Every dark cloud has a colored lining
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Chapter 3

Experiencing positive and negative affect in solo or in concert: The role of arousal

Based on:
Abstract

The Dynamic Model of Affect (DMA) postulates that positive affect (PA) and negative affect (NA) become more unidimensional, that is more inversely related to each other, at stressful moments, because stress narrows attention and enhances quick-and-dirty decision making. Studies investigating the DMA use measures of stress that intertwine high arousal and unpleasantness, and are therefore unable to examine the unique role of high arousal. Employing an Experience Sampling design in which participants were measured 5 times a day for 14 days, we examined whether arousal was associated with a more unidimensional structure of PA and NA in daily life rather than in artificial lab situations. Corresponding to our hypothesis, high momentary arousal was associated with a more unidimensional relation between PA and NA within-persons. We did not find between-subject effects of arousal, that is, individuals with higher mean scores of arousal did not have a stronger inverse relation between PA and NA, illustrating that within-subjects effects do not necessarily imply between-subjects effects. Our results expand the DMA by showing that PA and NA become more inversely related to each other at higher levels of momentary arousal, regardless of unpleasantness, and highlight the importance of measuring PA and NA with separate scales rather than a unidimensional scale, especially in conditions with low arousal. The differences between within-subject effects and between-subject effects of arousal underline the importance of examining momentary arousal repeatedly over time rather than using aggregated measures of arousal when investigating the structure of PA and NA.
Introduction

It is often assumed that a reduction in negative affect (NA) automatically results in an increase in positive affect (PA) (Reich & Zautra, 2002). However, the dependency of PA and NA is a long existing controversial topic in emotion research (e.g. Russell & Carroll, 1999; Schmukle & Egloff, 2009; Tellegen, Watson, & Clark, 1999; Watson et al., 1999). While several researchers consider the dimensions of PA and NA as largely independent (e.g. Watson & Tellegen, 1985), others challenge this view by showing that this independence disappears when random and systematic measurement errors are taken into account (e.g. Green, Goldman, & Salovey, 1993). These uni- and bidimensional views of PA and NA are not necessarily mutually exclusive. Tellegen and colleagues (1999) suggested a hierarchy based on the degree of affective complexity, which ranges from differentiated discrete emotions, via a bidimensional structure, to a unidimensional structure of PA and NA.

The Dynamic Model of Affect (DMA) incorporates this hierarchical structure by postulating that PA and NA become more unidimensional at stressful moments, because stress narrows attention and causes more quick-and-dirty decision making in order to regulate negative emotions and to adjust rapidly to the uncertain stressful situation (Reich et al., 2003). The cost is that positive cues are neglected (Reich et al., 2003). Several studies in different populations have supported the DMA by indicating that, under high stress, PA and NA are inversely correlated, while a correlation between PA and NA is weak in situations with low stress (Davis et al., 2004; Pruchno & Meeks, 2004; Reich et al., 2003; Zautra et al., 2000).

Studies investigating the DMA use stress measures that intertwine high arousal and unpleasantness (i.e. the number of negative events or the occurrence of a specific stressor), and are therefore unable to examine the unique role of high arousal in the unidimensional structure of PA and NA. Reich and Zautra (2002) showed the important role of arousal in the structure of PA and NA: PA and NA responses to emotional pictures became more inversely correlated when the affective states were highly pleasant or unpleasant, but only when arousal was high as well, suggesting arousal is key. However, this study had low ecological validity and was unable to examine within-person effects because average responses to emotional pictures across persons were investigated. Other studies investigating the DMA did examine within-person effects in daily life, but did not include a separate arousal measure. Therefore, the unique impact of arousal on the
within-person structure of PA and NA is currently undetermined.

While the DMA essentially applies to the structure of PA and NA within persons across time, the structure of PA and NA also vary between persons (Rafaeli, Rogers, & Revelle, 2007). Between-person differences have been related to coping with stressful life events, subjective distress, and psychological resilience (e.g. Coifman, Bonanno, & Rafaeli, 2007; Hay & Diehl, 2011; Ong, Bergeman, Bisconti, & Wallace, 2006). In addition, anxious patients had a stronger inverse correlation between PA and NA and higher levels of arousal than depressed patients (e.g. Watson et al., 1995; Williams et al., 2004). These findings suggest that between-person differences in the typical structure of PA and NA can be partly explained by differences in mean level of arousal, but this has not yet been examined empirically.

Using Experience Sampling Methodology (ESM), this study aimed to clarify within-person and between-person effects of arousal on the relation between PA and NA. We hypothesized that within-person and between-person levels of arousal would predict a stronger inverse (i.e. more unidimensional) relation between PA and NA. In other words, we expected that high momentary arousal would be positively associated with a stronger inverse relation between PA and NA at that moment (within-person relation), and that individuals with higher mean scores of arousal would show a stronger inverse relation between PA and NA across time (between-person relation).

**Methods**

**Participants**

Of the 589 female students who were invited to participate in this study, which was part of a combined ESM-fMRI study on affect dynamics, 268 (45.5%) signed the informed consent form and filled out an online screening questionnaire (www.unipark.de). The screening questionnaire involved inclusion criteria (i.e. female gender, age between 18 and 25 years, and Dutch as native language), exclusion criteria (i.e. inability to keep an electronic diary five times a day, current psychiatric disorders, and standard MRI incompatibility criteria), and the neuroticism and extraversion scale of the NEO Five Factory Inventory (NEO-FFI, Hoekstra, Ormel, & De Fruyt, 1996). We used the 60th percentile score of the neuroticism scale (score = 31) as selection criterion for participation, and randomly selected 50 participants who scored above, and 25 who
scored below this criterion. This selection procedure resulted in an approximately normal distribution of neuroticism scores. The final sample consisted of 73 students, because one participant dropped out of the study after one measurement day and one was excluded from the statistical analyses due to a less than 50% compliance rate.

**Procedure**

ESM measurements were collected by either Personal Digital Assistants (Myin-Germeys et al., 2009, \(n = 32\) (43.8%)), or the participants’ smart phones via a web-based application (ROQUA, www.roqua.nl, \(n = 41\) (56.2%)). One day before the start of the ESM period, participants were instructed individually on how to use the PDA or web-based application and how to interpret the ESM questions.

The ESM measurement period lasted 14 days in which participants received automated auditory signals or web-based generated text messages five times a day to notify the occurrence of a new ESM measurement. The exact time points of the measurements were adjusted to the participants’ usual daily rhythm, but the measurements were always scheduled during waking hours, at fixed time points with 3-hour intervals. To minimize memory distortion, we asked the participants to complete the ESM measurements as soon as possible after the signal, but at maximum 30 minutes after the signal. All participants were paid €30 with a bonus of €20 for those who completed a minimum of 63 out of 70 measurements. The average number of completed responses was 64.95 (92.8%, \(SD: 3.32\)).

**Measures**

Momentary positive affect (PA) was measured by averaging for a certain time point the items ‘cheerful’, ‘energetic’, ‘enthusiastic’, satisfied’, ‘relaxed’, and ‘calm’; and momentary negative affect (NA) by averaging the items ‘upset’, ‘irritated’, ‘nervous’, ‘listless’, ‘down’, and ‘bored’. Participants rated the items on a scale ranging from 1 (not at all) to 7 (very). The Cronbach’s alphas of the PA and NA scale (calculated across all time points and individuals) were 0.84 and 0.79, respectively, indicating good internal consistency. Mean PA and mean NA were calculated by averaging PA or NA across all time points for each subject.

Correlations are commonly used to assess the relationship between two variables that have been measured at multiple time points (or in multiple cases). The assessment
of the momentary relation between PA and NA at each time point, however, calls for a novel approach: we created a dimensionality measure, which indicates how strongly unidimensional PA and NA are at a given moment in time by using a combination of the sum and the difference scores of PA and NA. More specifically, we converted the original PA and NA scores into $z_{PA}$ and $z_{NA}$ scores representing within-person deviation scores (i.e. personalized $z$-scores), and calculated their absolute sum ($\text{ABS}(z_{PA} + z_{NA})$) and absolute difference scores ($\text{ABS}(z_{PA} - z_{NA})$). A unidimensional relation is characterized by an inverse relation between PA and NA, that is high $z_{PA}$ and low $z_{NA}$ or vice versa. This is reflected by an absolute sum score that is close to 0, and an absolute difference score that is higher than 0; the larger the difference, the stronger the indication of unidimensionality. A bidimensional relation is characterized by high $z_{PA}$ and high $z_{NA}$ or low $z_{PA}$ and low $z_{NA}$. In these cases, the absolute sum score is larger than 0, and the absolute difference score close to 0. To adjust for the fact that the sum and the difference scores reflect a mixture of the intensity and the (uni- or bi-)dimensionality of PA and NA, we subtracted the absolute difference score from the absolute sum score. This way, a higher dimensionality score indicates a more bidimensional (and less unidimensional) relation between PA and NA at a given point in time. For example, a $z_{PA}$ of 2 and $z_{NA}$ of 2 results into a dimensionality score of 4 (very bidimensional), and a $z_{PA}$ of 2 and $z_{NA}$ of -2 in a dimensionality score of -4 (very unidimensional).

Arousal was measured by the question how activated participants felt at that moment. The scale ranged from 1 = not at all activated to 7 = very activated. We created a mean arousal and momentary arousal measure. Mean arousal reflects the average level of arousal of a subject, calculated across all time points. Momentary arousal reflects the level of arousal at a certain time point in relation to the average level of arousal of a subject, and was calculated by subtracting the mean arousal score from the momentary arousal score (i.e. person-specific mean centering).

**Statistical analyses**

Multi-level analyses with ML estimation were conducted in M-plus (Muthen & Muthen, 1998-2010), with the momentary repeated measurements (level 1) nested within subjects (level 2). An advantage of multi-level analyses is the possibility to model level 1 error variance and level 2 error variance simultaneously and to handle different numbers of observations for each subject. We included the dimensionality score as dependent
variable. To examine whether momentary arousal and mean arousal were associated with the dimensionality scores, we included momentary arousal as random predictor (i.e. the effect varies randomly within subjects) and mean arousal as fixed predictor, respectively. In addition, intercepts were allowed to vary (i.e. random intercept). Significance levels (two-tailed) were set at $p < .05$ for all analyses.

**Results**

**Descriptive statistics**

A paired t-test revealed that mean PA (4.51, $SD$: 0.69) was significantly higher than mean NA (1.71, $SD$: 0.58): Difference score = 2.80, 95% CI: 2.55 to 3.06, $t(72) = 21.99$. The mean arousal and dimensionality score were 3.49 ($SD$: 0.90) and -0.54 ($SD$: 0.26), respectively.

**Multilevel analyses results**

The results of the multilevel analyses are presented in Table 3.1. Momentary arousal was negatively associated with the dimensionality score. Please note that the dimensionality score reflects the extent of bidimensionality. Hence, high momentary arousal was associated with a more unidimensional relation between PA and NA. Mean-level differences in arousal between participants did not significantly predict the dimensionality score. As can be seen in the lower panel of Table 3.1, the variances of the intercept and momentary arousal score were significant, which indicates that the participants differed significantly in average levels of dimensionality and in the effect of momentary arousal on the momentary relation between PA and NA.
This study provides the first empirical evidence from a naturalistic daily life setting that the relationship between PA and NA is dependent on momentary arousal levels. In line with our hypothesis, within-subject higher levels of momentary arousal were associated with a stronger inverse (i.e. more unidimensional) relation between PA and NA. We did not find support for the hypothesis that individuals with higher mean scores of arousal showed a stronger inverse relation between PA and NA across time (between-person relation), illustrating that within-subjects effects do not necessarily imply between-subjects effects.

Our findings expand the DMA (Davis et al., 2004; Pruchno & Meeks, 2004; Reich et al., 2003; Williams et al., 2004; Zautra et al., 2000) by showing that PA and NA become more inversely related to each other at higher levels of momentary arousal, regardless of unpleasantness. This finding has important implications. First, it highlights the relevance of taking momentary arousal into account when investigating the structure of affect. Second, it argues for measuring PA and NA with separate scales rather than a unidimensional scale, especially in conditions with low arousal. That is, ratings on unidimensional scales such as the affect grid (Russell et al., 1989) may be biased, because these scales do not allow participants to concurrently rate high PA and high NA. Third, it suggests that if positive and negative events evoke high arousal, these events influence

### Table 3.1: Multilevel model to examine the influence of arousal on the dimensionality between positive affect (PA) and negative affect (NA)

<table>
<thead>
<tr>
<th>Fixed effects</th>
<th>B</th>
<th>95% CI</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept arousal</td>
<td>-0.57</td>
<td>[-0.82, -0.33]</td>
<td>-4.67***</td>
</tr>
<tr>
<td>Mean arousal</td>
<td>0.01</td>
<td>[-0.06, 0.08]</td>
<td>0.28</td>
</tr>
<tr>
<td>Momentary arousal⁵</td>
<td>-0.08</td>
<td>[-0.12, -0.04]</td>
<td>-3.73***</td>
</tr>
</tbody>
</table>

**Random effects**

<table>
<thead>
<tr>
<th></th>
<th>Variance</th>
<th>95% CI</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.05</td>
<td>[0.03, 0.07]</td>
<td>4.14***</td>
</tr>
<tr>
<td>Momentary arousal⁵</td>
<td>0.01</td>
<td>[0.01, 0.03]</td>
<td>2.50**</td>
</tr>
</tbody>
</table>

**Note.** N = 4741 momentary assessments (level 1), 73 participants (level 2)

⁵Average level of arousal of a participant, calculated across all time points

⁶Arousal score at a certain time point minus the average arousal score of the participant

*p < .05, **p < .01, ***p < .001.

### Discussion

This study provides the first empirical evidence from a naturalistic daily life setting that the relationship between PA and NA is dependent on momentary arousal levels. In line with our hypothesis, within-subject higher levels of momentary arousal were associated with a stronger inverse (i.e. more unidimensional) relation between PA and NA. We did not find support for the hypothesis that individuals with higher mean scores of arousal showed a stronger inverse relation between PA and NA across time (between-person relation), illustrating that within-subjects effects do not necessarily imply between-subjects effects.

Our findings expand the DMA (Davis et al., 2004; Pruchno & Meeks, 2004; Reich et al., 2003; Williams et al., 2004; Zautra et al., 2000) by showing that PA and NA become more inversely related to each other at higher levels of momentary arousal, regardless of unpleasantness. This finding has important implications. First, it highlights the relevance of taking momentary arousal into account when investigating the structure of affect. Second, it argues for measuring PA and NA with separate scales rather than a unidimensional scale, especially in conditions with low arousal. That is, ratings on unidimensional scales such as the affect grid (Russell et al., 1989) may be biased, because these scales do not allow participants to concurrently rate high PA and high NA. Third, it suggests that if positive and negative events evoke high arousal, these events influence
PA and NA in concert, whereas if positive or negative events evoke low arousal, these events solely influence PA or NA, respectively. Although further research is needed, one could contemplate on the significance of this finding for clinical practice. Prevention and intervention strategies for depression may, for instance, benefit from a focus on arousal. In depressed patients, who typically have high NA or low PA, increasing arousal during the experience of positive events might be a beneficial intervention strategy, because high arousal may result in a ‘double positive effect’ on well-being, that is a decrease in NA in concert with an increase in PA.

Our study does not elucidate why we found a positive association between arousal and unidimensionality of PA and NA. One explanation might be that high arousal is accompanied by changes in information processing such as narrowing of attentional focus, which could result in a unidimensional structure of affect. However, prior research is inconclusive with respect to the influence of arousal and motivational intensity (i.e. a concept closely related to arousal) on information processing (e.g. Easterbrook, 1959; Gable & Harmon-Jones, 2010; Gable & Harmon-Jones, 2012; Gable & Harmon-Jones, 2013; Harmon-Jones, Gable, & Price, 2013; van Steenbergen, Band, & Hommel, 2011). Furthermore, one cannot simply extrapolate findings from the influence of arousal on information processing to our results, because the former results are largely based on studies using a physiological measure of arousal, while we focused on perceived arousal. Future research is required that directly investigates whether changes in information processing mediate the influence of arousal on the unidimensionality of PA and NA by including good measures of both perceived and physiological arousal.

In our study perceived arousal was measured by a single item. Although we are aware that single items are more susceptible to random measurement error, we think that the use of a single item for arousal did not influence our findings to a great extent. We think that our measure was valid because we gave participants detailed instructions on the meaning of the concept of arousal and use of the scale. Nonetheless, future studies might benefit from including an additional perceived arousal item, such as the Self-Assessment Manikin of arousal (Bradley & Lang, 1994).

Our study was the first that directly tested whether individuals with higher mean levels of arousal showed a stronger inverse correlation between PA and NA. Contrary to our hypothesis, mean arousal did not explain between-subject differences in the structure of PA and NA. Hence, in our healthy female study population, between-
subject effects of arousal on the structure of PA and NA were different from within-
subject effects of arousal: arousal was only related to the unidimensionality of PA and
NA at the within-person level. This finding underlines the importance of examining
momentary arousal and the structure of PA and NA repeatedly over time rather than
using aggregated measures of arousal when investigating the structure of PA and NA.
Further research is required to investigate whether these findings generalize to clinical
populations, males, and groups from different ages and social economic classes.

To conclude, employing a strong ESM methodology characterized by a long follow-
up period and a high number of measurements per person, we were the first to examine
the effect of arousal on the relation between PA and NA in the realm of daily life.
Our results expand the DMA (Davis et al., 2004; Pruchno & Meeks, 2004; Reich
et al., 2003; Williams et al., 2004; Zautra et al., 2000) by showing that higher levels
of momentary arousal, regardless of unpleasantness, were associated with a stronger
inverse relation between PA and NA within-persons. Hence, our findings highlight the
importance of measuring PA and NA with separate scales rather than a unidimensional
scale, especially in conditions with low arousal. The absence of between-subject effects of
arousal illustrates that within-subjects effects do not necessarily imply between-subjects
effects and underline the importance of examining momentary arousal repeatedly over
time rather than using aggregated measures of arousal when investigating the structure
of PA and NA.
Part 2

The relation between factors that are associated with increased risk of depression on the one hand, and reactivity to positive and negative events on the other hand