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# A comparison of dimensional models of emotion: Evidence from emotions, prototypical events, autobiographical memories, and words

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The intensity and valence of 30 emotion terms, 30 events typical of those emotions, and 30 autobiographical memories cued by those emotions were each rated by different groups of 40 undergraduates. A vector model gave a consistently better account of the data than a circumplex model, both overall and in the absence of high-intensity, neutral valence stimuli. The Positive Activation – Negative Activation (PANA) model could be tested at high levels of activation, where it is identical to the vector model. The results replicated when ratings of arousal were used instead of ratings of intensity for the events and autobiographical memories. A reanalysis of word norms gave further support for the vector and PANA models by demonstrating that neutral valence, high-arousal ratings resulted from the averaging of individual positive and negative valence ratings. Thus, compared to a circumplex model, vector and PANA models provided overall better fits.

***Keywords:*** Autobiographical memory; Emotion; Circumplex; Vector.

One prominent conception of emotion is the dimensional view in which all emotions are characterised by two, or sometimes three, dimensions (Duffy, 1934; Osgood, 1966). Over much theoretical and empirical work, the dimensions include some measure of valence or pleasantness and some measure of intensity or arousal (Watson & Tellegen, 1985). Within the dimensional view, the dominant models are the circumplex model (Russell, 1980; see also Feldman Barrett & Russell, 1998), the "consensual" Positive Activation – Negative Activation (PANA) model (Watson & Tellegen, 1985; Watson, Weise, Vaidya, & Tellegen, 1999), and the vector model (Bradley, Greenwald, Petry, & Lang, 1992). The circumplex model holds that emotions are distributed in space with dimensions of arousal and valence in a circular, or doughnut, pattern centred on medium arousal and neutral valence. The vector model holds that there is an underlying dimension of arousal and a binary choice of valence that determines direction. This results in two vectors that both start at zero arousal and neutral valence and proceed as straight lines, one in a positive and one in a negative valence direction. Figure 1 shows one instantiation of these models assuming intensity is rated from 1 to 7 and valence from –3 to + 3.

One main difference between the circumplex and vector model lies in the possibility of emotions,

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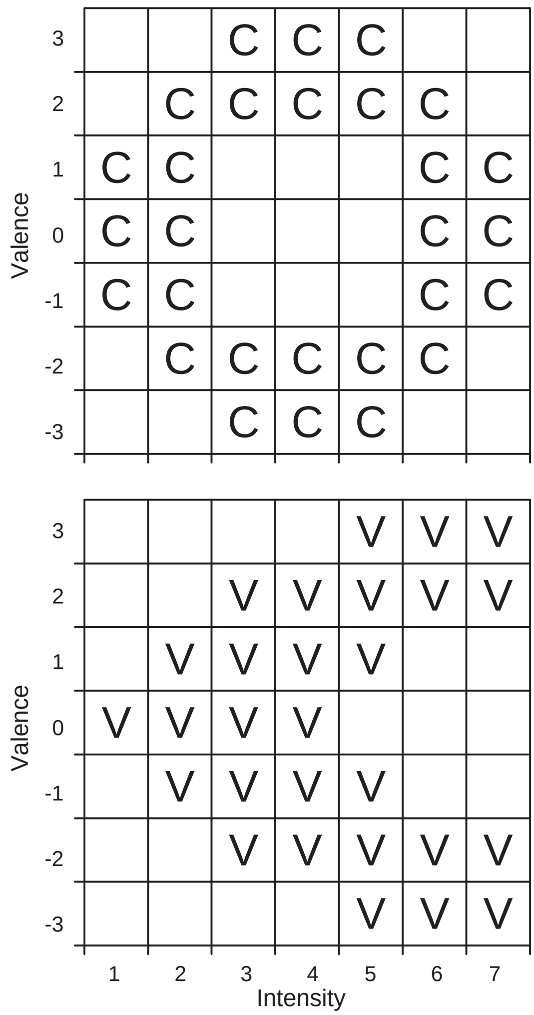


**Figure 1.** Instantiations of a circumplex (top panel) and vector (bottom panel) model. Squares filled with a C represent predictions of where emotional stimuli should occur according to a circumplex model. Squares filled with a V represent predictions of where emotional stimuli should occur according to a vector model.

or emotional stimuli, that have high arousal and neutral valence; that is, are there emotions such as *aroused*, *astonished*, and *excited*, or other emotional stimuli, that are emotionally intense yet neither very positive or negative? Such points are needed to complete the circumplex, but the vector model holds that at high arousal, positive and negative valences are distinct from one another and that true neutrality cannot be intensely felt. Our design deliberately selects emotions that are meant to fill this void and includes three distinct stimulus types. Furthermore, it uses inferential tests to directly compare the fit of each dataset against mathematically specified models.

The PANA model (Watson & Tellegen, 1985; Watson et al., 1999) is commonly understood as a 45-degree rotation of the circumplex model (see Watson & Tellegen, 1985, Fig. 1) defined by two primary axes reflecting two basic behavioural systems. Positive Activation (PA) is anchored at one end by mood terms like *active*, *elated*, and *excited*, and at the other by *drowsy*, *dull*, and *sluggish*. The other axis, Negative Activation (NA), is anchored by *distressed*, *fearful*, *nervous* and by *calm*, *at rest*, and *relaxed*. The axes are not arbitrary for PANA as they provide the best quantitative description under several different factor-analytic techniques. The 45-degree rotation, however, makes no difference for the circumplex model as it is a circle—which end is up is arbitrary. However, we consider PANA to be more similar to the vector model because the axes are "truly unipolar constructs that essentially are defined by their high [ends]" (Watson et al., 1999, p. 827). As with the vector model, low arousal states are more likely to be neutral and high arousal states are differentiated by their valence. When reviewing studies of self-reported affect, Watson and colleagues (1999) note that "the High NA and High PA octants are among the most densely populated areas within [affective] space" (p. 828), which is also consistent with the vector prediction of an absence of high intensity, neutral items. Therefore the predictions of PANA are more similar to a vector model than a circumplex. It is difficult to make clear predictions such as those shown in Figure 1 for all values of intensity or arousal for the PANA model, but for the crucial tests of high intensity or arousal PANA would be like the vector model.

Methodological differences also discriminate the models. The circumplex is usually found in multidimensional scaling (MDS) solutions of similarity matrices of all stimuli or with principal components analysis of self-reports, whereas the vector model typically uses direct scaling of the dimensions of each stimulus individually. We use direct scaling here as it allows for precise dimensions to be articulated, making the testing of the models easier. Rather than having our participants make similarity judgements among all stimuli, which are then transformed by MDS into a two dimensional space, our participants specified directly the intensity (or arousal) and valence and thus the actual location of each of the stimuli in the two-dimensional space. However, direct scaling also provides a fair test of all models, as a main proponent of the circumplex, Russell (1980), compared both MDS and direct-scaling methods and found no difference. The stimuli used to test each model also typically differ. Circumplex models have been identified for emotion words, emotional facial expressions, and affective states (see Remington, Fabrigar, & Visser, 2000, for a review). Vector models typically examine word and picture stimuli (for examples, see Bradley et al., 1992; Bradley & Lang, 1999). In both cases the models are meant to generalise to emotional experience. Here, we use emotion words and two kinds of emotional experience stimuli—semantic knowledge of generic emotional events (e.g., funerals) and episodic memories of personally experienced emotional events (e.g., a specific autobiographical memory of being sad). The same 30 emotion words were used as the emotion terms, to cue memories and to find the general emotional events.

In our studies we had undergraduates rate valence and either intensity or arousal as the two dimensions differ (e.g., Reisenzein, 1994). Arousal is a particular kind of physiological mechanism whereas intensity is the degree of subjective evaluation of feelings. Thus arousal makes theoretical claims based on physiology. In situations where these claims are right, arousal has an advantage; but they are not always right. In research of memory and emotion, physiological arousal alone as induced by physical exercise (Dutton & Carroll, 2001; Libkuman, Nichols-Whitehead, Griffith, & Thomas, 1999) or arousal-inducing drugs such as adrenaline (Christianson & Mjöerndal, 1985) does not increase memory performance. In autobiographical memory the intensity of emotions predicts increased recall (Talarico, LaBar, & Rubin, 2004) in situations where physiological arousal is low but depth of feeling is high, such as in memories of loneliness.

Intensity has a long history as one of the dimensions of emotional stimuli (Duffy, 1934, 1957) and is widely used outside formal models of affect because it is a more general term. It is the dimension used in the autobiographical memory literature (for a review see Talarico et al., 2004) and in some clinical situations. For instance, to have post-traumatic stress disorder it is necessary that "the person's response involved intense fear, helplessness, or horror" (American Psychiatric Association, 2000, p. 468). The intensity, rather than arousal, is noted in the diagnosis; physiological arousal is low for helplessness. Thus we explore both intensity and arousal in our studies.

Our earlier autobiographical memory data (Talarico et al., 2004) had strongly favoured the vector model. Here we extend that study in two ways. First, we examine whether it extends to abstract emotions and typical situations that are evoked by those emotions. That is, we examine semantic knowledge as well as episodic memory. Second, we were concerned that our earlier work unintentionally favoured the vector model because it might have lacked enough neutral valence emotions, especially those of high arousal, despite our efforts to include them (also see Watson & Tellegen, 1985, p. 221). We therefore biased our stimuli to try to find a set of emotion terms that would result in a circumplex when their average values on intensity and valence were plotted. We started with the emotions used by Talarico and colleagues (2004) and added what we expected to be relatively neutral valence emotions of high or low intensity that could help complete a circumplex: alarmed, aroused, astonished, droopy, eager, interested, relaxed, sleepy, and tired. We then had undergraduates do ratings of valence and intensity (Study 1) or valence and arousal (Study 2) for three types of stimuli: the words used to label emotions, prototypical events related to the emotions, and autobiographical memories cued by the emotions. Thus, we investigated semantic knowledge for emotions, semantic knowledge of events, and episodic memory. Finally, in the discussion we reanalyse existing word norms to extend our findings with emotion words.

## STUDY 1: INTENSITY AND VALENCE

### Method

*General.* In each of our three conditions, 40 different Duke University undergraduates were asked to rate 30 emotion related stimuli on 7-point rating scales for pleasantness, unpleasantness, and emotional intensity (adapted from Talarico et al. 2004). We subtracted the ratings of unpleasantness from the ratings of pleasantness and divided by two to provide a rating of valence. The emotions were chosen from previously published studies of emotion (primarily from Russell, 1980, and Watson & Tellegen, 1985) specifically to include emotions of high and low intensity, positive, negative, and neutral valence. Four different random orders of stimuli and their reverses were generated, with the only rule being that the last two stimuli for each of the eight lists were positive to avoid a negative mood induction. The emotions and their respective events were: afraid, being alone at night; alarmed, hearing an unexplained noise; amused, watching a comedy; angry, arguing with a friend; annoyed, someone interrupting; anxious, taking a test; aroused, taking off in an aeroplane; ashamed, telling a lie; astonished, witnessing a rare event; bored, sitting in a lecture; calm, being on vacation; disappointed, getting a bad grade; disgusted, vomiting; droopy, slouching in a chair; eager, waiting for test results; embarrassed, falling in public; excited, accepting a gift; guilty, stealing; happy, celebrating a holiday; interested, learning new things; lonely, breaking up with someone; love, going out with someone; proud, winning; relaxed, getting a massage; relieved, completing a project; sad, attending a funeral; satisfied, eating a large meal; sleepy, staying up late; surprised, receiving an unplanned visit; tired, finishing a workout. These events were the most commonly occurring autobiographical memory responses to emotion cues in previous testing.

*Emotion condition*. For each word, participants ($M = 19.0$ years old, 23 males) were asked to "Think about that emotion for a minute or so until you have indeed remembered the meaning of the word in its entirety and to its fullest emotion." The introductions to the rating scales were "While thinking about this word, I feel that the emotion is positive/negative/intense." The valence scales were: "1 not at all, 3 hardly, 5 somewhat, and 7 entirely". The intensity scale was "1 not at all, 3 somewhat, 5 very, and 7 extremely". The introductions to the rating scales were changed only to reflect the content of the cue for the other conditions.

*Event condition*. Participants ($M = 19.3$ years old, 12 males) were asked to rate the 30 distinct emotional situations above. For each cue, participants were asked, "Please do NOT think of a specific instance of each event from your own life, but rather what events like this are typically like."

*Autobiographical condition*. Participants ($M =$ 19.2 years old, 16 males) were asked to recall and rate 30 distinct emotional autobiographical events cued by the emotion words above. Participants were asked to "recall the first memory from your life that comes to mind when you experienced a number of different emotions". For each cue, the instructions contained the request to: "Please think about a specific event when you felt ____."

## Results

Figure 1 is our instantiation of circumplex and vector models. It provides a direct, easily interpretable view of our instantiation of the circumplex and vector theories, one that is more specific than the descriptive theories themselves. In the general statement of the theories, the exact shape of the circumplex circle and vectors are not specified. The centre, but not radius, of the circumplex is specified. The general direction, but not the angle and magnitude, of vectors is specified. Although somewhat arbitrary, Figure 1 has several advantages. First, it is a neutral, quantitative instantiation of the theories that can be tested directly against the individual responses of the participants. The more standard approach is to average similarity ratings across participants and compare the resulting multidimensional scaling solutions to the theories. Second, the crucial theoretical difference between the existence or absence of high intensity neutral emotions is preserved. Third, as drawn, both models predict emotions in 28 of the 49 cells and thus both have the same .57 probability of having randomly placed points fit the models. Fourth, the models are balanced with respect to the marginal distribution of valence ratings: each model has three cells predicted in rows with valence equal to $\pm 3$, five cell in rows with valence equal to $\pm 2$, and four cells in rows with valence equal to 0 and $\pm 1$. Thus, comparisons of the models are not affected by whether the participants tend to use extreme values of valence or not, only which exact squares they choose. We could not also balance the marginals for intensity, but instead provide an additional test that only uses high-intensity responses.

Fitting the constraints just listed within the seven by seven matrix that results from using common 7-point rating scales for valence and intensity provides the one obvious solution shown in Figure 1. For instance, one could consider making the nine square void in the middle of the circumplex smaller, but that would require reducing it to be only one square. This would also require the removal of eight marked squares elsewhere in the circumplex model or adding eight marked squares to the vector model so that both would have an equivalent base rate. Nonetheless, because of the necessarily arbitrary nature of our particular instantiation of these theories that are not as specific as our models, for all tests of the overall fit of the circumplex and vector models shown in Figure 1, we also provide a much more constrained test using only high-intensity ratings. Although the theories are less specific than our models, at high intensities they are both better defined. Fortunately, the results from these high-intensity only tests differentiate the models as least as clearly as the overall tests using the entire models.

To test and contrast the two models, each individual participant's responses were compared to the two models before any calculations over participants took place. To do this the proportion of responses from each participant that fell in the squares shown for each model in Figure 1 were calculated and this proportion was entered into a 2 (within-participant fit to each model: vector or circumplex) by 3 (between-participant condition: emotion, event, or autobiographical) ANOVA. The effect of vector versus circumplex was $F(1, 117) = 98.49$, $p < .0001$, and there was no effect of condition ($F(2, 117) = 1.98$, $p = 0.14$) nor their interaction ($F(2, 117) = 0.07$, $p = .47$). For the emotion condition the proportions for the vector and circumplex model were .73 versus .56; for the event condition .78 versus .57; and for the autobiographical condition .81 versus .57. Overall the circumplex was near the chance value of .57 and the vector was well above chance: $t$-tests comparing the vector model means to a chance level of .57 were all significant—minimum $t(39) = 7.10$, all $p < .0001$—for the circumplex model none was.

The key place in which the vector versus circumplex models differ is in their prediction of high-intensity neutral valence emotions; a circumplex model requires them, a vector model denies their existence. The PANA model agrees with the vector model. We included the following as examples of high-intensity or arousal emotions that could have neutral valence to afford the opportunity to observe such ratings: aroused, astonished, eager, excited, and interested. Examining the high intensity cells of Figure 1 (i.e., the rightmost two columns), there are six cells that are predicted only by the circumplex model, six cells predicted only by the vector and PANA models and two cells that both models predict. We counted the number of responses in each of the six cells each model predicted uniquely for each participant and divided by the total number of high-intensity responses that the participant made. As there are 6 out of a possible 14 high intensity cells predicted, chance would be .43. We repeated the analysis reported in the previous paragraph, but this time only for the proportion of high-intensity responses. This reduced the number of observations per participant from 30 to an average of 8.5 and made the data a bit noisier, although still consistent with the previous analysis. The effect of the vector versus circumplex model was $F(1, 115) = 48.55$, $p < .0001$, and there was no effect of condition ($F(2, 117) = 1.38$, $p = 0.26$) nor their interaction ($F(2, 117) = 1.43$, $p = .24$). For the emotion condition the proportions for the vector and circumplex model were .54 versus .28; for the event condition .51 versus .27; and for the autobiographical condition .57 versus .17. For all three conditions the vector value was numerically above the chance level of .43, $t(38) = 2.29$, $p < .05$; $t(39) = 1.71$, $p = .09$; and $t(38) = 3.19$, $p < .01$, respectively, and the circumplex significantly below the .43 chance level (minimum absolute level of $t = 3.66$, all $p < .001$).

## STUDY 2: AROUSAL AND VALENCE

### Method

Study 2 was a direct replication of Study 1, except that the rating of intensity was replaced by a rating of arousal, ''While thinking about this word/situation/event, I feel that the emotion is arousing'', which ranged from 1 not at all to 7 extremely. As in Study 1 there were 40 different participants in the emotion, event, and autobiographical conditions. The mean ages for the emotion, event, and autobiographical condition were 18.8, 18.6, and 18.9 years (13, 9, and 14 males), respectively.

### Results

The effect of vector versus circumplex was $F(1, 117) = 8.87$, $p < .01$, and there was no effect of condition ($F(2, 117) = 1.26$, $p = 0.29$) nor their interaction ($F(2, 117) = 1.26$, $p = .29$). For the emotion condition the proportions for the vector and circumplex model were .57 versus .55; for the event condition .61 versus .51; and for the autobiographical condition .65 versus .58. Unlike in the intensity data, the means for the vector and circumplex models in the analyses based on arousal were much closer for the emotion condition than for the event or autobiographical conditions. Thus, in spite of a lack of an interaction, we examined each of the emotion, event, and autobiographical conditions separately. The $F$-tests for the vector and circumplex model were $F(1, 39) = 0.36$, $p = .55$, $F(1, 39) = 5.29$, $p < .05$, and $F(1, 39) = 4.63$, $p < .05$, respectively. Compared to the chance value of .57, the vector model was significantly better for the autobiographical condition, $t(39) = 2.55$, $p < .05$, and the circumplex model was worse for the event condition, $t(39) = 2.80$, $p < .01$.

The analyses based on proportion of high-arousal responses reduced the number of observations per participant from 30 to an average of 5.6, but the results were more robust. The effect of the vector versus circumplex model was $F(1, 98) = 34.82$, $p < .0001$, and there was no effect of condition ($F(2, 117) = 0.15$, $p = 0.86$), but there was an interaction ($F(2, 117) = 3.79$, $p = .05$). For the emotion condition the proportions for the vector and circumplex model were .44 versus .33; for the event condition .62 versus .18; and for the autobiographical condition .59 versus .20. For these three conditions the $F$-tests for the vector and circumplex model were $F(1, 35) = 1.57$, $p = .22$, $F(1, 27) = 16.38$, $p < .001$, and $F(1, 36) = 23.34$, $p < .0001$, respectively. The vector value was above chance for the event and autobiographical conditions, $t(27) = 3.02$, $p < .01$, and $t(36) = 3.15$, $p < .01$, respectively, and the circumplex below chance for the emotion, event, and autobiographical conditions (the minimum absolute level of $t = 2.05$, all $p < .05$).

Thus, in both analyses, the two models were not statistically different for the emotion word ratings, which are closest to the stimuli that Russell (1980) used. However, the vector model was statistically superior for both the semantic situations and the autobiographical memory stimuli. Although a vector model is better supported than a circumplex model for semantic and episodic experiences, with linguistic stimuli, the trend is less clear. Therefore, we turn our attention to a larger word set than just emotion terms to further test the two models.

## DISCUSSION

We found that a vector model was usually a better quantitative predictor of our data than a circumplex model in spite of our attempts to include circumplex-specific high-intensity, neutral valence emotions. This held for judgements of intensity and valence of the semantic concepts of emotions, for prototypical emotional events, and for autobiographical memories cued by the emotions. It also held for judgements of arousal and valence of prototypical events, autobiographical memories. We confirmed the predictions of PANA and vector models that high-intensity stimuli have either positive or negative, rather than neutral valence. We also failed to find examples of high-intensity, neutral stimuli predicted by the circumplex model, as have previous investigators (Remington et al., 2000).

One of the most widely used norms of the emotional properties of words allowed us to further test our ideas. The Affective Norms for English Words (ANEW, Bradley & Lang, 1999) provides means and standard deviations of the ratings of arousal (1 to 9) and valence (1 to 9) of 1034 words. When plotted in affective space, these data clearly favour a vector model, but there are still many instances of high-arousal, neutral valence words that do not fit the vector model. To further investigate this we selected all 269 words of relatively neutral mean valence in the ANEW norms (all words between 4 and 6, where 5 was neutral). If the vector model holds for individual responses then the neutral valence words of low intensity should have resulted from averaging individual ratings that were neutral in valence. In contrast, the neutral valence words of high intensity should have resulted from the averaging of individual ratings that were either positive or negative, but not neutral, in valence. The prediction, then, is that for these neutral valence words the standard deviation of valence should increase with the mean of intensity. The correlation between the standard deviation of valence and the mean of intensity for the 269 neutral words was .60 ($p < .0001$, assuming words are independent observations). To provide a more descriptive idea of the magnitude of this effect, we divided the neutral words into those with intensity less than 3.5 ($n = 35$), between 3.5 and 4.0 ($n = 78$), between 4.0 and 4.5 ($n = 71$), between 4.5 and 5.0 ($n = 34$), between 5.0 and 6.0 ($n = 34$), and greater than 6.0 ($n = 17$). The average standard deviations of valence for these groups were: 1.26, 1.44, 1.59, 1.78, 2.08, and 2.23, respectively, $F(5, 263) = 31.67$, $p < .0001$ assuming words are independent observations. A practical implication is that selecting high-intensity, neutral valence words from norms might be a mistake in that, as predicted by the vector model, such words may not really exist at the level of individual participant responses.

The structure of affective space may differ depending on the specific stimuli studied (Watson et al., 1999). Importantly, our data do not challenge the circumplex model of affect in the domain in which it was primarily developed, emotion concepts defined by valence and arousal (Russell, 1980)—however, it offers no support for it in that case over the vector or PANA models. When studying mood or emotion concepts using arousal and valence as dimensions, our data do not favour either model, but if intensity and valence are being used or if stimuli similar to events, autobiographical memories, or random words are being used, the vector or PANA models are superior.

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