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BRIEF REPORT

Changes in affect interrelations as a function of stressful events

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This paper examines the proposition that stress shrinks affective space, increasing the inverse correlation between positive affect (PA) and negative affect (NA). The experience sampling method was used to record the levels of PA and NA and stress reported by white-collar employees 10 times a day for 5 days. These data were subjected to hierarchical linear modelling to determine whether the relationship between affective states becomes increasingly inverse as a function of stress, as predicted by Zautra, Potter, and Reich (1997). Caution was taken to address measurement issues that have been raised in recent debates over the independence of PA and NA, and a contingency analysis was also used to supplement the linear modelling approach. Both types of analyses revealed evidence consistent with the hypothesis that the degree to which PA and NA are inversely related varies with the level of stress.

One critical question about positive and negative affective experiences has remained unresolved in the many enquiries about them: To what extent is the relationship between positive emotional states and negative states context-dependent? Current debates over this question focus for the most part on methodological issues relating either to measurement, such as the choice of affect adjectives in scale construction, or to the effects of statistical procedures, such as the type of factor rotation or how measurement error is accounted for (Feldman-Barrett & Russell, 1998; Green, Goldman, & Salovey, 1993; Russell & Carroll, 1999; Watson & Clark, 1997). Although these methodological issues

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are important, we would like to suggest that certain psychological contexts might be responsible for at least part of the observed variability in the size of correlation between positive and negative affective states. In particular, stressful life events may promote more bipolarity in judgements of one's own affect than is found during nonstressful occasions (Zautra et al., 1997; Potter, Zautra, & Reich, 2000; Reich, Zautra, & Potter, 2001). We examine this hypothesis in the current study.

Sources of information about how we feel are plentiful and include both internal states and life events. Indeed, many person-environment transactions are richly textured with a complex array of affect-laden information, some positive and some negative. Most of the time the person may benefit from processing positive and negative affective information independently of each other, because in that way he/she may gain the maximum amount of information. By retaining two separate registers for affective information about events and features of the environment, the person may be capable of making more thorough and precise evaluations of everyday life (Zautra et al., 1997).

Information processing requires cognitive resources, however, and treating positive and negative affects as separate is expensive. There may be many situations when the benefits of fuller information are more than offset by that expense. One such situation occurs during times of stress, when resources are at a premium. Stressors often increase uncertainty (Ursin & Olff, 1993), and uncertainty increases informational demands. Linville (1985) has proposed that stress induces a narrowing of attentional focus, leading to an increased difficulty in making complex judgements and producing more unified responses (see also Easterbrook, 1959). Linville's (1985, 1987) studies have shown that normally unrelated cognitive processes were substantially correlated under stress, suggesting a shrinkage of informational space. If stress has similar effects on evaluations of affective information, it would lead to a compression of affect dimensions as information-processing demands increase. Such an affective narrowing may be highly adaptive during stress, allowing for more rapid and adaptive responses (Paulhus & Lim, 1994).

In a prior study, we found increases in the PA-NA correlation from baseline to stress in two separate samples of individuals who underwent a stressful laboratory task (Zautra, Reich, Davis, Nicolson, & Potter, 2000). Past research is also consistent with this model. Diener and Emmons (1985) have found that, at extremes of negative affect, the inverse correlation between positive and negative affects was stronger. To the extent that the extremes of negative affect were the result of stressful events, these findings would support the model we propose. Indeed, there are a number of studies that report reduction of negative affects for those experiencing positive events during stress that may be interpreted as in agreement with the model proposed here (Cohen & Hoberman, 1983; Nelson, 1990; Reich & Zautra, 1981). These last studies provide only indirect evidence in support for our proposition, however, as the study designs permitted only comparisons between individuals and not within individuals over repeated observations. Such within-person designs are needed to test for a change in the level of correlation between PA and NA as a function of stress.

In the current study we use data from Van Eck, Nicolson, and Berkhof (1998) to examine whether the correlation between PA and NA was more negative under stress. Van Eck et al. (1998) collected data on stressful events and mood 10 times daily for five days in a study of male white-collar workers. This dataset is particularly useful for the current research question. The study population is relatively healthy and young, unlike some previous studies examining PA-NA relationships (Potter et al., 2000; Zautra et al., 1997). Further, there are many observations per person, allowing for the thorough examination of stress-related changes in PA-NA correlations within persons. Because observations concern real-life events, artifacts introduced by laboratory procedures are also reduced. Lastly, by studying people with repeated observations using the same instruments over time we hold constant the affect items, the rating scaling, and method of administration across observations. Any shift in the degree of independence between affective states cannot therefore be attributed to differences in item content or in method.

METHODS

Participants

The personnel departments of six Dutch industries and government agencies were approached to identify male employees with white-collar functions. Questionnaires were distributed among these employees, accompanied by a letter explaining the goals of the study. The screening response rate was roughly 30–40%. Of the 316 men who responded, 81% indicated initial willingness to participate in the main study. Of the 123 respondents subsequently approached by telephone, 18 were no longer willing and 12 were not able to take part in the study on the scheduled dates. One participant dropped out after the first day of sampling. Data from 7 of the 92 participants who completed the study were later excluded from the analysis: six due to inadequate data and one due to antidepressant use (an exclusion criterion). In the final sample of 85 participants, mean age was 42.1 years (range 27–57 years), 93% were married or living with a partner, and 70% had children living at home. Educational level ranged from lower vocational school through university, with 88% of the sample having completed degrees beyond Dutch secondary school education. All participants were Caucasian and fluent in Dutch.

Procedure

The experience sampling method (ESM; Csikszentmihalyi & Larson, 1987; deVries, 1992) was used to collect data from participants at selected moments during their normal daily activities. Participants received auditory signals (beeps) to complete self-report forms from a wristwatch programmed to emit 10 beeps between the hours of 8 am and 10 pm each day, at semi-random intervals of approximately 90 minutes. During an initial session, study aims and procedures were explained and informed consent obtained. Participants then completed ESM questionnaires over a period of five consecutive days, from Thursday through Monday. The criteria set for inclusion in the analysis (> 20 ESM reports completed within 20 minutes after the beep and no entire days missing) were met by all but six participants. The remaining participants completed an average of 83% of all possible responses within the time limit, for an average of 41.5 valid responses per participant.

Measures

Assessment of mood. Positive and negative emotional states were assessed with 11 ESM items rated on 7-point scales (from 1 ‘‘not at all’’ to 7 ‘‘very’’). Positive affect (PA) items were cheerful, satisfied, relaxed, energetic, self-assured, and enthusiastic (Cronbach’s alpha for the scale consisting of these items was .88, based on 3501 reports). Negative affect (NA) items were depressed, anxious, worried, lonely, and miserable (alpha = .79). It is important to note that the items on these scales differ from those in the Positive and Negative Affect Scales (PANAS; Watson, Wiese, Vaidya, & Tellegen, 1999). Unlike the PANAS scale, which contains items only with relatively high levels of arousal, our scales include both low and high activation items. Participant means on NA and PA were negatively correlated ($r = -.37$; $p < .001$). Over all reports, moderate intercorrelations between NA and PA were found for raw scores ($r = -.40$; $p < .001$) as well as for within-participant z-scores ($r = -.36$; $p < .001$).

Assessment of stressful events. At each beep, participants were asked to briefly describe any stressful event or situation that may have taken place in the interval since the last ESM report, indicating beginning and end times when possible. It is important to note that events took place during the interval between two beeps and were not necessarily continuing at the moment participants were signalled. This approach was chosen to obtain as complete as possible a record of each individual's stressful experiences. Participants rated events on a number of dimensions, including expectedness, unpleasantness, and controllability. The research assistant explained how these items were to be interpreted during the ESM briefing session in order to increase the comparability of responses across participants. Response options ranged from 1 ''not at all'' to 7 ''very''.

RESULTS

Across the five days of ESM, participants reported an average of 6.9 events (SD = 6.8). Seven participants reported no stressful events. The remaining 78 participants reported a total of 587 stressful daily events or situations, representing an average frequency of 16.3% (SD = 15.4) of all valid ESM reports. Examples of reported events are: ''argument with the boss about a missed work deadline'' and ''conflict with spouse about how to raise our son''. On average, these events were rated as moderately unpleasant ($M = 3.6$, SD = 1.4), important ($M = 4.1$, SD = 1.4), at the mid-point on controllability ($M = 3.6$, SD = 1.5), and expectedness ($M = 3.4$, SD = 1.4). Next, we calculated the average PA and NA scores for subjects during stress and nonstress occasions. As expected, average scores on NA were generally higher during the stress observations ($M = 1.35$, SD = 0.47) than nonstress ($M = 1.14$, SD = 0.25): $t(77) = 6.19$, $p < .01$. PA scores showed less variation but did decrease significantly from nonstress ($M = 4.87$, SD = 0.91) to stress ($M = 4.59$, SD = 1.15): $t(77) = -3.77$, $p < .01$. As a preliminary analysis, we calculated correlations between PA and NA . The product moment correlation between average PA and average NA for nonstress was $-.33$; for stress the correlation between PA and NA scores was $-.53$.

To examine PA-NA correlations over the entire set of repeated ESM observations, we used hierarchical linear modeling (HLM). HLM (or multilevel modelling) is a variant of the multiple regression model appropriate for data sets with a hierarchical structure (Bryk & Raudenbush, 1992; Goldstein, 1995; Longford, 1993). Our purpose in using this approach was to estimate the average within-person correlation between PA and NA at times of stress and at times of no stress, in a way that removes biases in that estimation due to differences between subjects in their levels of PA and NA during the experience sampling. To accomplish this, we used a two-level multivariate HLM approach. First we wrote equations for the two response variables: PA and NA. Each equation provides an intercept value of the response variable at stress and at nonstress. In four other regression equations, each of these intercept values was predicted by those factors that might bias the estimates, yielding residual variances and covariances for those four scores. These residuals provide estimates of the correlations between PA and NA at stress and nonstress beeps. These regression equations were estimated simultaneously through the use of the MLn program (Prosser, Rasbash, & Goldstein,1996). The Appendix provides a more detailed account of this estimation procedure.

The estimated fixed effects, beep level variances, and covariances are presented in Table 1. As Table 1 shows, the beep level variances of the NA and PA scores were highest following a stressful event. Because the covariances depend on the scales of the affect measures, we also tabulated the correlations, which can be directly computed from the tabulated variances and covariances. The negative correlation was highest for stress moments ($r = -.50$ for stress compared to $r = -0.36$ for nonstress). A likelihood ratio test (Bryk & Raudenbush, 1992, p. 57) of the difference between PA-NA correlations for stress versus nonstress was highly significant, χ^2 (1) change = 16.2, $p < .0001$.

Contingency analysis

The HLM analysis can be criticised for assuming normality of the NA and PA scales. It is well-known that NA scores are skewed to the right (Russell & Carroll, 1999). Indeed, for the current dataset the mode of the NA scores is located at the lowest score. Russell and Carroll (1999) suggest that a contingency analysis may provide a more accurate estimate of relationships between affects. A contingency analysis applied here provides data on the proportion of time that subjects report various combinations of positive and negative affect when in stress versus when not in stress. There are four possible combinations of interest: high PA coupled with low NA, high NA coupled with low PA, low NA coupled with low PA, and high NA coupled with high PA. The first two conditions constitute a

TABLE 1
HLM model estimates for negative effect (NA) and positive effect (PA)

	No stress		*Stress*	
	Estimate	*SE*	*Estimate*	*SE*
A. Fixed effects (variable)				
NA	1.13	.03	1.35	0.4
PA	4.86	.10	4.58	.11
B. Beep level variances (variable)				
NA	.076	.002	.228	.014
PA	.593	.016	.731	.046
C. Beep level NA-PA covariances and correlations				
Covariance	−.077	.004	−.203	.021
Correlation	−.361		−.496	

Note: The analysis was based on 3497 beeps (including 574 events) nested within 85 participants.

way of representing an inverse relationship between PA and NA without relying on correlational methods.

We were interested in whether the proportion of these inverse relationships was higher under stress than under nonstress. To examine this question we first computed scores for PA and NA that were adjusted for individual differences in both average NA and PA, and stress-related increases in NA and PA. The adjusted NA and PA scores were dichotomised using a median split (see the Appendix for further details). Under stress, inverse relationships, as a percentage of the total, averaged of 69.5% per individual. Under nonstress, the percentage averaged 57.5% per individual. There were 57 out of 78 participants who had larger ratios of inverse relationships under stress than under nonstress (7 participants had no stressful events during the study so were excluded from these analyses. If stress did not affect these ratios, we would expect that 78 × 50% = 39 participants would have ratios higher under stress. Through the use of a sign test (Mood, Graybill, & Boes, 1974, p. 519), we found that the probability that we would observe 57 or more participants with a higher ratio during stress under the null was < .00002. In sum, these contingency analyses were consistent with the other analyses of these data supporting the study's principal hypothesis that stress increases the likelihood of an inverse relationship between PA and NA.

DISCUSSION

The goal of this study was to determine whether the relationship between positive and negative affects changed as a function of stressful events in everyday life. To support this proposition, we needed two pieces of evidence. First, the correlation between positive and negative affect scales had to be relatively small. This datum was needed to support the inference that the two affects, as we measured them, represented separate constructs. Second, we needed to demonstrate a significant increase in the inverse correlation between PA and NA during times the person had just experienced a stressful event compared with those times when he reported no stress. The results support both of these propositions.

The statistical methods employed allowed us to rule out some alternative explanations with considerable confidence. First, since the study examined changes in PA-NA relationships within persons, individual differences cannot account for the effects observed. It is possible that other methods of estimating PA and NA, including different affect items and different Likert scale anchors, could have increased (or decreased) the average level of inverse correlation (Green et al., 1993). However, there is no reason such method factors would play a different role during stressful as opposed to nonstressful occasions, and thus they do not provide an explanation for shifts in the level of correlation we observed.

Changes in mean level and variance in NA and PA do occur with greater stress, and these changes, especially in NA, have been offered as an alternative explanation for changes in the size of the correlation (e.g., Russell & Carroll, 1999). We employed a contingency analysis, which is not affected by such potential biases, and again found results consistent with our model.

Some theorists might prefer to interpret these results as evidence that the affect dimensions are curved inward at the extremes rather than postulating a set of external influences, such as stress, and cognitive operations, such as information processing, as responsible for the effects observed. Only future studies can address the relative suitability of alternative models. Although curved affective space may appear a more parsimonious explanation, it may not be as accurate. Our model predicts that extremes in positive affect do not cause less affective differentiation and may actually allow for more differentiation, dependent on the nature of the positive affective experience (Aspinwall, 1998; Isen, 1987). In the current study we did not assess occurrences of positive events, so we are unable to examine their effects on affective differentiation.

From our results, it would appear that the manner in which we interpret affective information and our ability to differentiate among different affects are influenced by demands on the organism for adaptation to stress. Evidence for cognitive mechanisms underlying the change in relationship between positive and negative affects was not available in this study. The use of measures of cognitive structure like those developed by Linville (1987) may be particularly useful to examine such mechanisms. We hope the findings presented here will encourage future research along these lines.

This study also has two limitations that are especially worthy of note. First, we used a select set of affect terms, which limits the generalisability of our findings. Future research on this topic may wish to begin with a set of affect terms that fully represents both low and high arousal states. Second, we do not know whether these findings would generalise to other populations, such as working women, or those who are not employed. What our study provides is one demonstration of how the correlation between PA and NA may vary as a function of the adaptation demands on the person at the time of assessment.

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APPENDIX[1]

Multilevel analysis

The current dataset has two hierarchical levels, which we refer to as beep level and participant level. At the beep level, we have two regression equations, one for PA and one for NA. They relate the affect scores of the *i*-th participant at the *j*-th beep ($i = 1, \ldots, 85$; $j = 1, \ldots, 50$), denoted by PA_{ij} and NA_{ij}, to the occurrence of a stressful event:

$$PA_{ij} = \alpha_{(1)ij}\ NoEvent_{ij} + \beta_{(1)ij}\ Event_{ij} + v_{(1)i};$$
$$NA_{ij} = \alpha_{(2)ij}\ NoEvent_{ij} + \beta_{(2)ij}\ Event_{ij} + v_{(2)i}.$$

The predictor $Event_{ij}$ takes one value (1) when a stressful event is reported, and (0) otherwise. The predictor $NoEvent_{ij}$ is defined as 1 minus $Event_{ij}$. The coefficients $v_{(1)i}$ and $v_{(2)i}$ are random participant level factors that represent the participant's deviations from the overall scores. The regression coefficients $\alpha_{(g)(ij)}$ and $\beta_{(g)(ij)}$ ($g = 1,2$) are modelled as:

$$\alpha_{(g)ij} = \alpha_{(g)} + u_{(\alpha g)ij}.$$
$$\beta_{(g)ij} = \beta_{(g)} + w_{(g)i} + u_{(\beta g)ij}.$$

The intercepts, $\alpha_{(g)}$ and $\beta_{(g)}$, constitute the overall PA and NA scores at stress and nonstress, $w_{(g)i}$ is the participant-specific random effect of a stressful event, and $u_{(\alpha g)ij}$ and $u_{(\beta g)ij}$ are beep level residual terms.

The coefficients $v_{(g)i}$ and $w_{(\beta g)i}$ are included to obtain beep level correlations, such as the correlation between $u_{(\alpha 1)ij}$ and $u_{(\alpha 2)ij}$, that are not biased by participant level factors. We assumed that any bias would be due to: (1) a participant level correlation, or intraclass correlation, that differs from zero when two observations from the same participant are more alike than two observations from different participants (accounted for by $v_{(g)i}$; and (2) an effect on the participant-level correlation (accounted for by $w_{(g)i}$), that differs from zero when the intraclass correlation among the average PA and NA scores is stress-related.

The model parameters are the fixed effects $\alpha_{(1)}$, $\alpha_{(2)}$, $\beta_{(1)}$, and $\beta_{(2)}$, the beep level variance and covariance terms var ($u_{(\alpha 1)ij}$), var ($u_{(\alpha 2)ij}$), var ($u_{(\beta 1)ij}$), var ($u_{(\beta 2)ij}$), cov ($u_{(\alpha 1)ij}$, $u_{(\alpha 2)ij}$), and cov ($u_{(\beta 1)ij}$, $u_{(\beta 2)ij}$), and the participant-level variance and covariance terms var ($v_{(1)i}$), var ($v_{(2)i}$), cov ($v_{(1)i}$, $v_{(2)i}$), var ($w_{(1)i}$), var ($w_{(2)i}$), and cov ($w_{(1)i}$, $w_{(2)i}$). To estimate the model using a software package like MLn (Prosser et al., 1996), we need to reformulate it as a univariate three-level model where level one is an (NA, PA) indicator level, level two is the beep level, and level three is the participant level. The response variable is now y_{ijk} which is either a PA score ($k = 1$) or a NA score ($k = 2$). The regression equation for y_{ijk} is:

$$y_{ijk} = \alpha_{(1)ij}\ (NoEvent_{ij} \times PA_{ijk}) + \beta_{(1)ij}\ (Event_{ij} \times PA_{ijk}) + v_{(1)i} +$$
$$\alpha_{(2)ij}\ (NoEvent_{ij} \times NA_{ijk}) + \beta_{(2)ij}\ (Event_{ij} \times NA_{ijk}) + v_{(2)i},$$

where PA_{ijk} is equal to PA_{ij} if $k = 1$ and 0 if $k = 2$, and NA_{ijk} is equal to NA_{ij} if $k = 2$ and 0 if $k = 1$.

Contingency table analysis

For each participant and separately for the stressor and nonstressor situation, a frequency table is constructed that registers high and low PA and NA scores. The PA or NA scores are classified as high if they are larger than the overall median. The high/low dichotomisation is done on scores that are adjusted for individual differences in: (1) the mean PA and NA scores, and (2) the effect of a stressful event on PA or NA. To do the adjustments, separate multilevel models are fitted with NA and PA as response variables and the stressor as a predictor. The multilevel regression equations are:

$$PA_{ij} = \gamma_{(1)i} + \delta_{(1)i}\ Event_{ij} + \varepsilon_{(1)ij};$$
$$NA_{ij} = \gamma_{(2)i} + \delta_{(2)i}\ Event_{ij} + \varepsilon_{(2)ij}.$$

The parameters $\gamma_{(1)i}$, $\gamma_{(2)i}$, $\delta_{(1)i}$, and $\delta_{(2)i}$ are participant-specific random regression coefficients and $\varepsilon_{(1)ij}$ and $\varepsilon_{(2)ij}$ are beep level residual terms. The adjusted scores are defined as:

$$PA_{ij}^{*} = PA_{ij} - \gamma_{(1)i}^{*} - \delta_{(1)i}^{*}\ Event_{ij};$$
$$NA_{ij}^{*} = NA_{ij} - \gamma_{(2)i}^{*} - \delta_{(2)i}^{*}\ Event_{ij},$$

where $\gamma_{(1)i}^{*}$, $\gamma_{(2)i}^{*}$, $\delta_{(1)i}^{*}$, and $\delta_{(2)i}^{*}$ are the empirical Bayes estimates (Bryk & Raudenbush, 1992, p. 40; Morris, 1983).

Unidimensionality of the affect scales is supported by the occurrence of a high PA and a low NA score or a low PA and a high NA score. The support for an inverse PA-NA relationship is therefore expressed as the proportion of dichotomised PA-NA scores in the nondiagonal cells of the 2×2 frequency table.

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[1] The Appendix was prepared by Johannes Berkhof.