European Journal of Personality
Eur. J. Pers. **14**, 325–345 (2000)

Dimensional Models of Core Affect: A Quantitative Comparison by Means of Structural Equation Modeling

ULRICH SCHIMMACK[1]* and ALEXANDER GROB[2]

[1]*University of Toronto at Mississauga, Canada*
[2]*University of Bonn, Germany*

Abstract

The present article compares dimensional models of affect with each other. The article focuses on the pleasure–arousal model, the energetic and tense arousal model, and a three-dimensional model with separate pleasure–displeasure, awake–tiredness, and tension–relaxation dimensions. The results show that the three-dimensional model cannot be reduced to a two-dimensional model. Problems of the two-dimensional models' reductionism are discussed. We conclude that a three-dimensional description of affect is necessary. However, the three-dimensional model is not sufficient to account for all aspects of the structure of affect. Copyright © 2000 John Wiley & Sons, Ltd.

INTRODUCTION

Since the beginning of psychology the structure of affect has been a topic of controversies. Wundt (1896)—in Leipzig—argued for his well known three-dimensional theory of affective experiences (see Reisenzein, 1992, for a comprehensive review). He proposed that affective experiences are mixtures of six basic feelings. Some of these feelings were considered mutually exclusive so that they were represented as bipolar opposites, namely pleasure–displeasure, tension–relaxation, and arousal–calmness. In contrast, Titchener (1908)—in Cornell—argued that the structure of affect is only one-dimensional because the pleasure–displeasure dimension is the only basic dimension of affect. In a review of this controversy, Beebe-Center (1932) suggested jokingly that the structure of affect might be "three-dimensional in Leipzig but uni-dimensional at Cornell" (p. 67).

One hundred years later one might come to a similar conclusion. The North American literature favors two-dimensional models (e.g. Lang, 1995; Larsen and Diener, 1992; Russell, Weiss and Mendelsohn, 1989; Thayer, 1989; Watson and Clark,

*Correspondence to: Ulrich Schimmack, Department of Psychology, University of Toronto at Mississauga, Erindale College, 3359 Mississauga Road North, Mississauga, Ontario, Canada L5L 1C6; E-mail: uschimma@s.psych.uinc.edu

Received 30 March 1999
Accepted 22 October 1999

1997). In contrast, European researchers from Sweden (Sjöberg, Svensson and Persson, 1979), Britain (Matthews, Jones and Chamberlain, 1990), and Germany (Steyer, Schwenkmezger, Notz and Eid, 1994) favored a three-dimensional model. However, the present cross-Atlantic differences did not create a controversy because the two-dimensional model dominated the affect literature, whereas the three-dimensional model was often ignored. For example, a recent special issue on the structure of affect in the *Journal of Personality and Social Psychology* did not mention this model at all (cf. Diener, 1999). The three major publications supporting the three-dimensional model have been cited 132 times (Sjöberg *et al.*, 1979), 80 times (Matthews *et al.*, 1990), and 13 times (Steyer *et al.*, 1994). In contrast, major publications supporting the two-dimensional models have been cited 721 times (Watson and Tellegen, 1985), 413 times (Russell, 1980), and 178 times (Thayer, 1989).[1] Due to the neglect of the three-dimensional model, there exist virtually no explicit comparisons of two-dimensional models with the three-dimensional model (see Matthews *et al.*, 1990; Schimmack, 1999, for exceptions). The main aim of the present article is to provide a quantitative comparison of the models by testing the fit of these models to actual data.

There are several reasons why researchers in different regions of the world could propose different structural models of affect. One explanation could be that the structure of affect indeed varies across cultures. However, several arguments render this explanation unlikely. First, structural analyses of affect often yield similar results across cultures when the same method is used (Shaver, Wu and Schwartz, 1992). Second, Reisenzein and Schimmack (1999) found that the correlation matrices among mood ratings in different studies are very similar, even though these studies proposed different structural models. The authors proposed that differences in structural models of affect are often due to methodological preferences. For example, historically researchers used the eigenvalue-greater-than-one criterion to determine the number of factors. This approach supported models with up to 12 distinct mood scales (see Schimmack, 1997, for a review). When researchers used the scree test, the same data sets supported a structure with two orthogonal bipolar factors (Watson and Tellegen, 1985). When researchers specified models with three factors that were allowed to covary, the three-dimensional model received support.

We suggest that the use of different methods also explains the discrepancy between US American and European structural models. The European three-dimensional model was found in factor analyses with oblique rotation; these analyses suggested a structure with three correlated dimensions (Figure 1). The bipolar dimensions are marked by pleasure–displeasure, awake–tired, and tension–relaxation. The arrangement of the dimensions in Figure 1 reveals that pleasure–displeasure is positively correlated with awake–tired and negatively correlated with tension–relaxation (Matthews *et al.*, 1990; Steyer *et al.*, 1994). Although Figure 1 displays the three dimensions in a two-dimensional figure, the three-dimensional model implies that a reduction to two dimensions entails a loss of valid information and does not fit the data.

In contrast, US American researchers preferred models with orthogonal factors. These analyses suggested a structure with two factors. It is commonly assumed that different two-dimensional models represent the same two-dimensional space, but

[1] Numbers of citations were taken from the Social Science Citation Index on the Web of Science as of September 1999.

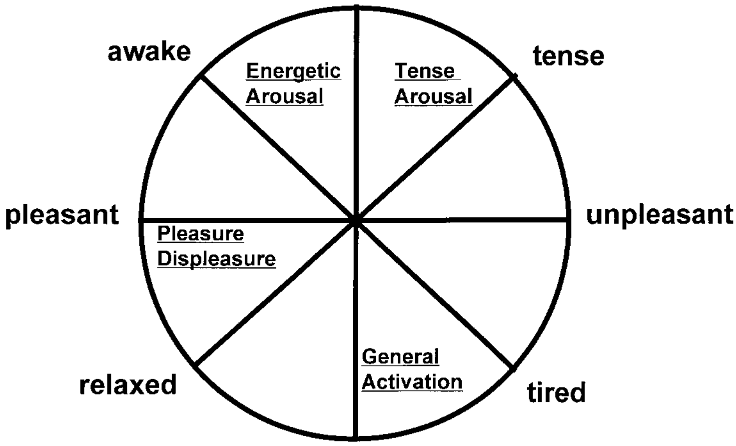

Figure 1. Dimensional models of core affect

consider different sets of dimensions as basic (Russell and Feldman Barrett, 1999). Some researchers describe the structure in terms of a bipolar pleasure–displeasure dimension and an orthogonal arousal dimension, which is called general activation in Figure 1 (e.g. Russell and Feldman Barrett, 1999). Others use a different set of dimensions that are assumed to be a 45° rotation of pleasure–displeasure and general activation. These dimensions are called *energetic arousal* and *tense arousal* (Thayer, 1989; see Figure 1). These models imply that the three dimensions of the European model can be placed into a two-dimensional space because some dimensions are mixtures of other dimensions. The energetic and tense arousal model entails that pleasure–displeasure and general activation are mixture of energetic arousal and tense arousal (Thayer, 1989). In contrast, the pleasure–arousal model proposes that tense and energetic arousal are mixtures of pleasure–displeasure and general activation.

Over the past 15 years affect researchers have focused nearly exclusively on the two-dimensional models and tried to determine which of the two-dimensional models reflects basic dimensions of affect. In other words, it was already taken for granted that the structure of affect is best characterized by two orthogonal dimensions; the remaining question was to determine which rotation reflects the basic components of affective experiences (e.g. Frijda, 1993; Larsen and Diener, 1992; Reisenzein, 1994; Russell and Feldman Barrett, 1999; Watson and Tellegen, 1985). However, recent confirmatory tests of the two-dimensional model undermine the basic assumption that the structure of affect is two dimensional. For example, Watson, Wiese, Vaidya and Tellegen (1999) concluded that "all of the major conceptualizations of the circumplex [i.e. the two-dimensional model] have been found wanting, even after key assumptions (such as equal spacing around the perimeter of the circle) are relaxed. Clearly, the neat schematic depicted in Figure 1 fails to capture the complexity of real-world data" (p. 822). In addition, the two-dimensional models and their operationalizations encounter several other problems (e.g. Larsen and Diener, 1992). We discuss each of these problems in turn and demonstrate how the three-dimensional model solves these problems.

Poor Fit of Two-Dimensional Models to the Data

The major problem of the two-dimensional model is that it does not fit the data. We suggest that the reason for this finding is very simple. Even proponents of two-dimensional models recognize that further dimensions are needed to provide a complete description of affective experiences (Reisenzein, 1994; Russell and Feldman Barrett, 1999; Watson *et al.*, 1999). For example, Reisenzein (1994) noted that two-dimensional models cannot explain the finer distinctions between specific emotions such as anger, envy, disappointment, or love, gratitude, and pride. He proposed that a two-dimensional model might represent the affective core of affective experiences, but that additional non-affective components are needed to account for further distinctions (see also Russell and Feldman Barrett, 1999, for a similar view). The distinction between core dimensions and additional dimensions might account for the poor fit of two-dimensional models when researchers study the structure of emotions (Shaver, Schwartz, Kirson and O'Connor, 1987; Storm and Storm, 1987). However, these results do not refute the possibility that the structure of core affect is two dimensional (Reisenzein, 1994; Russell and Feldman Barrett, 1999).

To test the structure of core affect, researchers first need to select a set of affect words that describe core affects. Schimmack and Siemer (1995) found that lay people distinguish between typical mood descriptors and typical emotion descriptors. For example, relaxed and tense were typical mood words, whereas disgusted and guilty were typical emotion words (see also Reisenzein, 1994). Furthermore, the authors found that mood words and emotion words were distinguished by ratings of intentionality. Emotion words usually imply an object (e.g. I love somebody, I am afraid of dogs), whereas mood words are not directed at objects (e.g. I am relaxed, I am tired). Based on Reisenzein's (1994) model of core affect, Schimmack and Siemer (1995) proposed that typical mood words denote non-intentional affective states that could also be at the affective core of intentional states such as emotions. Hence, a structural analysis of typical mood terms, but not emotion terms, might illuminate the number of basic affect dimensions (see Frijda, 1993; Reisenzein and Schönpflug, 1992; Russell and Feldman Barrett, 1999; Steyer *et al.*, 1994, for similar distinctions).

There also appears to be general agreement regarding descriptors of core affect. For example, Russell and Feldman Barrett (1999) list alert, excited, elated, happy, pleasant, contented, serene, relaxed, calm, fatigued, lethargic, depressed, sad, unpleasant, upset, stressed, nervous, and tense as examples of core affects. This list overlaps with the selection by Steyer *et al.* (1994) of pleasant, unpleasant, awake, tired, relaxed, tense (and close synonyms). In short, there is agreement that at least pleasure, displeasure, tension, relaxation, wakefulness, and tiredness are descriptors of core affect. Two-dimensional models imply that correlations among descriptors of core affect form a two-dimensional space (e.g. Russell and Feldman Barrett, 1999). However, empirical studies show that two-dimensional models do not fit the intercorrelations among descriptors of core affects (Watson *et al.*, 1999). We propose that the poor fit was due to the misrepresentation of some dimensions as mixtures of other dimensions. We propose that energetic and tense arousal are basic dimensions that cannot be reduced to mixtures of pleasure–displeasure and an orthogonal activation dimension. Similarly, we propose that pleasure–displeasure is not a mixture of energetic and tense arousal. All three dimensions are basic affect dimensions that can vary separately from each other. The poor fit of two-dimensional models is due to the false assumption that some dimensions of core affect are mixtures of others.

The Nature of Arousal

One major problem of the pleasure–arousal model is that the arousal dimension is poorly defined. Russell and Feldman Barrett (1999) define the arousal dimension as a unidimensional continuum "ranging from, at the low end, sleep through drowsiness, relaxation, alertness, activation, hyperactivation, and finally, at the opposite end, frenetic excitement" (p. 809). This description of the arousal dimension suggests that arousal varies along a single dimension with tired and relaxation as markers of low arousal and tension and wakefulness as markers of high arousal. In contrast, other models suggest that there exist two separate and largely independent arousal dimensions, awake–tired or energetic arousal, and tense–relaxed or tense arousal (Matthews *et al.*, 1990; Steyer *et al.*, 1994; Thayer, 1989). We suggest that sometimes the poor fit of two-dimensional models is due to the combination of two separate arousal dimensions into a single activation dimension (cf. Watson *et al.*, 1999).

A revised pleasure–arousal model (Russell and Feldman Barrett, 1999) claims the existence of three arousal dimensions. Besides the already familiar energetic and tense arousal dimensions, it postulates a third arousal dimension that is orthogonal to the pleasure–arousal dimension. We call this dimension the *general activation* dimension. This model recognizes that tension–relaxation and wakefulness–tiredness are two separate dimensions. It explains this finding by assuming that energetic arousal reflects a mixture of pleasure and general activation, whereas tense arousal reflects a mixture of displeasure and general activation. As a consequence, it is still a two-dimensional model because two arousal dimensions are merely mixtures of a basic pleasure–displeasure and a basic general activation dimension.

However, this model encounters two new problems. First it has been difficult to find words that describe the general activation dimension. For example, Watson and Tellegen (1985) found only six markers of this dimension, namely aroused, astonished, surprised for high general activation, and quiescent, quiet, and still for low general activation. However, surprised and astonished cannot be considered descriptors of core affect because these are intentional states (Meyer, Reisenzein and Schützwohl, 1997). Surprise can also not be a marker of a basic affect dimension that combines with pleasure to produce wakefulness. This would imply that people are always pleasantly surprised when they are awake. This prediction is inconsistent with the fact that people are much more often awake than surprised. Hence, surprise cannot be a descriptor of a basic affect that is underlying wakefulness because a basic affect has to be present whenever one of its mixtures is present (Reisenzein, 1995). At the low end, *quiet* and *still* are not very typical affect descriptors (Schimmack and Siemer, 1995). Furthermore, Schimmack (1998, unpublished manuscript) found that markers of the general activation dimension often have very low communalities (<0.30). Hence, even items that seem to describe the general activation dimension are only weakly related to this dimension. In short, there is very little support for the existence of a general activation dimension, and it has been difficult to measure it directly (Watson *et al.*, 1999).

Another problem of the revised pleasure–arousal model is its prediction that wakefulness is always pleasant because pleasure is a component of wakefulness, and that tiredness is always unpleasant because displeasure is a component of tiredness.

However, common sense and empirical data (Schimmack, 1999) show that it is possible to feel awake and unpleasant—for example when one needs to sleep but cannot fall asleep—and to feel tired and pleasant—for example after a strenuous and successfully completed task.

The three-dimensional model provides an easy solution to the conceptualization of arousal. First, it recognizes that wakefulness–tiredness and tension–relaxation frequently emerge as separate dimensions (Thayer, 1989; Watson and Tellegen, 1985). Second, it does not postulate a third arousal dimensions that lacks descriptors in everyday language. Third, it does not make the assumption that arousal is intrinsically pleasant or unpleasant. It simply assumes that wakefulness–tiredness and tension–relaxation are two separate arousal dimensions that are not mixtures of other more basic dimensions.

The Nature of Pleasure

Even Wundt and Titchener agreed that pleasure and displeasure are fundamental properties of affective experiences, and most models of affect have maintained this assumption (Frijda, 1999; Ortony, Clore and Collins, 1988; Reisenzein, 1994; Russell and Feldman Barrett, 1999; Steyer *et al*., 1994). The energetic and tense arousal model is a notable exception (Thayer, 1989). This model assumes that pleasure and displeasure are mixtures of two arousal dimensions. Pleasure is characterized as a state of high energetic arousal and low tense arousal, whereas displeasure is a state of high tense arousal and low energetic arousal. Empirical tests of this hypothesis, however, consistently fail to support this prediction (Matthews *et al*., 1990; Schimmack, 1997, 1999; Steyer *et al*., 1994). The three-dimensional model does not make this controversial and unsupported prediction. It recognizes that pleasure–displeasure is a basic dimension of affect, and yet allows for empirical relations between the two arousal dimensions and pleasure–displeasure.

The Unsolved Question of Basic Dimensions

For the past 15 years, researchers have contemplated the question of "which pair of axes [in the two-dimensional model] actually reflects the fundamental, 'basic' dimensions of affect" (Watson *et al*., 1999, p. 828). Proponents of the pleasure–arousal model have stressed that it is easy to define affect words as combinations of pleasure and arousal, whereas it is more difficult to define affect words as combinations of energetic and tense arousal. For example, excitement can be defined as a mixture of pleasure and arousal, but it sounds odd to define pleasure as a combination of wakeful relaxation (Reisenzein, 1994). In contrast, proponents of the alternative model have pointed out that the orthogonal arousal dimension is poorly defined, difficult to measure, and a questionable candidate for a basic affect dimension (Watson *et al*., 1999).

We suggest that both views are limited by the assumption that there can be only two orthogonal basic dimensions. By giving up this restrictive and unsupported assumption, the three-dimensional model captures the appealing aspects of two-dimensional models. First, in line with the pleasure–arousal model, it maintains that pleasure–displeasure is a basic dimension of affect. Second, in line with the energetic and tense arousal model, it maintains the well replicated finding that common descriptors of arousal (i.e. awake, tired, tense, relaxed) vary along two separate dimensions, namely awake–tired and tense–relaxed. The three-dimensional model also avoids the problematic assumptions of two-dimensional models. First, unlike the pleasure–arousal model, it does not postulate a basic, general activation dimension that has no markers in everyday language. Second, it does not assume that awake and tired are intrinsically pleasant or unpleasant. Third, unlike the energetic and tense arousal model, it does not assume that pleasure–displeasure is a mixture of two activation dimensions.

OVERVIEW

We present two studies that test the dimensionality of core affect. For this purpose, we focus on three bipolar dimensions that are common to dimensional models of affect, namely pleasure–displeasure, awake–tiredness, and tension–relaxation. Then we tested the fit of two-dimensional and three-dimensional models to the data. In study 1, we obtained affect ratings at one moment in time. In study 2, we obtained affect ratings on two occasions. This approach has two advantages. First, it allows us to control response styles and systematic measurement error (e.g. Watson *et al.*, 1999). Second, it allows us to explore the relation between changes in different affect dimensions.

We used bipolar indicators of core-affect dimensions for two reasons. First, our main goal was to compare dimensional models of core affect that all postulate bipolar dimensions. Hence, the assumption of bipolarity is shared by all models and does not discriminate between models. Second, it has become clear that Pearson correlations are inappropriate for the test of bipolarity (Eid, Notz, Schwenkmezger and Steyer, 1994; Diener and Iran-Nejad, 1986; Russell and Carroll, 1999; Schimmack, Bockenholt, Reisenzein and Diener, 1999, manuscript submitted for publication). The reason is that even if, for example, pleasure and displeasure were mutually exclusive, the Pearson correlation would not approach a value of -1 for purely mathematical reasons. Furthermore, the exact Pearson correlation depends on the distribution of responses. Hence, a Pearson correlation does not reveal whether two affects are mutually exclusive or not. It is possible that the poor fit of two-dimensional models in previous studies (cf. Watson *et al.*, 1999) was due to the use of unipolar indicators of basic affects. As a consequence, bipolar indicators are more appropriate to test the assumption that some bipolar dimensions represent mixtures of other bipolar dimensions (we return to the bipolarity assumption in the general discussion).

STUDY 1

Method

Participants

Two hundred and seven students (53% females) at the University of Illinois, Urbana-Champaign participated in the study for course credit. The students' average age was 18 years (17 to 24).

Materials and procedure

Participants came to the laboratory in groups of 20 to 30 students. They received a questionnaire package that started with a mood questionnaire. After the first mood assessment, participants completed additional questionnaires. The present article is based on the initial mood ratings. In the instructions, participants were informed that they should report their momentary feelings. Furthermore, participants were instructed to decide first whether they felt a particular affect or not, and to use the lowest response category if they did not feel an affect. These instructions have been used before to reduce the influence of response styles, in particular the tendency to use the middle of the scale regardless of the absence or presence of a particular affect (Schimmack, 1997; Schimmack and Diener, 1997).

The mood questionnaire comprised 84 items. All items were preceded by the phrase "I feel, ...". The mood questionnaire also included two response formats because earlier studies suggested that multiple response formats can help to reduce response styles (Green, Goldman and Salovey, 1993; see also Schimmack, Bockenholt, Reisenzein and Diener, 1999, manuscript submitted for publication). The first 48 items were given with a verbal scale with the response categories *not at all*, *very slightly*, *slightly*, *moderately*, *intensely*, *very intensely*, *maximum intensity*. The second format was a numeric format that ranged from 0 to 15.

Eighteen adjectives of interest were selected on the basis of previous operationalizations of dimensions of core affect. All items were rated on unipolar scales. To obtain bipolar indicators of bipolar dimensions, ratings of one pole were subtracted from ratings of the other pole. This procedure has the advantage that it controls an extremity response style (cf. Schimmack and Diener, 1997). The indicators for pleasure–displeasure (P) were pleasant–unpleasant, good–bad, positive–negative (Cronbach's alpha = 0.90). The indicators for the awake–tiredness (A) dimension were awake–sleepy, wakeful–tired, and alert–drowsy (Cronbach's alpha = 0.91). The indicators for the tension–relaxation dimension (T) were tense–relaxed, clutched up–calm, and jittery–at rest (Cronbach's alpha = 0.83). Subsequently, we use the acronyms P, A, and T to refer to the pleasure–displeasure, awake–tiredness, and tension–relaxation dimensions.

RESULTS

Missing values were replaced by the item mean. Outliers (i.e. values more than three standard deviations above or below the mean) were truncated to values three standard deviations above or below the mean (cf. Tukey, 1977). Preliminary analyses revealed that results did not differ between the two response formats. As we learned after the study was completed, the use of multiple formats is not a suitable way of controlling response styles (Russell and Carroll, 1999; Schimmack *et al.*, 1999, manuscript submitted for publication). As a consequence, we treated the two formats as equivalent. We used common fit indices to evaluate fit of structural equation models, namely chi^2, comparative fit index (CFI), Bentler–Bonnett normed fit index (BBNFI), Bentler–Bonnett non-normed fit index (BBNNFI), and root mean square error of approximation (RMSEA). According to Browne and Cudeck (1993), RMSEA values smaller than 0.05 indicate a close fit, values between 0.05 and 0.08 an acceptable fit, and values greater than 0.10 a poor fit. In addition, we used differences in chi^2 to compare nested models with each other. As noted by Breckler (1990) "a difference in chi-square for the two models is itself a chi-square statistic that indicates whether a model with more free parameters is better able to reproduce the data" (p. 262). BBNNFI can be used to evaluate whether a less parsimonious model provides a substantial improvement in fit over a more parsimonious model (see Reisenzein, 1986, for an example).

Preliminary analyses

We started by testing the equivalence of different scales that are presumed to measure the same construct. First, we compared our pleasure–displeasure scale to the pleasure–displeasure scale of the Semantic Differential (Russell *et al*., 1989). The correlation between these two measures was 0.86. When this correlation was adjusted for reliabilities of the two scales, the correlation was 0.99. The correlations between our awake–tired scale and Thayer's energetic arousal scale was 0.90; our tension–relaxation scale correlated 0.94 with Thayer's tense arousal scale. Adjusted for reliability the estimated correlation coefficient exceeded 1.00. These results show that our measures of core affect dimensions are conceptually similar to scales in previous studies.

Fitting dimensional models

In the first structural equation model, we established a measurement model for the three dimensions. In this model (P–A–T in Table 1), we did not constrain the correlations between the three dimensions. Indicators of each dimension were specified to load only on their respective latent factor. The correlations among error terms were fixed to zero. The model fit was acceptable. This finding demonstrates that we were successful in establishing a measurement model for the three dimensions. The model also provided estimates of the error free correlations between the three dimensions (see Figure 2). P was positively correlated with A and negatively correlated with T; A and T were slightly negatively correlated. This pattern of correlations is consistent with previous findings (Matthews *et al*., 1990; Steyer *et al*., 1994).

In the next model, we tested the assumption that awake–tired and tense–relaxed are indicators of a single activation dimension (model P–AT in Table 1). For this purpose, we constrained the correlation between A and T to 1.00. Given the earlier finding of a negative correlation between A and T, it was not surprising that this model did not fit the data, and that it fitted the data significantly worse than the three-dimensional model. This finding confirms results of earlier exploratory factor analyses that arousal is not a unidimensional construct (Matthews *et al*., 1990; Schimmack, 1999; Steyer *et al*., 1994; Thayer, 1989; Watson and Tellegen, 1985; Watson *et al*., 1999).

The next model tested the assumption that pleasure–displeasure is a mixture of energetic and tense arousal. To test this hypothesis, we established a model with directed paths from A and T to P (model A–T $\rightarrow$ P in Table 1). In other words, the bidirectional paths between P–A and P–T in Figure 2 were converted into unidirectional paths from A to P and T to P. Furthermore, we constrained the amount of explained variance in P to 1.00. This model did not reach an acceptable fit, and a direct comparison to the three-dimensional model revealed that the fit was significantly

Table 1. Fit indices and model comparisons

Model	chi^2	df	*p*	CFI	BBNFI	BBNNFI	RMSEA	AIC
Study 1								
1. P–A–T	36.02	24	0.055	0.990	0.971	0.985	0.050	−11.98
2. P–AT	331.90	25	−0.001	0.742	0.730	0.629	0.244	173.59
3. A–T → P	139.69	25	< 0.001	0.904	0.886	0.861	0.149	80.69
4. P–GA → A–T	130.69	25	< 0.001	0.904	0.886	0.861	0.149	89.69
Model comparison								
1 vs 2	295.88	1	< 0.001	—	−0.241	−0.356	—	—
1 vs 3 & 1 vs 4	103.67	1	< 0.001	—	−0.085	−0.124	—	—
Study 2								
1. Unconstrained model	199.81	111	< 0.001	0.953	0.935	0.902	0.078	−22.19
2. Same factor loadings	203.90	120	< 0.001	0.956	0.943	0.900	0.073	−36.11
3. Same factor loadings and correlations	206.17	123	< 0.001	0.956	0.945	0.899	0.071	−39.83
4. A–T → *P	205.06	121	< 0.001	0.955	0.943	0.899	0.073	−30.04
5. A–T → P	420.03	127	< 0.001	0.841	0.808	0.791	0.133	170.03
6. Change scores	49.10	24	< 0.001	0.966	0.949	0.936	0.089	1.10
7. Change scores with theoretical factor correlations	53.56	27	< 0.001	0.964	0.952	0.931	0.086	−0.035
Model comparison 1 vs 2	4.09	9	> 0.05	—	0.008	−0.002	—	—
1 vs 3	6.36	12	> 0.05	—	0.010	−0.003	—	
4 vs 5	202.97	6	< 0.001	—	−0.135	−0.108	—	—
6 vs 7	4.46	3	> 0.05	—	−0.003	−0.005	—	—

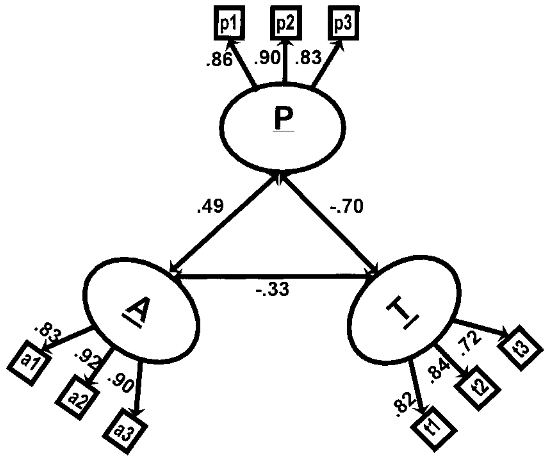

Figure 2. Factor loading pattern and factor intercorrelations of the PAT factors in study 1. *Note*: P = pleasure–displeasure, A = awake–sleepiness, T = tension–relaxation

worse (see Table 1). This finding shows that pleasure–displeasure is not merely a mixture of awake–tired and tense–relaxed. In another model, we allowed the amount of explained variance in P to be estimated. This model fitted the data as well as the three-dimensional model because it is mathematically identical. However, it revealed that A and T explained only 57% of the variance in P. Hence, the energetic and tense arousal model achieves its greater parsimony by failing to account for about half of the variance in pleasure–displeasure.

The following model explored the possibility that the awake–tiredness and tension-relaxation dimension are a mixture of pleasure–displeasure and a general activation dimension. Furthermore, this model did not assume that the general activation dimension has markers in everyday language. For this purpose, we introduced a fourth factor that was not based on directly observed variables. The model postulated that energetic and tense arousal are mixtures of the pleasure–displeasure and the general activation factor and that all of the variance in awake–tiredness and tension–relaxation are explained by pleasure–displeasure and general activation (i.e. the P–GA $\rightarrow$ A–E model). The fit of this model is equivalent to the fit of the previous model because both models make essentially the same prediction that one pair of dimensions is sufficient to capture all of the variance in the PAT dimensions. They only take different dimensions as basic. In other words, the model is merely a rotation of the energetic arousal and tense arousal model (Russell and Feldman Barrett, 1999; Watson and Tellegen, 1985). As a consequence, the revised pleasure–arousal model cannot fit the data better than the energetic and tense arousal model, and it equally fails to account for the correlations among core affect dimensions. However, it was instructive to specify a model that estimated the amount of variance in A and T explained by pleasure–displeasure and general activation. This model revealed that pleasure–displeasure and general activation explained only 26% of the variance in awake–tiredness and 63% of the variance in tension–relaxation. This finding shows that awake–tiredness and tension–relaxation are not merely mixtures of pleasure–displeasure and general activation.

Discussion

Study 1 tested the prediction that the structure of core affect is two dimensional. Various models were tested and repeatedly failed to confirm this prediction. First, we tried to combine awake–tired and tense–relaxed into a single activation dimension. This model did not fit the data because these two dimensions are indeed slightly negatively correlated. Clearly an individual can be awake and relaxed or awake and tense, tired and relaxed or tired and tense. Arousal is not a unidimensional construct. Next, we attempted to explain pleasure–displeasure from combinations of energetic and tense arousal. This model fitted the data somewhat better than the previous model, but the fit indices indicated that it also had to be rejected. Maybe more important, additional analyses revealed that this model neglects about 50% of the valid variance in pleasure–displeasure. We believe that any researcher who is interested in the pleasure–displeasure dimension cannot afford to lose so much information.

Then we tested the revised pleasure–arousal model. This model is mathematically identical to the energetic arousal and tense arousal model (cf. Larsen and Diener, 1992). Hence, it also could not fit the data. Moreover, further analyses revealed that the model was only capable of predicting 26% of the variance in awake–tiredness. This finding is consistent with other evidence that awake–tiredness is not strongly related to other affect dimensions (Russell, 1980; Schimmack, 1997). As a consequence, one can hardly make any inferences about variation in this dimension when it is not directly measured. Furthermore, the revised pleasure–arousal model has the problem that one needs to measure energetic and tense arousal to estimate a latent general activation dimension. Hence, the revised pleasure–arousal model requires the measurement of all three PAT dimensions, but then discards reliable variance in these dimensions to estimate a dimension that does not correspond to people's everyday descriptions of their experiences. We suggest that researchers obtain a better understanding of affect, by maintaining the initial awake–tiredness and tension–relaxation dimensions.

STUDY 2

The main purpose of study 2 was to replicate the findings of study 1 in a separate data set. In addition, we wanted to extend the findings in two ways. First, our attempt to control systematic measurement error by means of different response formats was unsuccessful due to problems of the multi-format procedure (cf. Schimmack *et al.*, 1999, manuscript submitted for publication). A better way of controlling systematic measurement error appears to be the use of repeated measurement designs (Watson *et al.*, 1999). In these designs, it is assumed that response styles influence the response of a participant systematically across repeated measurements. Thus response style variance is part of the stable between-subject variance, but it does not contribute to the unstable within-subject variance. Hence, by calculating change scores that eliminate the stable variance between participants, the response style variance is also controlled.

Method

Participants

One hundred and thirty-five students (53% females) at the University of Illinois, Urbana-Champaign participated in the study for course credit. The students were enrolled in a semester long study on subjective well-being. As part of the course requirements, students came to a laboratory twice a week, where they completed sets of questionnaires.

Materials and procedure

Participants completed an 18-item affect questionnaire at the beginning of two laboratory sessions about one week apart. The affect questionnaire was designed to measure the three PAT dimensions with three items for each pole of the three dimensions. Instructions read "First we have a few questions regarding your feelings right now at this moment. We use scales that range from the absence of a feeling to its maximum intensity of the feeling. Please, decide first whether you experience the feeling described by a particular mood word. If you do not experience it, please respond with 1. If you do experience the feeling slightly use 2, if you feel it moderately use 3 and if you feel it strongly use 4. 1 = DO NOT FEEL it, 2 = I feel it SLIGHTLY, 3 = I feel it MODERATELY, 4 = I feel it STRONGLY". The items appeared in the following order: awake, unpleasant, at rest, tired, pleasant, alert, restless, positive, sleepy, negative, calm, wakeful, good, jittery, relaxed, bad, and drowsy. As in study 1, we formed bipolar indicators of the three dimensions by subtracting items of one pole from items of the other pole. The indicators were pleasant–unpleasant, positive–negative, good–bad for P, awake–sleepy, alert–tired, and wakeful–drowsy for A, and restless–at rest, tense–relaxed, and jittery–calm for T. The reliability of the three-item scales was good at time 1 and time 2 (alphas >0.80).

Results

First, we fitted a measurement model to the 18 scales. The model included six factors, three factors for the PAT dimensions at time 1 and three factors for the PAT dimensions at time 2. In addition, error terms between identical indicators (e.g. pleasant–unpleasant time 1 and pleasant–unpleasant time 2) were allowed to covary to allow for systematic variance in the indicators that is not shared with other indicators of the same construct. All factors were allowed to covary freely with each other. This model had an acceptable fit (Table 1). Next, we constrained the factor loading pattern at time 1 and time 2. The model fit was acceptable, and direct comparisons revealed that the model fit was not significantly worse (Table 1). Next, we also constrained the covariations among the three PAT dimensions to be identical. This model also fitted the data as well as the unconstrained model (Table 1). The correlations between the PAT factors were 0.47 (P–A), −0.57 (P–T) and −0.20 (A–T). In addition, the model revealed significant correlations between PAT dimensions at time 1 and time 2, namely 0.30 for P, 0.30 for A, and 0.40 for T. These coefficients are similar to previous stability estimates of mood dimensions (Steyer *et al.*, 1994).

We also tested whether it would be possible to reduce the PAT dimensions to a two-dimensional model. For this purpose, we first established a model with direct paths from A and T to P. The path coefficients at time 1 and 2 were constrained to be equivalent. First, we allowed the variance explained in P to be estimated by the model (A–T $\rightarrow$ *P). This model of course fitted the data as well as the previous models (Table 1). As in study 1, A and T explained about half of the variance in P (45%). As a consequence, it is not surprising that a model that constrained the explained variance to be 1.00 (A–T $\rightarrow$ P) did not fit the data (Table 1).

The previous analyses revealed some stability in mood ratings from time 1 to time 2. This stability can be partly due to stable individual differences in affect dispositions and it can be due to response styles. To remove this source of variance from our structural analyses, we created difference scores by subtracting time 2 indicators from time 1 indicators. A concern with difference scores is that difference scores tend to be less reliable. However, the difference scores of the PAT dimensions showed good reliabilities (alpha > 0.80). Hence, we proceeded and established a measurement model based on difference scores. This model reflects the covariation between changes in P, A, and T from time 1 to time 2. The fit of this model was only marginal, but closer inspection of the standardized residuals revealed that freeing individual indices would not have produced a significant improvement in fit (i.e. all standardized residuals were within a -0.20 to 0.20 range). Inspection of the factor correlations revealed that the associations among PAT factors were slightly weaker than in the previous model that did not control for the stable component in PAT scores, namely 0.35 (P–A), -0.54 (P–T), and -0.01 (A–T). However, when we tested a model that constrained these correlations to be equivalent to the correlations in model 3, the fit was not significantly worse (Table 1). It should be noted that these tests are not very powerful due to the relatively small sample size. In general, the results show that controlling for stable components in mood ratings that are either due to affective dispositions or due to response styles does not produce substantial changes in the results.

Discussion

Study 2 replicated the main finding of study 1 in a different sample. It was possible to fit a measurement model to the three PAT dimensions, and it was not possible to reduce these three dimensions to two dimensions. As in study 1, pleasure–displeasure was positively correlated with awake–tiredness and negatively correlated with tension–relaxation, whereas awake–tiredness and tension–relaxation were slightly negatively correlated. Together the two arousal dimensions explained half of the variance in pleasure–displeasure. Furthermore, study 2 demonstrated that the same measurement model and factor correlations could be fitted to two repeated assessments of the PAT dimensions. This finding indicates that the structure of the PAT dimensions and their correlations are relatively stable when the same indicators are used in similar situations. It is possible, however, that the structure of correlations changes when PAT dimensions are assessed in a different situation (Watson *et al.*, 1999). Finally, study 2 replicated earlier findings that mood ratings show low but significant stability over repeated assessments over short time periods (Schimmack, 1997; Steyer *et al.*, 1994). When this stable component in mood ratings was removed, changes in PAT dimensions maintained the same pattern of correlations. This finding provides further evidence that our findings are not biased by response styles because change scores also remove stable individual differences in response styles. In sum, study 2 demonstrated that three dimensions of core affect, namely pleasure–displeasure, awake–tiredness, and tension–relaxation cannot be reduced to a two-dimensional structure without loss of valid information.

GENERAL DISCUSSION

Is the core of affective experiences two dimensional in the USA and three dimensional in Europe? We demonstrated that this is not the case. A three-dimensional model provided a better fit to two US American data sets than two-dimensional models. Models that attempted to fit the three dimensions in a two-dimensional space consistently yielded a poor fit to the data that was substantially worse than the fit of the three-dimensional model. Further analyses revealed that two-dimensional models achieve their greater parsimony by discarding variance from at least one of the three PAT dimensions. The pleasure–arousal model neglects unique variance in the two arousal dimensions by assuming that arousal is a unidimensional construct. The revised pleasure–arousal model fails to capture mainly the variance in awake–tiredness, but also some of the variance in tension–relaxation. The energetic and tense arousal model fails to capture about half of the variance in the pleasure–displeasure dimensions. The present results confirm that a three-dimensional model with inter-correlated factors is *necessary* to capture the variation in dimensions of core affect (Matthews *et al.*, 1990; Schimmack, 1997, 1999; Steyer *et al.*, 1994). The present results do not show that a three-dimensional model is *sufficient* to capture all aspects of affective experiences (Schimmack, 1997, 1999).

One possible objection to our conclusions could be that our model specifications were too restrictive. It might seem unreasonable to propose that one can explain 100% of the variance in a criterion variable. However, we believe that 50% or more unexplained variance is not acceptable for several reasons. First, our models assessed the relations between core dimensions at the level of latent variables. Hence, random error variance can no longer explain the unexplained variance. Second, we control systematic measurement error by subtracting opposing items from each other, using multiple formats, and eliminating stable individual differences. Hence, the unexplained variance cannot be attributed to systematic measurement error. Third, we used bipolar indicators to measure bipolar constructs. Hence, the poor fit cannot be attributed to problems of measuring bipolar constructs with unipolar scales (cf. Russell and Carroll, 1999). The remaining most plausible explanation for our findings is that the models' assumptions are wrong. Pleasure–displeasure is a basic affect, not a mixture of energetic and tense arousal. Energetic arousal is a basic affect that is not a mixture of pleasure and general activation. Tense arousal is a basic affect that is not a mixture of displeasure and general activation.

Another possible objection to our results could be that the results appears to be trivial. One might think that three dimensions can always be better fitted to a three-dimensional model compared to a two-dimensional model. We do not agree. The idea that some affect dimensions are a mixture of others has its roots in the beginning of emotion research (Wundt, 1896; cf. Reisenzein, 1992), and is a common assumption in contemporary models of affect (Feldman Barrett and Russell, 1998; Reisenzein, 1994; Russell and Feldman Barrett, 1999; Watson and Tellegen, 1985). Furthermore, recent publications using structural equation modeling claimed that the three dimensions can be represented in a two-dimensional space. For example, Feldman Barrett and Russell (1998) concluded that they "demonstrated that other affective descriptors can be defined as combinations of the valence and activation dimensions" (p. 978). However, this conclusion was based on a structural equation model with a poor fit (cf. Watson *et al.*, 1999). The present results reveal that the poor fit was due to false assumptions about the structure of affect. Energetic arousal and tense arousal are not a mixture of pleasure–displeasure and general activation.

Finally, one might be concerned about the value of a model with intercorrelated dimensions. From a psychometric point of view, models with orthogonal dimensions seem preferable. Maybe researchers should still use models with two orthogonal dimensions to measure affect, even though these dimensions might not correspond to basic affects. For example, Feldman Barrett and Russell (1998) emphasized that their model is merely "a descriptive map of the affect domain. On its own, it is not a model of affect" (p. 978). However, we propose that measurement models of affect should aim to represent the actual structure of affect. As we discuss below, the use of parsimonious descriptive models that do not capture the nature of affect can be misleading.

The Cost of Parsimony

The energetic and tense arousal model implies that one can create a parsimonious measure of affect by dropping the pleasure–displeasure dimension. As a consequence, one can assess affect with two largely independent arousal dimensions. The present results reveal that this approach cannot capture all of the variation in pleasure–displeasure. We argue that the loss of information about pleasure–displeasure is more costly than the addition of a third dimension. For example, Schimmack (1999) compared the influence of different situations (a daily positive event, a daily negative event, at the beginning of a lecture, and at bedtime) on the PAT dimensions. Not surprisingly, participants had much higher levels of pleasure–displeasure during positive events and much lower levels of pleasure–displeasure during negative events than during the other situations. This is a rather trivial finding. More important was the finding that situations still explained 80% of the variance in pleasure–displeasure after controlling for variation in the two arousal dimensions. This finding demonstrates how dangerous it can be to infer pleasure–displeasure from arousal patterns. A direct assessment of pleasure–displeasure is essential whenever researchers are interested in the hedonic tone of affective experiences.

Similarly, the unidimensional assessment of activation can be costly at times. Gold, MacLeod, Deary and Frier (1995) injected insulin into the blood stream of healthy participants to induce hypoglycemia. Mood reports along the PAT dimensions revealed increasing tension and decreasing wakefulness during states of hypoglycemia. If both dimensions had been combined in a general activation–deactivation scale, the authors would have erroneously concluded that hypoglycemia had no influence on activation. Similarly, investigations of diurnal rhythms consistently find that energetic arousal follows a circadian rhythm (i.e. people are more awake during the day than in the early morning or late at night), whereas pleasure–displeasure and tense arousal do not (cf. Schimmack, 1999). The revised pleasure–arousal model cannot explain this finding. It assumes that energetic and tense arousal are mixtures of the same two basic dimensions. Hence, if one of the basic dimensions shows a diurnal rhythm, it should be reflected in diurnal rhythms of both arousal dimensions. Finally, in Schimmack's (1999) study of situational effects on PAT dimensions, participants reported low levels of wakefulness–tiredness at the end of the day, but pleasure–displeasure, and tense arousal were unchanged compared to a neutral situation during the day. If researchers had simply inferred wakefulness from a combination of pleasure–displeasure and activation, researchers would have underestimated the effect of time of day on wakefulness–tiredness.

Future Questions

Neurological substrates of affect

Panksepp (1993, p. 100) noted that at present affective neuroscience has "more speculation than substance to share with respect to the molecular underpinning of emotions". Hence, readers should not take the following speculations as support for the PAT model. Nevertheless it is noteworthy that the distinction between two activation dimensions is similar to a distinction in the neuropsychological literature between arousal and activation (Buck, 1984; Pribram and McGuiness, 1975; Routtenberg, 1968; Tucker and Williamson, 1984). Tucker and Williamson (1984) proposed that the two systems have different functions and different substrates. The arousal system regulates the processing of perceptual inputs, and high levels of arousal are associated with broader attention, shifts in attention to novel or emotionally important stimuli, and a high signal-to-noise ratio. It involves the neurotransmitters norepinephrine (NE) and serotonin, and it is predominant in the right hemisphere. The activation system regulates motor readiness. It involves dopaminergic pathways (DA) that are predominantly located in the left hemisphere.

Some findings reported by Tucker and Williamson (1984) suggest that the awake–sleepiness dimension reflects activity of the arousal system, whereas the tension–relaxation dimension reflects activity of the activation system. For example, animal studies show that activity in norephinephrine pathways in the brain covaries with the animals' sleep–wake cycle, while research with human participants shows that the awake–sleepiness dimension follows a diurnal rhythm (Thayer, 1989). Tucker and Williamson (1984) related activity in the activation system to anxiety, which is highly correlated with the tension–relaxation dimension (Schimmack, 1997). Furthermore, they propose that a major function of relaxation techniques is to reduce the chronic motor readiness due to heightened activity in the activation system. Future research on affect should take notice of the fact that neither self-report measures nor neurological evidence support the outdated view of arousal as a single dimension (cf. Duffy, 1962).

Finally, the pleasure–displeasure dimension might have its own neurological underpinning. Panksepp (1993) notes that b-Endorphin is related to diverse pleasurable experiences, but that this opioid peptide also tends to reduce displeasure. LeDoux (1993) points out that the amygdala processes sensory inputs for their emotional significance, and might provide a global integration of diverse good–bad evaluations. He also points out a probable link between the amygdala and the arousal system. As noted earlier, the arousal system directs attention to emotionally important stimuli, but it does not 'know' which stimulus is emotionally significant. The amygdala might provide this information. The study by Gold *et al.* (1995) on hypoglycemia showed that the PAT model is useful in psychobiological investigations. Neuropsychologists might also find the PAT model heuristically useful.

Bipolarity of the pleasure–displeasure dimension

The present article compared dimensional models of core affect with each other. This comparison relied on bipolar indicators of core affect. As a consequence, our conclusions are limited by this assumption. We demonstrated that three bipolar dimensions cannot be reduced to a smaller set of bipolar dimensions. We did not demonstrate that the three dimensions are really bipolar. As noted earlier, this question cannot be addressed by Pearson correlations (Diener and Iran-Nejad, 1986). Whether pleasure and displeasure are opposite ends of a single bipolar dimension or two separate affects needs to be addressed by means of other methods (Schimmack *et al.*, 1999, manuscript submitted for publication). The present article demonstrates that the dominant conception of core affect as a set of two orthogonal bipolar dimensions is insufficient. The three-dimensional model is a more complex and more appropriate model. If the assumption of bipolarity turns out to be false, structural models of core affect will be even more complex. The aim of the present article is not to propose a new premature structural model of affect. Rather we attempted to demonstrate that progress in affect structure research has been delayed by a false consensus that the structure of core affect is two dimensional (cf. Watson *et al.*, 1999).

Hierarchical models of affect

The notion of core affect assumes that all affective experiences share a few basic affects, and are differentiated by patterns of core affect and additional components (Reisenzein, 1994). The present article focused on the structure of core affect. Future tests need to explore the second assumption that basic dimensions are really at the core of non-basic ones. The best test of 'basicness' is based on the plausible assumption that a basic affect should always be present when a non-basic affect is experienced (Reisenzein, 1995). In contrast, a basic affect can also be experienced without a non-basic affect. This prediction implies an asymmetric relation between basic and non-basic affects. However, Pearson correlations and structural equation modeling assume symmetric relations between variables and therefore cannot be used to test this aspect of models that propose a set of basic dimensions of affect. Future research with asymmetric coefficients needs to explore this question.

Implications for models of trait affect

The present article focused on the structure of core affect, that is affective experiences at one moment in time. However, the results also have implications for theories of trait affect. Some researches have proposed that the structure of state affect is the same as the structure of trait affect (Watson and Tellegen, 1985). One of the most common measures of trait affect, namely the Positive Affect Negative Affect Schedule (PANAS, Watson, Clark and Tellegen, 1988) is theoretically based on the two-dimensional model of state affect (Watson and Tellegen, 1985). Given that the present analyses undermine the validity of this model as a model of affective states, it also questions whether affective traits can be characterized by two dimensions (see also Schimmack, Oishi, Diener and Suh, 2000). For example, Schimmack and Diener (1997) found that individual differences in trait affect intensity (i.e. the typical intensity of emotional experiences) were systematically related to trait differences in pleasure–displeasure, but not systematically related to trait differences in wakefulness–tiredness or tension–relaxation.

There are additional problems with the idea that trait affect can be characterized by a few basic dimensions. The reason is that it is theoretically implausible that traits mix with each other to produce other traits. Assume, for example, that state excitement is a mixture of state pleasure and state arousal. Even if this were true, knowing that an individual frequently experiences arousal and frequently experiences pleasure does not mean that this individual frequently feels excitement, because it is possible that the individual feels arousal and pleasure at different times. It follows that one would need to measure individual differences in trait affects even for mixed feelings because one cannot infer these individual differences from individual differences in traits of basic affects. Additional problems arise from the fact that people can have different dispositions to experience an affect frequently, intensely, or for long durations (Schimmack *et al.*, 2000). Hence, for each affect, there are three different traits. It follows that the structure of trait affect must be even more complex than the structure of state affect, and that the structure of trait affect also cannot be two dimensional (see also Diener, Smith and Fujita, 1995; Schimmack *et al.*, 2000; Watson and Clark, 1992).

CONCLUSION

Science often starts with simple models. After empirical findings start to accumulate simple models often turn out to be simplistic and have to replaced by more complex models. We suggest that it is time to recognize the limitations of two-dimensional models of affect. One step in this direction is the three-dimensional PAT model. This model should be considered a stepping stone toward increasingly more sophisticated models of affect that increase with our understanding of the phenomenon. Hopefully the PAT model will look simplistic in comparison to affect models of the future.

ACKNOWLEDGEMENTS

We thank Phani Radhakrishnan, Joe Tomaka, Peter Borkenau, and two anonymous reviewers for valuable suggestions on a previous draft of this article. This study was supported by a post-doctoral scholarship of the German Research Foundation (DFG).

REFERENCES

Beebe-Center JG. 1932. *Psychology of Pleasantness and Unpleasantness*. Van Nostrand: New York.

Breckler SJ. 1990. Applications of covariance structure modeling in psychology: Cause for concern?. *Psychological Bulletin* **107**: 160–273.

Browne MW, Cudeck R. 1993. Alternative ways of assessing model fit. *Testing Structural Equation Models*, Bollen KA, Long JS (eds). Sage: Newbury Park, CA; pp. 136–162.

Buck R. 1984. *The Communication of Emotion*. Guilford: New York.

Diener E. 1999. Introduction to the special section on the structure of emotion. *Journal of Personality and Social Psychology* **76**: 803–804.

Diener E, Iran-Nejad A. 1986. The relationship in experience between different types of affect. *Journal of Personality and Social Psychology* **50**: 1031–1038.

Diener E, Smith H, Fujita F. 1995. The personality structure of affect. *Journal of Personality and Social Psychology* **69**: 130–141.

Duffy E. 1962. *Activation and Behavior*. Wiley: New York.

Eid M, Notz P, Schwenkmezger P, Steyer R. 1994. Sind Stimmungsdimensionen monopolar? [Are mood dimensions unipolar?]. *Zeitschrift für Differentielle und Diagnostische Psychologie* **4**: 211–233.

Feldman Barrett L, Russell JA. 1998. Independence and bipolarity in the structure of affect. *Journal of Personality and Social Psychology* **74**: 967–984.

Frijda NH. 1993. Moods, emotional episodes, and emotions. *Handbook of Emotions*, Lewis M, Haviland JM (eds). Guilford: New York; pp. 381–403.

Frijda NH. 1999. Emotions and hedonic experience. *Well-being: The Foundations of Hedonic Psychology*, Kahneman D, Diener E, Schwarz N (eds). Sage: New York; pp. 190–212.

Gold AE, MacLeod KM, Deary IJ, Frier BM. 1995. Changes in mood during acute hypoglycemia in healthy participants. *Journal of Personality and Social Psychology* **68**: 498–504.

Green DP, Goldman SL, Salovey P. 1993. Measurement error masks bipolarity in affect ratings. *Journal of Personality and Social Psychology* **64**: 1029–1041.

Lang PJ. 1995. The emotion probe: Studies of motivation and attention. *American Psychologist* **50**: 372–385.

Larsen RJ, Diener E. 1992. Promises and problems with the circumplex model of emotion. *Review of Personality and Social Psychology: Emotion*, Vol. 13, Clark MS (ed.). Sage: Newbury Park, CA; pp. 25–59.

LeDoux JE. 1993. Emotional networks in the brain. *Handbook of Emotions*, Lewis M, Haviland JM (eds). Guilford Press: New York; pp. 109–118.

Matthews G, Jones DM, Chamberlain AG. 1990. Refining the measurement of mood: The UWIST Mood Adjective Checklist. *British Journal of Psychology* **81**: 17–42.

Meyer WU, Reisenzein R, Schützwohl A. 1997. Towards a process analysis of emotions: The case of surprise. *Motivation and Emotion* **21**: 251–274.

Ortony A, Clore GL, Collins A. 1988. *The Cognitive Structure of Emotions*. Cambridge University Press: Cambridge.

Panksepp J. 1993. Neurochemical control of moods and emotions: Amino acids to neuropeptides. *The Handbook of Emotions*, Lewis M, Haviland J (eds). Guilford: New York; pp. 87–107.

Pribram KH, McGuiness D. 1975. Arousal, activation, and effort in the control of attention. *Psychological Review* **82**: 116–149.

Reisenzein R. 1986. A structural equation analysis of Weiner's attribution–affect of helping behavior. *Journal of Personality and Social Psychology* **50**: 1123–1133.

Reisenzein RA. 1992. A structuralist reconstruction of Wundt's three-dimensional theory of emotions. *The structuralist program in psychology: Foundations and applications*, Westmeyer H (ed.). Hogrefe: Toronto; pp. 141–189.

Reisenzein R. 1994. Pleasure–arousal theory and the intensity of emotions. *Journal of Personality and Social Psychology* **67**: 525–539.

Reisenzein R. 1995. On Oatley and Johnson-Laird's theory of emotion and hierarchical structures in the affective lexicon. *Cognition and Emotion* **9**: 383–416.

Reisenzein R, Schimmack U. 1999. Similarity judgments and covariations of affects: Findings and implications for affect structure research. *Personality and Social Psychology Bulletin* **25**: 539–555.

Reisenzein R, Schönpflug W. 1992. Stumpf's cognitive–evaluative theory of emotion. *American Psychologist* **47**: 34–45.

Routtenberg A. 1968. The two-arousal hypothesis: reticular formation and lymbic system. *Psychological Review* **75**: 51–80.

Russell JA. 1980. A circumplex model of affect. *Journal of Personality and Social Psychology* **39**: 1161–1178.

Russell JA, Carroll JM. 1999. On the bipolarity of positive and negative affect. *Psychological Bulletin* **125**: 3–30.

Russell JA, Feldman Barrett L. 1999. Core affect, prototypical emotional episodes, and other things called emotion: Dissecting the elephant. *Journal of Personality and Social Psychology* **76**: 805–819.

Russell JA, Weiss A, Mendelsohn GA. 1989. Affect grid: A single-item scale of pleasure and arousal. *Journal of Personality and Social Psychology* **57**: 493–502.

Schimmack U. 1997. Das Berliner-Alltagssprachliche-Stimmungsinventar (BASTI): ein Vorschlag zur kontentvaliden Erfassung von Stimmungen [The Every-Day Languge Mood Inventory (ELMI): Toward a content valid assessment of moods]. *Diagnostica* **43**: 150–173.

Schimmack U. 1999. Die Struktur der Stimmungen: Rückschau, Rundschau, Ausschau [The structure of moods: Review, overview, and outlook]. *Psychologische Rundschau* **50**: 90–97.

Schimmack U, Diener E. 1997. Affect intensity: Separating intensity and frequency in repeatedly measured affect. *Journal of Personality and Social Psychology* **73**: 1313–1329.

Schimmack U, Oishi S, Diener E, Suh E. 2000. Facets of affective experiences: A new look at the relation between pleasant and unpleasant affect. *Personality and Social Psychology Bulletin* **26**: 655–668.

Schimmack U, Siemer M. 1995. *$e = m \times c$! Über Emotionen, Stimmungen und Kognitionen* [*Emotions, Mood, and Cognition*]. Positionsreferat gehalten auf der 37. TeaP, Bochum.

Shaver P, Schwartz J, Kirson D, O'Connor C. 1987. Emotion knowledge: Further exploration of a prototype approach. *Journal of Personality and Social Psychology* **52**: 1061–1086.

Shaver P, Wu S, Schwartz JC. 1992. Cross-cultural similarities and differences in emotion and its representation: A prototype approach. *Review of Personality and Social Psychology: Emotion*, Vol 13, Clark MS (ed.). Sage: Newbury Park, CA; pp. 175–212.

Sjöberg L, Svensson E, Persson LO. 1979. The measurement of mood. *Scandinavian Journal of Psychology* **20**: 1–18.

Steyer R, Schwenkmezger P, Notz P, Eid M. 1994. Testtheoretische Analysen des Mehrdimensionalen Befindlichkeitsfragebogens [Test theoretical analyses of the Multidimensional State Questionnaire]. *Diagnostica* **40**: 320–328.

Storm C, Storm T. 1987. A taxonomic study of the vocabulary of emotions. *Journal of Personality and Social Psychology* **53**: 805–816.

Thayer RE. 1989. *The Biopsychology of Mood*. Oxford University Press: New York.

Titchener EB. 1908. *Lectures on the elementary psychology of feeling and attention*. New York.

Tucker DM, Williamson PA. 1977. Asymmetric neural control systems in human self-regulation. *Psychological Review* **91**: 185–215.

Tukey JW. 1977. *Exploratory Data Analysis*. Addison-Wesley: Reading, MA.

Watson D, Clark LA. 1992. Affects separable and inseparable: On the hierarchical arrangement of the negative affects. *Journal of Personality and Social Psychology* **62**: 489–505.

Watson D, Clark LA. 1997. Measurement and mismeasurement of mood: Recurrent and emergent issues. *Journal of Personality Assessment* **68**: 267–296.

Watson D, Clark LA, Tellegen A. 1988. Development and validation of a brief measure of Positive and Negative Affect: The PANAS scales. *Journal of Personality and Social Psychology* **54**: 1063–1070.

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

Watson D, Wiese D, Vaidya J, Tellegen A. 1999. The two general activation systems of affect: Structural findings, evolutionary considerations, and psychobiological evidence. *Journal of Personality and Social Psychology* **76**: 820–838.

Wundt W. 1896. *Grundrisse der Psychologie [Outlines of psychology]*. Engelmann: Leipzig.

