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Using signal detection theory to test the impact of negative emotion on sub-clinical paranoia

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A novel experimental paradigm for measuring state paranoia by means of signal detection theory was evaluated. A liberal response bias, indicating the tendency to recognize facial expressions as threatening, was expected to reflect paranoia. Against theoretical expectations, heightened paranoia questionnaire scores were associated with a non-liberal bias, which was not affected by negative emotion per se. However, subsequent analyses revealed that, if anxious, participants with heightened paranoia adopted a comparatively more liberal response bias. These findings corroborate the eminent role of anxiety in paranoia and demonstrate that state paranoia can be captured with the presented paradigm.

1. Introduction

Persecutory delusions involve the anticipation of harm which is intended by a malevolent persecutor (Freeman & Garety, 2000). Freeman, Garety, Kuipers, Fowler, and Bebbington (2002) proposed a cognitive model of persecutory delusions that explains the formation of delusional threat beliefs in terms of a distorted attribution process. This process is adversely influenced by three factors: anomalous experiences, cognitive biases and emotional disturbances. Negative emotions, particularly anxiety, are assumed to have a direct influence on the formation and maintenance of persecutory delusions (Freeman, 2007; Freeman et al., 2005). They influence a search for meaning of anomalous or unusual experiences, resulting in a persecutory threat belief. Furthermore, negative emotions are supposed to maintain the threat belief by means of safety behavior (Freeman et al., 2007). Several studies have found correlational association between anxiety and paranoia (Freeman & Fowler, 2009; Martin & Penn, 2001; Startup, Freeman, & Garety, 2007). Moreover, in a recent experimental study, anxiety was identified as a mediator of the impact of stress on paranoia (Lincoln, Peter, Schäfer, & Moritz, 2008).

The benefit of the cognitive model of persecutory delusions is the integration of empirical and practical findings in a theoretical framework that allows the deduction of predictions. Surprisingly however, in the last six years there have only been a few *experimental* studies to test the prediction that negative emotions increase paranoia (e.g. Ho-Wai So, Freeman, & Garety, 2008; Lincoln et al., 2008). This lack of testing might be due to the absence of measures of persecutory ideation. So far, solely self-report questionnaires have been available for this purpose (e.g. the Paranoia Scale by Fenigstein & Vanable, 1992; or the Paranoia Checklist by Freeman et al., 2005). These are disadvantageous because of their susceptibility to unquantifiable response biases. Furthermore, they are designed to capture long-term or 'trait' persecutory ideation by response modalities like "once a month" to "at least once a day" (Freeman et al., 2005). Because of this lack of sensitivity they are not appropriate to measure experimentally induced changes. For this reason, in the present study an experimental paradigm for measuring *state* persecutory ideation – in contrast to questionnaires that are denominated as *trait* measures in the following – was developed to allow for experimental testing of models explaining persecutory delusions.

This paradigm is based on the assumption that the persecutory threat belief ("someone intends harm towards me") can bias the perception of the aggression-expressing, threatening emotion anger in faces (Averill, 1983; Öhman, 1986). Because persecutory delusions are "erroneous beliefs that usually involve a misinterpretation of perceptions" (DSM-IV; American Psychiatric Association, 1994, p. 275), it is proposed that they will be related to a bias to perceive other persons as angry (and thus socially

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threatening). In facial anger detection tasks such biases can be described by means of the signal detection theory (Wickens, 2002), with a liberal response bias indicating a tendency to perceive – or to report to have perceived – anger. In the theoretical framework of detection theory a liberal bias implies that the response criterion, i.e. the level of subjective evidence necessary to report having seen an angry face, is relatively low. The main advantage of the signal detection approach is its ability to separate the otherwise confounded aspects of decision behavior: the performance (how well can angry expressions be detected?) and the response tendency (how often are angry expressions chosen in case of uncertainty?). Without a signal detection analysis it is difficult to infer which aspect accounts for the results. For example, it would remain unclear if a higher ratio of correctly recognized angry expressions is due to an improved performance or to a liberal response bias.

Because of the novelty of the paradigm, the study was conducted with undergraduate students without clinical relevant paranoia. In line with a continuum hypotheses of psychotic symptoms (Johns & van Os, 2001) it is expected that associations in clinical levels of persecutory delusions are also present at sub-clinical levels. However, it has to be kept in mind that a simple generalization of sub-clinical findings onto clinically relevant levels of paranoia is improper.

The following study tests the assumption that higher levels of 'trait' paranoia, reflected in higher questionnaire scores, are related to a more liberal and thus paranoia-congruent response bias. Furthermore, in accordance with the cognitive model of persecutory delusions (Freeman et al., 2002), negative emotions, for example anxiety, are expected to amplify the liberal bias in individuals with heightened trait paranoia, because they trigger a paranoid threat belief and thus the anticipation of threat.

2. Method

2.1. Participants

A power calculation was conducted based on a repeated measures ANOVA with within–between interaction (medium effect size $f = 0.25$, $alpha = 0.05$, $power = 0.95$, correlation between measures $r = 0.5$, non-sphericity correction $epsilon = 1$), resulting in a minimal sample size of 44. A total of 53 undergraduate students were recruited via notice-boards in the local psychology department. All participants attended the experiment in partial fulfillment of a university course requirement. Three of them were excluded because of diminished sensitivity to angry faces ($d' < 1$) in at least one condition. Moreover, one participant was removed due to his indication of having felt better in the negative than in the positive emotion evocating condition. The mean age of the analyzed sample ($N = 49$) was $M = 21.9$ (SD = 2.4) with a rate of 87.8% females and 12.2% males.

2.2. Measures

Participants had to absolve a decision task (see 2.4 Procedure). The responses were transformed into the response bias index $\ln(\beta)$, representing the logarithm of the ratio of anger and neutral facial expression likelihoods assuming equal variance, Gaussian distributions (for details, see Wickens, 2002). Negative values of $\ln(\beta)$ indicate a liberal bias, that is a tendency to report to have seen a threatening facial expression, while positive values indicate the contrary. Additionally, the index of sensitivity d' was computed, which reflects the performance of discrimination between angry and neutral expressions.

The Paranoia Checklist (Freeman et al., 2005) and the paranoia and the delusion of reference items (numbers 6–15) of the long version of the Peters et al. Delusions Inventory (PDI; Peters, Joseph, & Garety, 1999) with a simplified yes-no response format were used to assess the trait level of persecutory ideation. The Paranoia Checklist total score was computed by summing up the products of subscale item scores, resulting in a measure that reflects the average level of persecutory thoughts regarding their frequency, conviction and distress (see Appendix A. 1).

A brief manipulation check questionnaire with three items repeatedly measured the effects of the emotion induction. It assessed the valence of the 'emotional state' (*bad–good*), the 'arousal' (*little–a lot*) and the 'attention' (*weary–rested*) using six-point scaling after each experimental condition (instruction: "Please appraise your present feeling after each block").

2.3. Stimulus material

The photorealistic facial expressions were computer-generated (with the software Poser version 5.0, www.e-frontier.com) and verified in a preparatory study ($N = 49$) in an independent sample. Visually, the mild angry expression differed from the neutral by revealing slightly frowning eyebrows, slightly more opened eyes, slightly raised nostril wings, and a compressed mouth (see http://www.uni-marburg.de/fb04/ag-klin/mitarbeiter/westermanns/JBTEP-D-09-00005). The angry expression was indeed judged as more angry (Cohen's $d = 1.52$) according to the preparatory study, less happy ($d = -1.35$), more repulsive ($d = 0.83$), more disgusted ($d = 0.78$), more sad ($d = 0.70$), less surprised ($d = -0.69$) and more anxious ($d = 0.67$) than the neutral expression (all differences significant: $|t(48)| > 4.41$; $p < 0.01$). The occurrence of unspecific medium effect sizes in other facial expression dimensions could not be avoided despite careful visual modeling.

The emotional evocative pictures were categorized into three sets, depending on their valence: positive, neutral and negative. Each set consisted of 150 International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999) pictures (for a listing of all picture identifiers, see Appendix A. 2). The set characteristics are presented in Table 1 (upper part). The classification of the pictures was conducted in several steps on the basis of valence and arousal norms of Lang et al. (1999). First, stimuli with an arousal PR > 90 were excluded due to the fact that they predominantly depicted violent scenes. Then, the upper and lower 150 pictures of the valence dimension were classified as positive and negative, respectively. Moreover, the 150 pictures close to the mean of the valence dimension were selected as neutral.

Table 1
Characteristics of the used IAPS stimulus material according to dimensional and discrete norms (means with standard deviations in parentheses).

Set	*N*	Dimensional[a]		Discrete[b]		
		Valence	Arousal	Fear	Sadness	Disgust
Positive	150	7.31 (0.41)	5.01 (1.00)			
Neutral	150	5.41 (0.48)	3.93 (1.16)			
Negative	150	2.88 (0.59)	5.53 (0.86)			
Anxiety	12	3.59 (0.31)	6.20 (0.51)	3.29 (0.43)	1.43 (0.24)	2.43 (0.52)
Sadness	27	2.61 (0.49)	5.36 (0.77)	2.55 (0.74)	4.35 (0.59)	2.52 (0.81)
Disgust	36	2.73 (0.60)	5.48 (0.73)	2.44 (0.68)	3.01 (1.18)	4.54 (0.82)

Note. The stimulus set characteristics of the main analysis are presented in the first three rows. For a post-hoc analysis the negative set was further divided into three discrete emotion subsets (lower three rows).
[a] Based on Lang et al. (1999), range 1–9.
[b] Based on Mikels et al. (2005), range 1–7.

2.4. Procedure

Before the experimental procedure, participants were made familiar with the experimental task by reading instructions and passing one or, if necessary, two practice blocks with visual feedback. Thereafter they attended an extended training block that was similar to the experimental blocks, but without emotion inducing stimuli. This block served to stabilize the response behavior. After attending the last block participants filled in two questionnaires to assess the trait level of paranoia (Paranoia Checklist and PDI).

The experimental procedure comprised three blocks (negative, neutral and positive), each containing 150 trials and lasting approximately 15 min. The order of the blocks was shuffled for every participant. In every block, one of the picture sets with 150 emotion eliciting IAPS stimuli as well as 75 angry and 75 neutral faces were used (see 2.3 Stimulus material). The orders of the IAPS pictures and the faces within a block were randomized independently for every participant. After each block participants completed the manipulation check questionnaire and could pause.

A single trial consisted of several parts. First, participants viewed an emotion eliciting picture from the IAPS for 2000 ms. Subsequently a blank screen (100 ms) and then a face (125 ms) were presented. A visual noise lasting 25 ms was presented immediately after the face in order to impede the task (stimulus onset asynchrony = 125 ms). Participants were required to decide if the face displayed an anger expression or not by pressing one of two response keys ('yes' and 'no'). After a button press, the next trial started after an inter-stimulus interval of 500 ms.

3. Results

3.1. Prerequisites

Participants were dichotomized into two groups (low vs. heightened sub-clinical paranoia; SCP) on the basis of their Paranoia Checklist total scores (median split; median = 113). The groups significantly differed in all Paranoia Checklist subscales ($t(47) \geq 3.47$; all $p < 0.01$; see Table 2). Furthermore, the group with heightened SCP had significantly higher scores in another, independent measure of paranoia, namely the PDI paranoia subscale ($t(47) = 2.57$; $p < 0.05$). This finding corroborates the validity of the group dichotomization. Additionally, the groups differed in the PDI reference subscale ($t(47) = 2.15$; $p < 0.05$).

The groups did not significantly differ in any pre-experimental manipulation check variable except for *attention* ($t(47) = 2.07$; $p < 0.05$), in which the heightened SCP group was slightly more alert (diff = 0.72). Furthermore, there was no significant difference between the groups regarding the response bias ($t(47) = 0.02$; $M_{low} = 0.19$ (SD = 0.79); $M_{high} = 0.18$ (SD = 0.63)) and the discrimination performance ($t(47) = 0.28$; $M_{low} = 2.25$ (SD = 0.79); $M_{high} = 2.91$ (SD = 0.65)) in the extended training block.

Table 2
Paranoia questionnaire scores separated by group (means with standard deviations in parentheses).

	Sub-clinical paranoia	
	Low	Heightened
Paranoia checklist[a]		
Frequency	22.44 (2.35)	28.88 (4.82)
Conviction	24.56 (4.05)	33.63 (5.60)
Distress	39.08 (14.53)	53.04 (13.59)
Total	75.01 (24.45)	189.33 (72.44)
PDI[b]		
Paranoia	0.44 (0.71)	1.13 (1.12)
Reference	1.96 (1.06)	2.67 (1.24)

[a] Freeman et al. (2005).
[b] a Peters et al. Delusion Inventory (Peters et al., 1999).

3.2. Manipulation check

According to a repeated measures ANOVA with the manipulation check variable *emotional state* (subjective valence of current feeling state) and the factors *emotion* (within-group; blocks: negative vs. neutral vs. positive) and *SCP* (between-group), emotions were successfully induced. This was indicated by a significant main effect of *emotion* ($F(2,94) = 45.56$; $p < 0.001$; $\eta^2 = 0.49$) with a linear trend ($F(1,47) = 69.58$; $p < 0.001$; $\eta^2 = 0.60$; positive > neutral > negative). No other effects were significant ($F < 1.5$). Analog analyses were conducted with the manipulation check variables *arousal* and *attention*. The effect pattern of *arousal* showed similar results as *emotional state* but was attenuated: A significant main effect of *emotion* on the manipulation check variable *arousal* ($F(2,94) = 26.34$; $p < 0.001$; $\eta^2 = 0.36$) was found, forming a linear trend ($F(1,47) = 32.43$; $p < 0.001$; $\eta^2 = 0.41$). No other effects were significant ($F < 1.3$). Thus, the more negative the induced emotions were, the more they had an arousing effect. The manipulation check variable *attention* showed neither a significant main effect of *emotion* ($F(2,94) = 2.54$; $p < 0.10$) nor an interaction *emotion***SCP* ($F(2,94) < 1$). Also, the main effect of *SCP* was not significant ($F(1,47) = 2.90$; $p < 0.10$). Altogether, the induction of emotions by means of IAPS stimuli was successful.

3.3. Response bias

The main hypotheses were tested using a repeated measure ANOVA with the between-group factor *SCP* and the within-group factor *emotion* (see Table 3 for descriptive statistics). The expected *SCP* main effect was significant ($F(1,47) = 8.45$; $p < 0.01$; $\eta^2 = 0.15$). However, contrary to the hypotheses, the group with low SCP applied a more liberal bias ($M = -0.25$; $SD = 0.85$) than the group with heightened SCP ($M = 0.44$; $SD = 0.83$). The interaction between *SCP* and *emotion* was not significant ($F(2,94) < 1$), also the main effect of *emotion* was not significant ($F(2,94) < 1$). Thus, participants did apparently not adjust their response biases to the emotional condition. Moreover, it seemed that their level of sub-clinical persecutory ideation had no differential influence on the (unexpectedly inverted) response bias under the different emotion conditions.

3.4. Sensitivity, hits and false alarms

The sensitivity measure *d*' was investigated in the same way as the bias measure to exclude possible effects of disparate abilities to

Table 3
Dependent variables (means with SD in parentheses) under different emotion conditions.

Condition	Frequency		ln(β)	d'
	Hits	False alarms		
Negative				
SCP+[a]	0.87 (0.07)	0.09 (0.10)	0.42 (0.85)	2.67 (0.66)
SCP−[b]	0.88 (0.10)	0.14 (0.11)	−0.25 (1.00)	2.53 (0.75)
Neutral				
SCP+	0.87 (0.07)	0.08 (0.07)	0.59 (0.82)	2.80 (0.77)
SCP−	0.89 (0.09)	0.12 (0.09)	−0.22 (1.02)	2.75 (0.84)
Positive				
SCP+	0.88 (0.07)	0.09 (0.07)	0.30 (0.91)	2.71 (0.73)
SCP−	0.88 (0.11)	0.13 (0.10)	−0.27 (1.22)	2.73 (0.93)

[a] Sub-clinical paranoia heightened.
[b] Sub-clinical paranoia low.

detect anger expressions. Participants with heightened SCP showed equal performance in detecting anger expression ($M = 2.72$; $SD = 0.71$) as participants with low SCP ($M = 2.67$, $SD = 0.84$). The accordant ANOVA revealed no effects ($F < 1$) except for a marginally significant and small effect of emotion ($F(2,94) = 2.70$; $p < 0.10$; $\eta^2 = 0.05$).

Similar analyses were conducted with the ratio of hits (percent of correctly recognized angry faces) and false alarms (percent of incorrectly recognized neutral faces as angry) as dependent variables. No effect was statistically significant ($F < 1$), only the main effects of *SCP* ($F(1) = 3.38$; $p < 0.10$; $\eta^2 = 0.07$) and *emotion* ($F(2) = 2.57$; $p < 0.10$; $\eta^2 = 0.05$) regarding the ratio of false alarms reached marginal significance.

3.5. Discrete emotions

In addition to the valence-based strategy of analysis (negative vs. positive emotions), the experimental condition with negative emotion eliciting pictures was further subdivided into three *post-hoc* discrete emotion conditions on the basis of the IAPS norms of Mikels et al. (2005). Stimuli that were classified according to the IAPS norms as discretely eliciting 'anxiety', 'sadness' or 'disgust' were selected. If a selected picture belonged to more than one category, it was assigned to the category with the highest rating score. For example, if a picture of a spider (IAPS #1050) was both anxiety ($M = 3.28$) and disgust ($M = 2.55$) eliciting, it was assigned to the anxiety condition. The subset characteristics are presented in Table 1 (lower part). Responses following the discrete emotion evocating pictures were analyzed to retrieve the accordant bias measures $\ln(\beta)$. These were realigned at the overall response bias under the negative emotion condition ($\ln_{\text{discrete emotion}}(\beta) - \ln_{\text{negative emotion}}(\beta)$), resulting in the relative response bias measure $\ln^*(\beta)$ displayed in Fig. 1.

After viewing anxiety-eliciting pictures, participants with heightened SCP adopted a relatively more liberal and participants with low SCP a more conservative response bias, whereas a similar pattern could not be observed with disgust or sadness eliciting pictures. Statistical analyses using a repeated measures ANOVA with the factors *discrete emotion* (within-subject) × *SCP* (between-subject) revealed a significant interaction effect ($F(2,94) = 5.93$; $p < 0.01$; $\eta^2 = 0.11$). This interaction was qualified by significant group differences in response biases regarding *anxiety* evoking stimuli ($t(47) = 3.02$; $p < 0.01$; diff = 0.80). Thus, anxiety was associated with a relatively liberal response bias in participants with heightened sub-clinical paranoia.

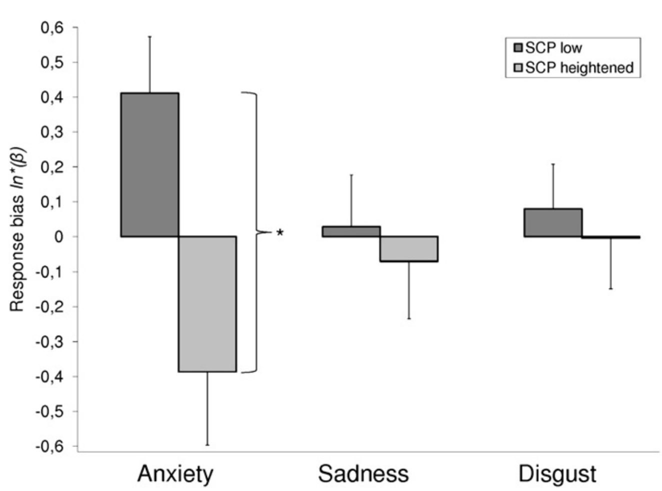

Fig. 1. Response bias deviations $\ln^*(\beta)$ of discrete negative emotions from overall bias under negative emotions of participants with low and heightened sub-clinical paranoia (SCP). Error bars represent standard errors. $^*p < 0.01$.

The associations between the relative bias measure for each negative, discrete emotion and the questionnaire scores are presented in Table 4. The bias under the influence of anxiety was significantly correlated with the Paranoia Checklist (total score: $r = -0.37$; $p < 0.01$) and the paranoia subscale of PDI ($r = -0.32$; $p < 0.05$), but not with the reference subscale.

4. Discussion

The aim of this study was to evaluate a novel paradigm for the experimental assessment of state paranoia and to test predictions of the Freeman et al. (2002) model of paranoia. It was postulated that (1) participants with heightened SCP generally adopt a more liberal, paranoia-congruent response bias, perceiving comparatively more faces as angry, and that (2) this bias is more pronounced in contrast to participants with low SCP under negative emotional conditions. However, the first hypothesis had to be rejected. In comparison to participants with low sub-clinical paranoia, participants with heightened sub-clinical paranoia applied a less liberal (conservative) response bias. This indicates a tendency to perceive faces as neutral rather than angry in ambiguous or perceptually uncertain situations. The second hypothesis was partially supported. Even if negative emotions per se did not go along with a liberal response bias, participants with heightened SCP adopted a relatively liberal response bias after viewing anxiety-evoking pictures. Moreover, under anxiety, the response bias as implicit state measure of paranoia was significantly correlated with two trait questionnaire measures of paranoia.

Though the conservative response bias was contrary to our hypothesis, it must be noted that comparable findings have been reported in other studies: For example, Phillips, Senior, and David (2000) investigated visual scan paths in participants who have schizophrenia with and without persecutory delusions and healthy controls. The group with persecutory delusions gazed *less* at threatening foreground areas than non-threatening foreground areas, particularly in ambiguous scenes. This can be considered as a conservative 'attentional bias'. Moreover, Chambon, Baudouin, and Franck (2006) discovered that patients with schizophrenia adopted a more conservative response bias in a facial emotion detection task than control subjects. Similarly, Combs, Michael, and Penn (2006) reported lower anger identification scores the more the subgroup was prone to paranoia. This could reflect an increasingly conservative response bias regarding angry faces, although this interpretation cannot be verified because signal detection theory analysis was not applied in their analyses.

Several factors could explain the adoption of a conservative bias regarding the recognition of threatening faces. Potentially, the conservative bias could reflect deficits in inferring the thoughts, emotions, intentions, etc. (mental states) of others, i.e. Theory of

Table 4
Pearson correlations between response bias deviations $\ln^*(\beta)$ from the overall bias under negative emotions and the questionnaire measures.

Condition	Paranoia checklist[a]				PDI[b]	
	Total	Frequency	Conviction	Distress	Paranoia	Reference
Anxiety	−0.47**	−0.36**	−0.38**	−0.29*	−0.29*	−0.19
Sadness	−0.20	−0.13	−0.13	−0.25	0.02	−0.07
Disgust	−0.22	−0.14	−0.12	−0.31*	−0.10	−0.15

$^*p < 0.05$, two-tailed. $^{**}p < 0.01$, two-tailed.
[a] Freeman et al. (2005).
[b] a Peters et al. Delusion Inventory (Peters et al., 1999).

Mind deficits (Frith, 2004; for a review of the role of Theory of Mind deficit in paranoia, see Mehl, Rief, Mink, Lüllmann, & Lincoln, in press). Furthermore, a 'vigilance-avoidance' mechanism could account for the data, with a conservative bias reflecting a late, cognitive avoidance strategy, contrary to an early, automatic vigilance process (Green & Phillips, 2004). This account seems to fit our findings best. For example, participants in the heightened SCP group reported to be more alert in the pre-experimental manipulation check, indicating higher levels of vigilance. The exploratory finding that the sensitivity *d*' to detect angry facial expressions is higher in the group with heightened SCP than in the group with low SCP under anxiety ($t(47) = 2.36$; $p < 0.05$; diff $= 0.43$) is also in line with this consideration. However, it is also conceivable that the conservative bias is a methodic artifact resulting from incomplete anger expression processing due to backward masking (the facial expressions were followed or 'masked' by visual noise), although this seems unlikely because of the high discrimination performance in both groups ($d' > 2.5$). Apart from these possible explanations, it must be noted that the association between perception and delusion is less direct than proposed. Unfortunately, the present experimental design is not able to test these post-hoc, rather speculative explanations against each other. Thus, further research is necessary.

Nevertheless, one goal of this study was to develop an experimental measure of state paranoia. This was achieved at least partially: When participants were anxious, their actual response bias deviated from their general, negative response bias and this (anxiety-induced) deviation was substantially correlated with trait paranoia. This association indicates convergent validity. Moreover, the deviation was not correlated to the related, but nevertheless delimitable construct of delusions of reference (PDI subscale), which can be considered as evidence for divergent validity. The fact that the association between the implicit state measure (response bias) and the trait measures (questionnaires) only appeared in the specific, paranoia-relevant situation of being anxious demonstrates an important issue: *state* paranoia can solely or at least better be measured in individuals if they *currently* are in such a mental state. Thus, the present paradigm can be regarded as a genuine state measure.

If we put the overall conservative bias aside and assume that its cause is unrelated to state paranoia, the present findings are highly convergent with the cognitive model of persecutory delusions of Freeman et al. (2002). Anxiety influences an attributional–or in the present paradigm: perceptual–process, that leads to or triggers a threat belief. The higher the trait paranoia level, the more liberal is the response bias under anxiety, and the more faces are perceived as threatening. The association of anxiety and paranoia has been found in several studies, but almost exclusively in correlational research so far (for a review, see Freeman, 2007). Thus, this is one of the first studies that could corroborate the association of anxiety and paranoia by means of experimental research.

Many of the IAPS pictures that elicit anxiety and were used in this study display phobic stimuli such as spiders. Thus, one could argue that they are not directly relevant to paranoia. However, in the cognitive model of paranoia, anxiety and other emotional disturbances are not conceptualized as a consequence of a paranoia-relevant threat. In fact, it is vice versa: (unspecific) anxiety is one factor that contributes to the resulting threat belief. Therefore, our finding that paranoia-irrelevant anxiety-eliciting stimuli had an impact on paranoid ideation is in line with the cognitive model. Nonetheless, anxiety induced by negative interpersonal interactions might have an even greater potential to trigger paranoid reactions (Freeman & Fowler, 2009).

Several shortcomings have to be mentioned: The sub-clinical sample consisted solely of students of which the majority was female. Therefore, generalizability is limited and one can expect restriction of variance of persecutory ideation. However, it has been demonstrated that students do not substantially differ from the general population in their level of delusion proneness if matched for demographic variables (Lincoln & Keller, 2008). Furthermore, it can be argued that the validity of the group classification based on results obtained in self-report measures is questionable and an interview would have resulted in more valid classifications. However, the accordance of self-assessed and interview-assessed psychotic symptoms is relatively high (Lincoln, Ziegler, Lüllmann, Müller, & Rief, 2009) and we successfully verified the classification by means of another, independent measure of paranoia, as was done in other studies before (Combs & Penn, 2004). Further limitations are the rather artificial experimental situation with only mild anger expressions in computer-generated faces that were displayed short-term and the absence of a facial expression control condition, which could have demonstrated the specificity of the findings. Also, the manipulation check measures were insufficiently differentiated, as only negative emotions in general were captured, not discrete emotions like anxiety. Thus, it cannot be stated with certainty that the participants were anxious (albeit the IAPS stimuli were rated as anxiety eliciting in Mikels et al., 2005).

Altogether, the paradigm provided unexpected, but interesting results. The absence of significant results in the analysis of the ratios of hits and false alarms underlines the usefulness of a signal detection analysis to decompose the otherwise confounded effects of performance and response bias. Further studies could clarify and corroborate the findings by using a sample with clinically relevant delusions, a more elaborated emotion induction technique and an additional control task (e.g. other facial expressions as control conditions). Despite these shortcomings, this study offers two valuable conclusions: First, state paranoia seems to be measurable by means of signal detection response bias indices, allowing new insights in persecutory processes. Second, the cognitive model of persecutory delusions can possibly be specified by the assertion that not negative emotions in general have an impact on the attributional process that leads to paranoia, but anxiety.

Appendix A. 1. Formula of paranoia checklist total score

$$PC_i = \sum_j \left(\text{freq}_{ij} \cdot \text{conv}_{ij} \cdot \text{distr}_{ij}\right) \text{with :}$$

i: Subject index.
j: Item index.
freq: Frequency subscale score.
conv: Conviction subscale score.
distr: Distress subscale score.

Appendix A. 2. Used IAPS stimuli

Negative category: (Disgust:) 1111, 1270, 1274, 1275, 1280, 2750, 3030, 3051, 3061, 3071, 3150, 3180, 3250, 3400, 6360, 7360, 7361, 7380, 8230, 9042, 9140, 9180, 9181, 9290, 9300, 9320, 9330, 9373, 9390, 9420, 9430, 9490, 9560, 9571, 9810, 9830, (Anxiety:) 1050, 1090, 1110, 1113, 1120, 1201, 1220, 1300, 1301, 1930, 3280, 6370, (Sadness:) 2053, 2205, 2490, 2590, 2700, 3220, 3230, 3300, 3350, 6570, 9041, 9050, 9182, 9252, 9415, 9421, 9470, 9530, 9561, 9600, 9611, 9620, 9910, 9911, 9912, 9920, 9921, (Undifferentiated:) 2110, 2120, 2682, 2691, 2692, 2710, 2722, 2730, 2751, 2753, 2900, 3190, 3500, 3550, 4621, 6010, 6020, 6190, 6200, 6210, 6211, 6212, 6230, 6241, 6242, 6243, 6244, 6250, 6260, 6300, 6312, 6313, 6350, 6410, 6510, 6530, 6540, 6550, 6560, 6561, 6571, 6610, 6821, 6830, 6831, 6940, 8480, 9001, 9005, 9006, 9007, 9008, 9045, 9090, 9101, 9102, 9110, 9160, 9220, 9250, 9253, 9265, 9270, 9280, 9340, 9400, 9404, 9417, 9432, 9440, 9452, 9500, 9622, 9630, 9800.

Neutral category: 1112, 1560, 1640, 2010, 2020, 2190, 2200, 2220, 2270, 2320, 2351, 2381, 2480, 2500, 2570, 2580, 2600, 2620, 2690, 2702, 2720, 2830, 2850, 2870, 2880, 2890, 4000, 4001, 4002, 4003, 4004, 4005, 4100, 4180, 4210, 4230, 4232, 4235, 4240, 4274, 4275, 4279, 4300, 4302, 4320, 4460, 4470, 4490, 4500, 4510, 4530, 4531, 4533, 4534, 4535, 4536, 4550, 4561, 4571, 4572, 4605, 4613, 4631, 4669, 4672, 4750, 4770, 5250, 5390, 5410, 5500, 5520, 5530, 5531, 5532, 5533, 5534, 5720, 5731, 5740, 5900, 5920, 5950, 6150, 6900, 6910, 7000, 7002, 7004, 7006, 7009, 7010, 7020, 7025, 7030, 7034, 7035, 7040, 7050, 7080, 7090, 7100, 7130, 7140, 7150, 7160, 7170, 7175, 7180, 7182, 7183, 7185, 7187, 7190, 7205, 7207, 7217, 7233, 7235, 7237, 7283, 7284, 7285, 7351, 7352, 7490, 7491, 7500, 7503, 7510, 7550, 7590, 7620, 7640, 7710, 7820, 7830, 7950, 8050, 8060, 8117, 8160, 8250, 8260, 8311, 8320, 8465, 9070, 9411, 9700.

Positive category: 1440, 1460, 1463, 1500, 1510, 1540, 1590, 1600, 1601, 1603, 1604, 1610, 1620, 1710, 1720, 1721, 1740, 1750, 1811, 1812, 1910, 1999, 2030, 2040, 2050, 2057, 2070, 2080, 2091, 2150, 2160, 2165, 2170, 2260, 2311, 2340, 2341, 2352, 2360, 2370, 2391, 2501, 2510, 2530, 2540, 2550, 2650, 2660, 4220, 4250, 4290, 4599, 4601, 4603, 4607, 4608, 4609, 4614, 4640, 4641, 4650, 4652, 4659, 4660, 4670, 4680, 4690, 4700, 5000, 5001, 5010, 5201, 5220, 5260, 5270, 5300, 5450, 5460, 5470, 5480, 5594, 5600, 5621, 5623, 5626, 5629, 5660, 5700, 5760, 5780, 5820, 5830, 5831, 5870, 5891, 5910, 5994, 7200, 7230, 7260, 7270, 7280, 7282, 7325, 7330, 7340, 7350, 7390, 7400, 7410, 7430, 7460, 7470, 7480, 7501, 7502, 7570, 7580, 8021, 8030, 8031, 8034, 8080, 8090, 8120, 8161, 8162, 8170, 8180, 8190, 8200, 8210, 8300, 8340, 8350, 8370, 8380, 8400, 8420, 8461, 8470, 8490, 8496, 8497, 8500, 8501, 8502, 8503, 8510, 8540.

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