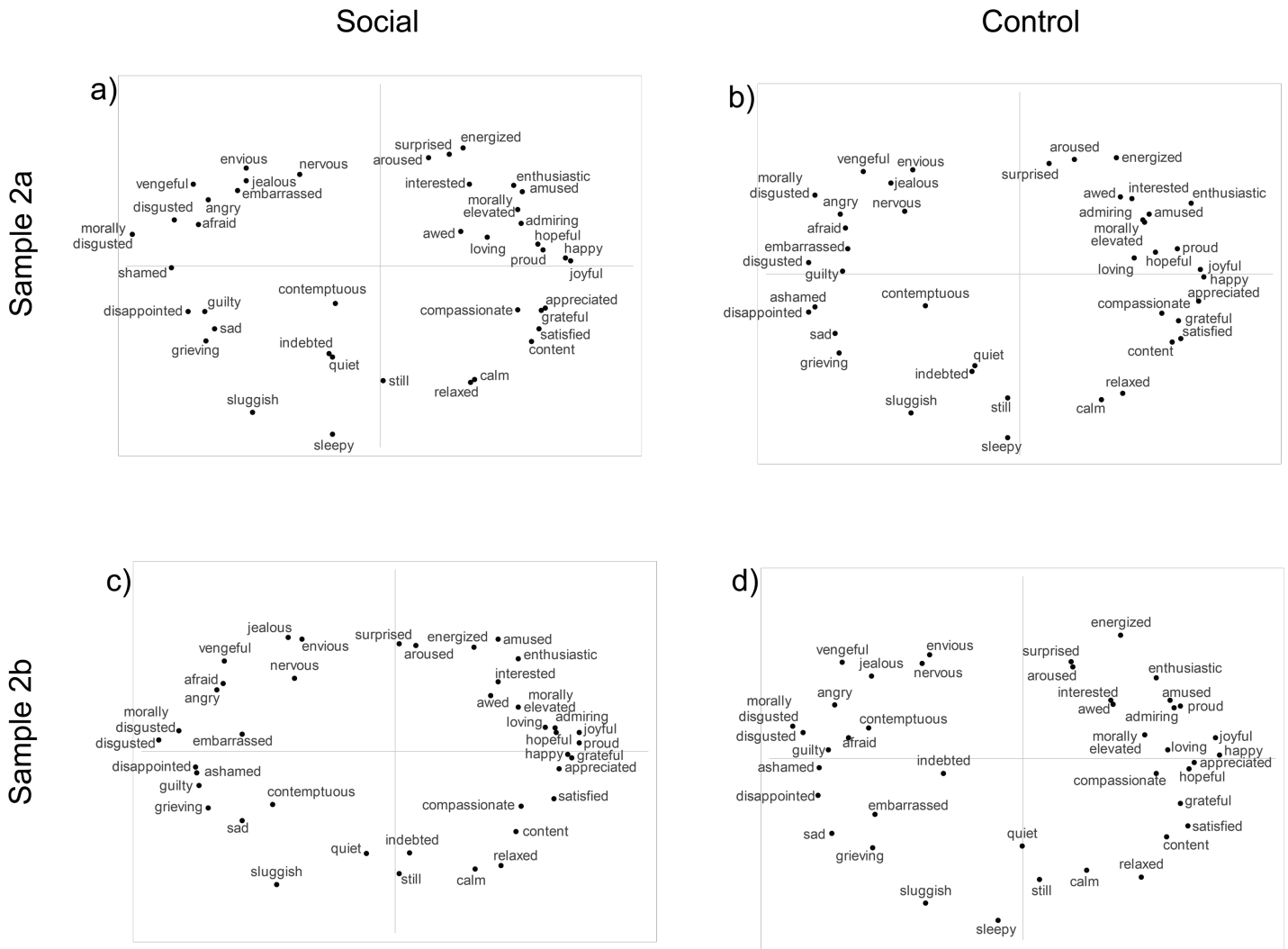

Figure S2. Study 2 Two Dimension Solutions for Sample 2a (top, a and b) and Sample 2b (bottom, c and d). Social conditions are plotted on the right (a and c) and control conditions are plotted on the left (b and d).