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Aberrant adapting of beliefs under stress: a mechanism relevant to the formation of paranoia?

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Original Article

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Abstract

Background. Difficulties in the ability to adapt beliefs in the face of new information are associated with psychosis and its central symptom – paranoia. As cognitive processes and psychotic symptoms are both known to be sensitive to stress, the present study investigated the exact associations between stress, adapting of beliefs [reversal learning (RL), bias against disconfirmatory evidence (BADE), and jumping to conclusions (JTC)] and paranoia. We hypothesized that paranoia would increase under stress and that difficulties in adapting of beliefs would mediate or moderate the link between stress and paranoia. Furthermore, we hypothesized that the investigated effects would be strongest in the group of individuals diagnosed with a psychotic disorder.

Methods. We exposed 155 participants (38 diagnosed with a psychotic disorder, 40 individuals with attenuated psychotic symptoms, 39 clinical controls diagnosed with an obsessive-compulsive disorder, and 38 healthy controls) to a control condition and a stress condition, in which we assessed their levels of paranoia and their ability to adapt beliefs. We applied multilevel models to analyze the data.

Results. Paranoia was higher in the stress condition than in the control condition, $b = 1.142$, S.E. = 0.338, $t(150) = 3.381$, $p < 0.001$. RL, BADE, and JTC did not differ between conditions and did not mediate or moderate the association between stress and paranoia (all $p_s > 0.05$).

Conclusions. The results support the assumption that stress triggers paranoia. However, the link between stress and paranoia does not seem to be affected by the ability to adapt beliefs.

Introduction

Decades of psychosis research strongly suggest that stress is associated with the development of psychotic symptoms, such as paranoia. Experimental studies have shown that when stress is induced, both clinical and non-clinical participants react with an increase of paranoia (Kesting, Bredenpohl, Klenke, Westermann, & Lincoln, 2013; Lincoln, Peter, Schäfer, & Moritz, 2009; Veling, Pot-Kolder, Counotte, Van Os, & Van Der Gaag, 2016). These findings are substantiated by experience sampling studies that consistently report an association between daily stress and paranoia (Ben-Zeev, Ellington, Swendsen, & Granholm, 2011; Kramer et al., 2014; Krkovic, Clamor, Schlier, & Lincoln, 2020; Krkovic, Krink, & Lincoln, 2018; Lataster, Valmaggia, Lardinois, van Os, & Myin-Germeys, 2013; Reininghaus et al., 2016; Van Der Steen et al., 2017). Moreover, a recent study by Grant and Hennig (2020) showed the increase in psychotic experiences under stress to be a function of disorganized and negative schizotypy, which further emphasizes the importance of stress reactivity for the etiology of psychosis. However, it remains unclear which mechanism determines whether stress translates into paranoia.

Traditional vulnerability stress models (Nuechterlein & Dawson, 1984) and their cognitive extensions (Garety, Kuipers, Fowler, Freeman, & Bebbington, 2001) emphasize aberrant information processing as a vulnerability factor for psychosis. In the event of stress, the aberrant information processing is assumed to render it difficult for individuals to integrate new evidence from the environment and to adapt their beliefs accordingly. So far, adapting of beliefs in psychosis has been investigated by two strands of research using different methods: One strand stems from the basic psychology and has utilized probabilistic reversal learning paradigms (RL; Cools, Clark, Owen, & Robbins, 2002) to investigate deficits in reinforcement learning in psychosis. The other strand has applied paradigms to investigate biases in decision-making, such as a bias against disconfirmatory evidence (BADE; e.g. Woodward, Moritz, Cuttler, & Whitman, 2006b) and a jumping to conclusions bias (JTC; Garety, Hemsley, & Wessely, 1991). The paradigms from both strands assess whether a person integrates new information and adjusts their decision accordingly. However, specific to the typical RL paradigms is the probabilistic nature of the feedback that can occasionally be misleading.

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Therefore, the challenge of such tasks is to accurately integrate information by taking into account the contingency of the feedback (Izquierdo, Brigman, Radke, Rudebeck, & Holmes, 2017). Specific to the BADE paradigms is that they directly assess to which extent evidence contradicting the initial decision is being integrated into the decision-making process (Moritz & Woodward, 2006; Woodward, Moritz, & Chen, 2006a; Woodward et al., 2006b). Specific to the JTC paradigms is the assessment of hasty decisions, i.e. making a judgment on the basis of weak evidence (Fine, Gardner, Craigie, & Gold, 2007; Garety et al., 1991). Hence, paradigms assessing RL and cognitive biases complement each other by focusing on somewhat different aspects of adapting of beliefs. Therefore, their concurrent assessment could offer more insight into the characteristics of adapting of beliefs in psychosis.

Empirical evidence suggests that individuals with psychosis generally show both RL deficits (Leeson et al., 2009; Murray et al., 2008; Reddy, Waltz, Green, Wynn, & Horan, 2016; Schlagenhauf et al., 2014; Waltz & Gold, 2007) and cognitive biases (Eisenacher & Zink, 2017; So, Siu, Wong, Chan, & Garety, 2016). At the same time, the extent to which these deficits are already evident at the earlier stage of the disorder development is still unclear: A study examining individuals at risk for psychosis, who are often referred to as individuals with 'schizotypal traits' could not find any deficits in RL (Humpston, Evans, Teufel, Ihssen, & Linden, 2017). Similarly, Juarez-Ramos et al. (2014) showed that psychosis patients have significantly higher BADE than low and high schizotypy participants, who did not significantly differ from each other in BADE. Furthermore, Le et al. (2019) investigated BADE and JTC under stress, and even report reversed effects, with only the group with low (but not with high) schizotypy showing stronger biases under stress. However, Buchy, Woodward, and Liotti (2007) report high schizotypy participants to show stronger BADE compared to low schizotypy participants. Finally, a recent meta-analysis (Livet, Navarri, Potvin, & Conrod, 2020) reveals different types of adapting of beliefs difficulties to be present in ultra-high-risk samples. Hence, the results in subclinical schizotypy samples are inconsistent and up to this point it remains inconclusive at which stage of the disorder development the impaired adapting of beliefs emerges.

Nevertheless, deficits in adapting of beliefs seem to be directly associated with delusions across the continuum of psychosis. For instance, delusions have been associated with behavior relevant to RL, such as shift errors (Laws, Kondel, Clarke, & Nillo, 2011) and aberrant decision switching behavior (Feeney, Groman, Taylor, & Corlett, 2017). Additionally, the severity of paranoia across the continuum of psychosis has been found to be associated with BADE and JTC (Buchy et al., 2007; Dudley et al., 2013; Dudley, Taylor, Wickham, & Hutton, 2016; Freeman, Pugh, & Garety, 2008; Sanford, Veckenstedt, Moritz, Balzan, & Woodward, 2014; Veckenstedt et al., 2011; Woodward et al., 2006a), whereby the meta-analysis by Livet et al. (2020) found only weak associations between JTC and positive psychotic experiences in community samples. Hence, RL and cognitive biases research have independently accumulated empirical evidence on the direct link between deficits in adapting of beliefs and paranoia.

Although stress reactivity and adapting of beliefs appear to be highly relevant to the emergence of paranoia, the exact mechanism that links these psychological constructs remains unclear. In particular, studies on psychosis demonstrate cognitive biases to increase under stress (Ellett, Freeman, & Garety, 2008; Keefe & Warman, 2011; Lincoln, Lange, Burau, Exner, & Moritz, 2010; Moritz et al., 2011). Moreover, studies on processes related to RL in the general population suggest that stress has a negative impact on the performance in tasks requiring cognitive flexibility (Alexander, Hillier, Smith, Tivarus, & Beversdorf, 2007) and that stress promotes behavioral persistence and habit behavior (Schwabe & Wolf, 2009, 2011). Therefore, it can be postulated that deficits in adapting of beliefs under stress could represent a mediating mechanism through which stress translates into paranoia. Alternatively, deficits in adapting of beliefs could also represent a vulnerability factor that potentiates the path from stress to paranoia, indicating a moderation model. Therefore, in the present study, we tested a mediation model and also a moderation model examining the association between RL, BADE, and JTC, stress, and paranoia. We applied a within-subject (stress condition *v.* control condition) and between-subject (individuals diagnosed with a psychotic disorder, individuals with attenuated psychotic symptoms, clinical controls and healthy individuals) design. The inclusion of the group with attenuated psychotic symptoms and the healthy controls was based on the hypothesis of a psychosis continuum (e.g. Johns & van Os, 2001; Van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009) and enables us to draw conclusions about whether the hypothesized mechanisms for a specific symptom dimension (i.e. paranoia) differ at different stages of disorder expression. The inclusion of an OCD group enables to test if these effects are psychosis-specific.

We hypothesized (1) that paranoia would be significantly higher in the stress compared to the control condition; that (2) participants would have more difficulties in adapting of beliefs in the stress condition compared to the control condition; that (3) difficulties in adapting of beliefs would predict paranoia and (4) mediate the link between stress and paranoia. Finally, we hypothesized that (5) this mediating effect would be strongest in the group of individuals diagnosed with a psychotic disorder, compared to the other groups (moderated mediation). We tested a moderation model by examining the interaction effect between stress and adapting of beliefs on paranoia: Here, we hypothesized (6) the effect of stress on paranoia to be strongest in individuals with deficits in adapting of beliefs. Furthermore, we expected that (7) these associations would be strongest in the group of individuals diagnosed with a psychotic disorder, compared to the other groups (moderated moderation).

Method

Participants

Participants were recruited via flyers distributed at health care facilities as well as through job websites and forums. The recruitment took place between April 2018 and March 2020. Participants were compensated with 120€.

The sample consisted of 155 participants clustered into four groups according to their diagnostic status: 38 participants diagnosed with a psychotic disorder (PSY), 39 participants diagnosed with an obsessive-compulsive disorder (OCD), 40 participants with attenuated psychotic symptoms (AS), and 38 healthy controls (HC). General eligibility criteria included age between 18 and 55 years, sufficient knowledge of German language, and an IQ > 85 [assessed with the Multiple-Choice Vocabulary Intelligence Test (MWT-B; Lehrl, 2005)]. Exclusion criteria for all groups were a diagnosis of dementia or any severe neurological disorder, bipolar disorder, social phobia or a substance use

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disorder during the previous 6 months. Furthermore, pregnant or acutely suicidal individuals were excluded. Participants were requested to refrain from sports, tobacco, caffeine, and food 2 h prior to testing. Specific eligibility criteria for the PSY group were a diagnosis of a psychotic disorder according to DSM-V and a score of 3 or higher on the P1 (i.e. one or more at least vague delusional ideas) or P6 (i.e. at least mild suspiciousness, careful behavior and attitude) items of the Positive and Negative Syndrome Scale (PANSS; Kay, Opler, & Lindenmayer, 1989). These items both assess persecutory delusions, and we chose this cut-off score to ensure that the PSY group showed at least mild persecutory delusions, which was necessary in order to test our hypotheses on the formation of paranoia. The OCD group fulfilled the criteria for OCD according to DSM-V and had no comorbid psychotic disorder. To select participants for the AS and HC group, we pre-screened individuals from the general population with the Community Assessment of Psychic Experiences (CAPE; Stefanis et al., 2002). Participants were assigned to the AS group if diagnostic criteria for a psychotic disorder were never met but the score on the positive symptoms subscale of the CAPE was above 8, which corresponds to the 50th percentile within a large community sample (Schlier, Jaya, Moritz, & Lincoln, 2015). If the score on the positive symptoms subscale of the CAPE was ≤8 and participants had no history of mental disorder, they were assigned to the HC group.

Design and procedure

All participants were exposed to a stress and a control condition in randomized order. Stress was induced with the Trier Social Stress Test (TSST; Kirschbaum, Pirke, & Hellhammer, 1993) and in the control condition, we conducted a commonly used placebo TSST (Het, Rohleder, Schoofs, Kirschbaum, & Wolf, 2009). In the TSST, participants are asked to prepare a speech (3 min), deliver it (5 min), and then perform a mental arithmetic task (5 min; sequentially subtracting 17 from 2043) in front of a committee with a camera facing them. In the placebo TSST, participants are asked to give a speech on any topic while standing in an empty room (5 min) and to do a simple arithmetic task (5 min; successively adding 15 starting from 0), while being reinsured that no one would be evaluating them.

Potential participants were informed via telephone about the study and pre-screened for the eligibility. Three appointments were made, of which two took place on consecutive days and the third took place a week after the first (for the detailed procedure, see Fig. 1).

During the first appointment, the German version of the Structured Clinical Interview for DSM-IV Axis I disorders adapted for DSM-V (SCID-I; Wittchen, Zaudig, & Fydrich, 1997) was carried out to confirm the diagnosis status. This was followed by the MWT-B, a questionnaire battery and an RL task training. The PSY group was additionally assessed with the PANSS. The assessment lasted between 1 and 2.5 h.

At the second appointment, following a cognitive assessment and a 30 min break, participants were exposed to the stress or the control condition and completed the RL, BADE and JTC paradigms during which state assessments of subjective stress, heart rate, salivary cortisol, and paranoia and OCD symptoms[†1] took place (t1–t6 in Fig. 1). Thereafter, participants were asked to rest for 15 min. The appointment lasted between 2.5 and 3.5 h.

At the third appointment, individuals participated in the remaining condition, which involved parallelized versions of the RL and the BADE paradigms (see Fig. 1) and lasted approximately 1 h.

Measures

The PANSS is a semi-structured interview for rating positive (seven items) and negative symptoms (seven items), and overall psychopathology (16 items) in psychosis. Each item is scored on a seven-point scale, ranging from 1 'absent' to 7 'extreme'. The PANSS has demonstrated good reliability, criterion, and construct validity (Kay et al., 1989). We used PANSS to assess the eligibility of the potential participants for the PSY group.

The CAPE is a 42-item self-report instrument assessing lifetime psychotic experiences on three subscales – negative, positive, and depression symptoms. Previous studies demonstrated good convergent and discriminative validity (Hanssen et al., 2003) and a good test–retest reliability of the instrument (Konings, Bak, Hanssen, Van Os, & Krabbendam, 2006). The German version of the CAPE has a good factorial and criterion validity (Schlier et al., 2015). We used scores of the positive symptoms subscale to check eligibility criteria for HC and AS group.

State assessment before, during, and after the stress and the control condition

State subjective stress was assessed with four items capturing anxiety, sadness, anger, and shame (items based on Stemmler, Heldmann, Pauls, & Scherer, 2001) as well as two items capturing the controllability of the situation and perceived stress (items based on Gaab, Rohleder, Nater, & Ehlert, 2005). This scale has been applied in a longer form in Krkovic et al. (2018). Participants were asked to which extent each of the statements applies to them at the moment of the assessment on a 10-point Likert scale. The reliability of the scale in our sample was good to excellent with between-subject multilevel Cronbach's $\alpha = 0.964$ and within-subject Cronbach's $\alpha = 0.840$.

State paranoia was assessed using a five-item version of the Paranoia Checklist (original version: Freeman et al., 2005; five-item version: Schlier, Moritz, & Lincoln, 2016) (e.g. 'I need to be on my guard against others'; 'My actions and thoughts might be controlled by others'). Participants were asked to which extent each of the statements applies to them at the moment of the assessment on a 10-point Likert scale. This short version has been validated and shown to be sensitive to change (Schlier et al., 2016). The reliability of the scale in our sample was acceptable with between-subject multilevel Cronbach's $\alpha = 0.949$ and within-subject Cronbach's $\alpha = 0.632$.

Measures of adapting of beliefs

The RL paradigm was based on the concept of the existing probabilistic RL tasks (Cools et al., 2002; Reddy et al., 2016). The paradigm consisted of six blocks. Throughout the 50 trials of a block, participants were presented with two visual stimuli. For each trial, participants were instructed to select which of the two stimuli they believed will lead to a reward, based on the feedback they received so far (reward = a green smiley face and a numerical score of +1; loss = a red sad face and a numerical score of −1).

†The notes appear after the main text.

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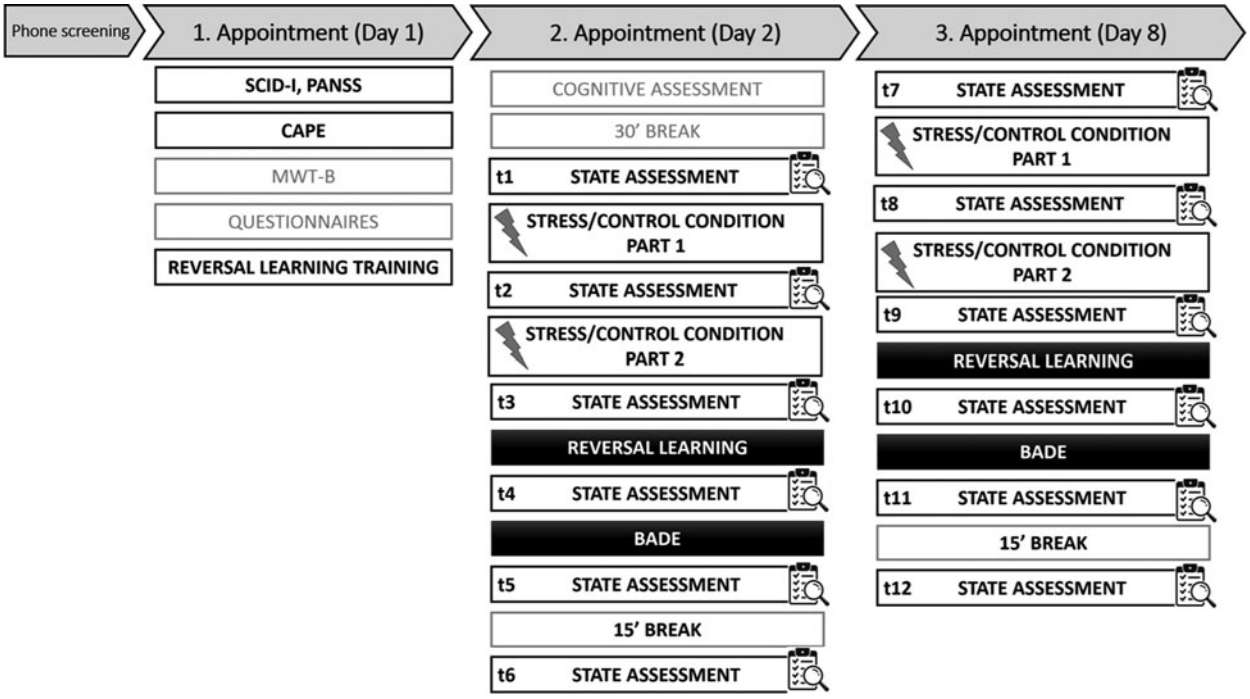

Fig. 1. Study procedure. SCID-I = Structured Clinical Interview for DSM-IV Axis I disorders; PANSS = Positive and Negative Syndrome Scale; CAPE = Community Assessment of Psychic Experiences; MWT-B = Multiple-Choice Vocabulary Intelligence Test; BADE = Bias Against Disconfirmatory Evidence paradigm; t1, t3, t4, t5, t6, t7, t9, t10, t11, t12 = State assessments of salivary cortisol, heart rate, subjective stress, paranoia and obsessive-compulsive symptoms; t2 and t8 = State assessment of heart rate, subjective stress, paranoia and obsessive-compulsive symptoms; Stress/control condition part 1 = Preparation and speech in Trier Social Stress Test in the stress condition or in Placebo Trier Social Stress Test in the control condition; Stress/control condition part 2 = Mental arithmetic in the Trier Social Stress Test or in the Placebo Trier Social Stress Test.

The stimuli were presented for 2000 ms within which the response had to be made (or else a 'too slow' message was presented). The choice of one stimulus resulted in a reward in 80% and a loss in 20% of the trials; the choice of the other stimulus resulted in a reward in 20% and a loss in 80% of the trials. The feedback was presented for 500 ms. After a pre-defined learning criterion (eight choices of the rewarding stimulus in a run of 10 consecutive trials) was achieved, the rewarded contingencies were reversed. An example of several consecutive trials of the task is depicted in the online Supplementary Material S1. The RL score was calculated as the total number of contingency reversals across six blocks, with higher scores reflecting more rewarding choices and faster learning of the reward contingencies.

The BADE paradigm consisted of 15 delusion-neutral, semantic tasks using stimuli from previous BADE studies (Buchy et al., 2007; Lüdtke, Kriston, Schröder, Lincoln, & Moritz, 2017; Woodward, Buchy, Moritz, & Liotti, 2007). In each task, one piece of information and three possible interpretations – one true and two lure interpretations – were presented. Participants were asked to rate for each interpretation how convinced they are that the interpretation is plausible (0%: not at all plausible; 100%: completely plausible). Subsequently, a second piece of information was presented and participants were asked to revise their plausibility ratings of the three interpretations. Finally, a third piece of information was introduced and a final revision of the plausibility of the three interpretations took place. Whereas the first piece of information is ambiguous and thus increases the plausibility of the lure interpretations, the subsequent pieces of information gradually disambiguate the task and disclose the true interpretation. An example is depicted in the online Supplementary Material S2.

We calculated a standard BADE score, where the change scores are computed subtracting the ratings of the lure interpretations following information 2 and 3 from the ratings of the lure interpretations following information 1 and averaging these across lure interpretations and tasks. The JTC score was calculated using the interpretation plausibility ratings after the first piece of information was provided and it represented the total number of interpretations where participants rated the plausibility between 75% and 100% (Lüdtke et al., 2017). We used two parallelized versions that we matched for item difficulty in an unpublished pilot study. Each participant completed one of these versions in the stress and control condition, respectively. Within the present sample, the parallel-forms' reliability was acceptable, as reflected in BADE scores Pearson correlation between two versions, $r = 0.674$, $p < 0.001$.

Statistical analyses

Technical errors resulted in one missing value on BADE/JTC and eight missing values on RL across the two conditions. MCAR-Test by Little showed that data were missing completely at random, χ^2 (24) = 12.66, $p = 0.971$. There were no missings on paranoia.

Due to the hierarchical structure of the data, all hypotheses were tested using multilevel linear modeling (MLM) with repeated measurements nested within individuals. For all analyses, we applied the restricted maximum likelihood estimator. Predictors were entered as fixed effects and if continuous, they were centered around subjects' mean. We added the intercepts for subjects as random effects. Random slopes were included if Bayesian information criterion (BIC) comparison of models with and without the random slope showed a substantial change, i.e. $\Delta BIC > 10$

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(this was only the case with condition as a predictor of paranoia; see online Table S3 in the Supplementary Material), otherwise slopes were fixed. The MLM was implemented through RStudio, version 3.6.2 (R Core Team, 2020; package nlme, function lme) and conducted according to guidelines (Hox, 2002; Tabachnick & Fidell, 2019).

As a manipulation check of the stress induction, we applied a MLM with state subjective stress (measured after the stress and control condition at t3/t9, see Fig. 1) as a dependent variable and condition (control *v.* stress) as an independent variable. Additionally, we added group as a predictor and the interaction term condition × group to test for moderating effects of the group.

To test the direct effect of stress on paranoia (hypothesis 1), we applied an MLM with paranoia (measured after the stress and control condition at t3/t9, see Fig. 1) as a dependent variable and condition (control *v.* stress) as an independent variable. Additionally, we added group as a predictor and the interaction term condition × group to test for moderating effects of the group.

Moderated mediation was tested in a series of steps: (1) Test for the main effect of condition on the mediators (RL, BADE, JTC, measured at t3/t9) (hypothesis 2); (2) test for main effects of the mediators on paranoia (hypothesis 3); (3) test whether the direct effect of condition on paranoia shrinks upon the addition of the mediators in the model (hypothesis 4); (4) test for moderating effect of group (PSY, AS, OCD, HC) by examining if the hypothesized mediating association between stress, RL, BADE, JTC and paranoia depends on the level of the moderator (hypothesis 5). Steps 2 and 3 were only performed given significance of steps 1 and 2, whereas step 4 was independent of the results of previous steps, since it is possible that the mediation mechanism is only present at the specific level of the moderating variable (for instance, only in PSY).

To examine the *moderated moderation hypothesis*, we first tested if there was an interaction effect of condition × moderator 1 (RL, BADE, JTC) (hypothesis 6). Then, we tested whether moderator 2 (group – PSY, AS, OCD, HC) influenced the effect of interaction condition × moderator 1 on paranoia (hypothesis 7).

Results

Descriptive statistics

Socio-demographic and clinical characteristics of all groups are presented in Table 1. Means and standard deviations of state subjective stress paranoia, RL, BADE, and JTC scores in the stress and the control condition per group are presented in Table 2.

Manipulation check

Condition was a significant predictor of subjective stress, $F_{(1,\ 150)} = 17.110$, $p < 0.001$. Subjective stress was higher in the stress than the control condition, $b = 2.013$, S.E. = 0.487, $t(150) = 4.137$, $p < 0.001$, 95% CI (1.064–2.962). Furthermore, across both conditions, group was a significant predictor of stress, $F_{(3,\ 150)} = 7.777$, $p < 0.001$, with stress being significantly higher in both clinical groups compared to AS and HC [OCD: $b = 2.316$, S.E. = 0.612, $t(150) = 3.783$, $p < 0.001$, 95% CI (1.122–3.510); PSY: $b = 2.408$, S.E. = 0.612, $t(150) = 3.933$, $p < 0.001$, 95% CI (1.214–3.602)]. There was no significant interaction effect between condition and group, $F_{(3,\ 150)} = 1.654$, $p = 0.179$.

Moderated mediation model: RL, BADE, and JTC as mediators of the association between stress and paranoia, group as a moderating factor

Step 1: Condition was a significant predictor of paranoia, $F_{(1,\ 150)} = 11.428$, $p < 0.001$. Paranoia was higher in the stress than the control condition, $b = 1.142$, S.E. = 0.338, $t(150) = 3.381$, $p < 0.001$, 95% CI (0.483–1.801). Across both conditions, group was a significant predictor of paranoia, $F_{(3,\ 150)} = 7.102$, $p < 0.001$, with paranoia being significantly higher in both clinical groups compared to AS and HC [OCD: $b = 1.279$, S.E. = 0.400, $t(150) = 3.197$, $p < 0.001$, 95% CI (0.499–2.059); PSY: $b = 1.574$, S.E. = 0.400, $t(150) = 3.934$, $p < 0.001$, 95% CI (0.794–2.354)]. There was a significant interaction effect between condition and group, $F_{(3,\ 150)} = 3.822$, $p = 0.011$ (in stress condition PSY, OCD, AS > HC).

Step 2: Condition was not a significant predictor of any of the hypothesized mediators [RL, $F_{(1,\ 146)} = 1.137$, $p = 0.288$; BADE, $F_{(1,\ 153)} = 0.236$, $p = 0.628$; JTC, $F_{(1,\ 153)} = 0.075$, $p = 0.784$]. Thus, the hypothesis of a mediation was rejected.

Step 3: Due to the non-significant associations between independent variable and mediators, step 3 of the mediation analysis was not performed.

Step 4: There was no significant interaction effect of group × condition on any of the hypothesized mediators (all $p_s > 0.05$). Thus, the hypothesis of moderated mediation was rejected. However, there was a direct effect of group on RL, $F_{(3,\ 151)} = 5.541$, $p = 0.001$ (PSY < HC, AS, OCD). There was no significant effect of group on BADE and JTC ($p_s > 0.05$).

Moderated moderation model: RL, BADE, JTC, and group as moderators of the association between stress and paranoia

Table 3 shows the fixed effects of the moderated moderation analysis. None of the interaction effects (i.e. condition × RL, condition × BADE, condition × JTC) was significant and including group as a moderator did not affect these interaction effects. Hence, we rejected the hypothesis of moderated moderation.

Additional analysis

The MLMs with condition order as a predictor (first the stress then the control condition *v.* first the control then the stress condition) showed that there was no order effect on any of the tested variables (i.e. subjective stress, paranoia, RL, BADE, JTC) (all $p_s > 0.05$; see online Supplementary Material S4).

Discussion

Aiming to understand the processes involved in the development of paranoia, we focused on the ability to adapt beliefs, which we assumed to mediate or moderate the association between stress and paranoia. We found that paranoia was significantly higher in the stress than in the control condition, which is in line with a series of previous experimental studies (e.g. Kesting et al., 2013; Lincoln et al., 2009; Veling et al., 2016). However, neither RL nor BADE or JTC were sensitive to stress. Thus, our results do not support the assumed mediating mechanism between stress and paranoia. Furthermore, RL, BADE, and JTC did not potentiate the association between stress and paranoia, so that we also rejected the hypothesis of a moderating mechanism.

Considering that a deteriorating effect of stress on decision-making and cognitive flexibility has often been found in healthy

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Table 1. Sample characteristics and group comparison analyses

	PSY ($n = 38$)	AS ($n = 40$)	OCD ($n = 39$)	HC ($n = 38$)	Group comparisons with Bonferroni-corrected post hoc tests
Age in years	37.71 (9.61)	30.53 (10.58)	35.92 (10.96)	36.32 (11.18)	$F_{(3, 154)} = 3.50$, $p = 0.017$, $\eta^2_{partial} = 0.07$ (PSY > AS)
Female (%)	50	55	64	47	χ^2 (3) = 2.54, $p = 0.469$
Education level (%) high/medium/low[a]	40/55/5	65/33/2	36/54/10	58/39/3	χ^2 (6) = 10.88, $p = 0.092$
CAPE positive scale	20.22 (10.15)[b]	15.56 (6.06)[c]	9.71 (7.43)[d]	3.71 (2.48)	Welch's $F_{(3, 71.53)} = 68.62$, $p < 0.001$; PSY > AS > OCD > HC
PANSS positive	16.66 (4.23)	–	–	–	
PANSS negative	10.82 (3.91)	–	–	–	
PANSS general	26.42 (6.66)	–	–	–	
OCI-R total score	–	–	30.65 (13.06)[b]	–	

PSY, participants diagnosed with psychotic disorders; AS, participants with attenuated psychotic symptoms; OCD, participants diagnosed with obsessive-compulsive disorder; HC, healthy controls; CAPE, Community Assessment of Psychic Experiences; PANSS, Positive and Negative Syndrome Scale; OCI-R, Obsessive Compulsive Inventory-Revised.
Note: Values indicate group means (standard deviations) unless otherwise specified.
[a]High = university degree or A-level equivalent; medium = equivalent of advanced-level GCSEs or vocational qualification; low = equivalent of low-level GCSEs or no formal qualification.
[b]$n = 37$.
[c]$n = 39$.
[d]$n = 38$.

Table 2. Means and standard deviations of state variables and adapting of beliefs in the control and stress condition per group

Condition	Control condition				Stress condition			
Group	PSY	OCD	AS	HC	PSY	OCD	AS	HC
State subjective stress at t3/t9	2.92 (3.08)	2.79 (2.88)	1.18 (1.62)	0.51 (0.96)	5.28 (3.53)	6.05 (3.00)	4.24 (2.55)	2.53 (2.89)
State paranoia at t3/t9	1.67 (2.74)	1.34 (2.07)	0.43 (0.63)	0.10 (0.21)	3.98 (3.01)	3.97 (3.01)	2.55 (2.04)	1.24 (1.40)
RL	20.29 (4.56)	22.53 (2.60)	21.88 (3.87)	22.59 (2.88)	19.50 (4.76)	22.53 (2.73)	21.48 (3.84)	22.63 (3.00)
BADE	35.04 (21.70)	34.35 (16.50)	30.91 (18.78)	31.67 (19.55)	35.66 (19.95)	33.37 (15.50)	32.15 (19.55)	28.47 (20.71)
JTC	9.08 (11.08)	7.18 (9.98)	11.58 (13.25)	5.58 (8.97)	9.24 (10.75)	7.90 (8.95)	9.10 (11.15)	6.74 (9.82)

T3/t9, assessment time-point immediately after the stress/control condition; RL, reversal learning; BADE, bias against discriminatory evidence; JTC, jumping to conclusions; PSY, participants diagnosed with psychotic disorders; AS, participants with attenuated psychotic symptoms; OCD, participants diagnosed with obsessive-compulsive disorder; HC, healthy controls.

samples (for an overview, see Shields, 2020; Shields, Sazma, & Yonelinas, 2016), the absence of an overall effect of stress on adapting of beliefs was surprising. However, previous findings in this domain have been heterogeneous with the differences in results possibly being attributable to various aspects of study designs, such as the stressor used, the procedure, or different sample characteristics. In particular, while in our study we used a well-evaluated social stressor that reliably triggers stress, previous studies have used other stressors, such as the cold pressor task that could potentially differently impact the stress axis and cognitive performance. Moreover, using different scales to assess subjective stress across the studies further contributes to the limited comparability in this research field. Furthermore, Shields (2020) emphasizes the importance of limiting the design to few cognitive tasks to avoid cognitive fatigue which could confound with the effects of stress. Although the present study fulfills many of the recently published Shield's criteria for conducting stress research (e.g. the application of a validated stressor, ensuring that the stress manipulation was successful), definite conclusions regarding the extent to which the process of adapting of beliefs is sensitive to stress will require further evidence accumulation from studies that adhere to the guideline. Moreover, in future, special attention should be given to forming a consensus on paradigms measuring adapting of beliefs, given that up until now, RL, BADE, and JTC have been administered and scored in various ways, which further contributes to the heterogeneity of results and limits their comparability. This shortcoming applies to the present study as well – although our RL and BADE tasks were strongly based on previously published tasks, they diverge in some characteristics, such as number of tasks and used stimuli.

Given the absence of an overall effect of stress on adapting of beliefs, one could assume that the effect would nevertheless become apparent in the PSY group (moderated mediation). However, although several studies with participants with psychosis and those vulnerable to psychosis found cognitive biases to be sensitive to stress (e.g. Ellett et al., 2008; Lincoln et al., 2010; Moritz et al., 2011; Moritz, Köther, Hartmann, & Lincoln, 2015), the findings from our study align with a second group of studies that did not confirm this effect: For example, in an experience sampling study with patients with psychosis, Lüdtke et al. (2017) found JTC not to be affected by anxiety and therefore, not to act as a mediator for the effect of anxiety on paranoia. Similarly, in a sample of students with varying psychosis vulnerability, Lincoln et al. (2009) found JTC not to be affected when noise stress was induced. Again, the heterogeneity of findings is challenging to interpret and is likely to result from differences

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Table 3. Moderated moderation results

	F	df	*p*
Model 1: RL as a moderator			
Condition	135.11	1, 137	<0.001
Reversal learning	0.01	1, 137	0.957
Group	12.08	3, 150	<0.001
Condition × RL	0.89	1, 137	0.346
Condition × RL × group	1.66	6, 137	0.137
Model 2: BADE as a moderator			
Condition	142.06	1, 144	<0.001
BADE	0.12	1, 144	0.728
Group	11.41	3, 149	<0.001
Condition × BADE	0.01	1, 144	0.994
Condition × BADE × group	0.80	6, 144	0.573
Model 3: JTC as a moderator			
Condition	144.13	1, 144	<0.001
JTC	0.03	1, 144	0.862
Group	10.71	3, 150	<0.001
Condition × JTC	0.60	1, 144	0.440
Condition × JTC × group	0.93	6, 144	0.474

Df, df denominator, df numerator; RL, reversal learning; BADE, bias against disconfirmatory evidence; JTC, jumping to conclusions.

in the study designs. For instance, previous studies have applied a variety of stressors, deployed varying samples ranging from undergraduate students to patients with remitted or acute psychosis, some studies used a control group and some did not, and in some studies, the putative effects have been examined in within-subject designs, whilst others applied between-subject designs. Therefore, we urge researchers to adhere to the Shields guideline when inducing stress in future studies. Moreover, the majority of aforementioned studies investigated the impact of stress on JTC only. The present study design is comparatively stronger as we used a wider range of belief adapting paradigms, including the established RL paradigm, several samples that reflect the range of psychotic severity and a validated, social-evaluative stressor (i.e. TSST), which – in our view – gives some weight to our finding that adapting of beliefs neither mediated nor moderated the effect of stress on paranoia.

Potentially, other cognitive facets related to information processing (i.e. encoding, storage, and retrieval and manipulation of information) that were not investigated in this study might be more relevant than adapting of beliefs. Specifically, Pot-Kolder, Veling, Counotte, and Van Der Gaag (2018) recently found that attention biases were more relevant to the emergence of paranoia than decision-making biases. Possibly, acute stress activates attention biases that in turn activate a threat-monitoring system, as has been found for symptoms of anxiety and stress-related disorders (Shechner & Bar-Haim, 2016). Once such threat-monitoring system has been activated, maladaptive schemas (i.e. negative beliefs about the self and others) that have been found to be prevalent in individuals prone to psychosis, could provide the basis for paranoid interpretations (Jaya, Ascone, & Lincoln, 2017; Sundag, Ascone, de Matos Marques, Moritz, & Lincoln, 2016). At the same time, difficulties in reversal learning that we found to be independent of stress could potentiate such paranoid interpretations by limiting learning from feedback in relevant situations. Hence, although our results suggest that difficulties in adapting of beliefs do not get triggered under stress, these seem to be present in patients with psychosis in general and could play a role in promoting paranoid interpretations.

Some additional findings warrant further discussion: The PSY group showed lower performance in RL than the comparison groups, which is in line with previous findings (Murray et al., 2008; Reddy et al., 2016; Schlagenhauf et al., 2014; Waltz & Gold, 2007). This result should also be interpreted in the light of the psychosis continuum. In line with Humpston et al. (2017), who examined RL deficits in individuals with high schizotypy, the group with attenuated symptoms in our sample did not show any deficits in RL. This could indicate that the deficits in RL exacerbate only later in the course of disorder development and cannot serve as a marker of vulnerability. Surprisingly, however, we found no group differences for BADE and JTC, contradicting the findings from the bulk of previous work (for a review on BADE, see Eisenacher & Zink, 2017; for a meta-analysis on JTC, see Dudley et al., 2016). Nevertheless, several recent studies also failed to replicate deficits in JTC in psychosis (Pytlik et al., 2020; Moritz et al., 2020). Similar to Pytlik et al. (2020), the present study had a 99% power to detect the effect found in Dudley et al. (2016) (Hedges $g = 0.52$), rendering a β-error unlikely. Although the reasons for these diverging results remain unclear, both Pytlik et al. (2020) and Moritz et al. (2020) highlight that the specifics of the paradigms used may offer an explanation. Such paradigms specifics include, for instance, the analysis of the probabilities of a correct decision based on the specific information sequence as well as misunderstandings of the instructions of the cognitive bias tasks (see Balzan, Delfabbro, & Galletly, 2012). As discussed in the review by Eisenacher and Zink (2017), similar methodological shortcomings could be a reason for heterogeneous results with regard to BADE, such as different number of items used across the studies, or varying manners of paradigm scoring. For this reason, we opted for a standard scoring of BADE and RL tasks and at the same time we recognize the need for sound psychometric research and recommendations for scoring of adapting of beliefs paradigms.

Several limitations of our study need to be discussed. One is that the stress induction took place before rather than during the RL and BADE tasks. Thus, the effect of stress may have already been wearing off when participants were completing the belief adaptation tasks. However, this is unlikely to sufficiently explain the non-significant result as previous studies have applied similarly short stressors or even stressors that are considered to be weaker (e.g. noise) and nevertheless found the effect of stress on the subsequent cognitive tasks (in psychosis samples: e.g. Keefe & Warman, 2011; Lincoln et al., 2010; Moritz et al., 2015; in general population: Shields et al., 2016). Another issue regards the characteristics of our sample and its representability: the PSY individuals who successfully participated in this demanding study may have been healthier than typical psychosis samples, which could, in turn, explain why their performance in JTC and BADE was comparable to the HC group. However, the PANSS positive mean score, which is associated with BADE and JTC performance (Zhu, Sun, & So, 2017), approximately corresponded to the mean found in a large-scale, heterogeneous sample of psychosis in- and out-patients from 25 countries and 29 research centers ($M = 14.81$, S.D. = 6.22) (Fountoulakis et al., 2019), so it is

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unlikely that these sample characteristics were a source of bias. Finally, the AS group recruited for this study does not represent a high-risk group but rather a group of individuals with elevated psychosis-like experiences.

Taken together, our study questions the relevance of adapting of beliefs for the path from stress to paranoia and suggest that improving adapting of beliefs under stress would not lead to a beneficial effect. Nevertheless, general deficits in reversal learning in psychosis patients found in our study can be interpreted as further evidence for the importance of targeting reasoning processes in psychosis patients.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0033291721003524

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Conflict of interest. None.

Note

1 Heart rate, salivary cortisol, and OCD symptoms are not considered in the present study and are reported for the sake of completeness.

References

Alexander, J. K., Hillier, A., Smith, R. M., Tivarus, M. E., & Beversdorf, D. Q. (2007). Beta-adrenergic modulation of cognitive flexibility during stress. *Journal of Cognitive Neuroscience*, *19*, 468–478. https://doi.org/10.1162/jocn.2007.19.3.468.

Balzan, R., Delfabbro, P., & Galletly, C. (2012). Delusion-proneness or miscomprehension? Re-examination of the jumping-to-conclusions bias. *Australian Journal of Psychology*, *64*, 100–107. doi:10.1111/j.1742-9536.2011.00032.x.

Ben-Zeev, D., Ellington, K., Swendsen, J., & Granholm, E. (2011). Examining a cognitive model of persecutory ideation in the daily life of people with schizophrenia: A computerized experience sampling study. *Schizophrenia Bulletin*, *37*, 1248–1256. https://doi.org/10.1093/schbul/sbq041.

Buchy, L., Woodward, T. S., & Liotti, M. (2007). A cognitive bias against disconfirmatory evidence (BADE) is associated with schizotypy. *Schizophrenia Research*, *90*. 334–337. https://doi.org/10.1016/j.schres.2006.11.012.

Cools, R., Clark, L., Owen, A. M., & Robbins, T. W. (2002). Defining the neural mechanisms of probabilistic reversal learning using event-related functional magnetic resonance imaging. *The Journal of Neuroscience*, *22*, 4563–4567. https://doi.org/20026435.

Dudley, R., Daley, K., Nicholson, M., Shaftoe, D., Spencer, H., Cavanagh, K., & Freeston, M. (2013). 'Jumping to conclusions' in first-episode psychosis: A longitudinal study. *British Journal of Clinical Psychology*, *52*, 380–392. https://doi.org/10.1111/bjc.12023.

Dudley, R., Taylor, P., Wickham, S., & Hutton, P. (2016). Psychosis, delusions and the 'Jumping to Conclusions' reasoning bias: A systematic review and meta-analysis. *Schizophrenia Bulletin*, *42*, 653–665. https://doi.org/10.1093/schbul/sbv150.

Eisenacher, S., & Zink, M. (2017). Holding on to false beliefs: The bias against disconfirmatory evidence over the course of psychosis. *Journal of Behavior Therapy and Experimental Psychiatry*, *56*, 79–89. https://doi.org/10.1016/j.jbtep.2016.08.015.

Ellett, L., Freeman, D., & Garety, P. A. (2008). The psychological effect of an urban environment on individuals with persecutory delusions: The Camberwell walk study. *Schizophrenia Research*, *99*, 77–84. https://doi.org/10.1016/j.schres.2007.10.027.

Feeney, E. J., Groman, S. M., Taylor, J. R., & Corlett, P. R. (2017). Explaining delusions: Reducing uncertainty through basic and computational neuroscience. *Schizophrenia Bulletin*, *43*, 263–272. https://doi.org/10.1093/schbul/sbw194.

Fine, C., Gardner, M., Craigie, J., & Gold, I. (2007). Hopping, skipping or jumping to conclusions? Clarifying the role of the JTC bias in delusions. *Cognitive Neuropsychiatry*, *12*, 46–77. https://doi.org/10.1080/13546800600750597.

Fountoulakis, K. N., Dragiot, E., Thofilidis, A. T., Wikilund, T., Atmatzidis, X., Nimatoudis, I., … De Hert, M. (2019). Staging of schizophrenia with the use of PANSS: An international multi-center study. *International Journal of Neuropsychopharmacology*, *22*, 681–697. doi:10.1093/ijnp/pyz053.

Freeman, D., Garety, P. A., Bebbington, P. E., Smith, B., Rollinson, R., Fowler, D., … Dunn, G. (2005). Psychological investigation of the structure of paranoia in a non-clinical population. *British Journal of Psychiatry*, *186*, 427–435. https://doi.org/10.1192/bjp.186.5.427.

Freeman, D., Pugh, K., & Garety, P. (2008). Jumping to conclusions and paranoid ideation in the general population. *Schizophrenia Research*, *102*, 254–260. https://doi.org/10.1016/j.schres.2008.03.020.

Gaab, J., Rohleder, N., Nater, U. M., & Ehlert, U. (2005). Psychological determinants of the cortisol stress response: The role of anticipatory cognitive appraisal. *Psychoneuroendocrinology*, *30*, 599–610. https://doi.org/10.1016/j.psyneuen.2005.02.001.

Garety, P. A., Hemsley, D. R., & Wessely, S. (1991). Reasoning in deluded schizophrenic and paranoid patients biases in performance on a probabilistic inference task. *Journal of Nervous and Mental Disease*, *179*, 194–201. https://doi.org/10.1097/00005053-199104000-00003.

Garety, P. A., Kuipers, E., Fowler, D., Freeman, D., & Bebbington, P. E. (2001). A cognitive model of the positive symptoms of psychosis. *Psychological Medicine*, *31*, 189–195. https://doi.org/10.1017/S0033291701003312.

Grant, P., & Hennig, J. (2020). Schizotypy, social stress and the emergence of psychotic-like states – A case for benign schizotypy? *Schizophrenia Research*, *216*, 435–442. https://doi.org/10.1016/j.schres.2019.10.052.

Hanssen, M., Peeters, F., Krabbendam, L., Radstake, S., Verdoux, H., & van Os, J. (2003). How psychotic are individuals with non-psychotic disorders? *Social Psychiatry and Psychiatric Epidemiology*, *38*, 149–154. https://doi.org/10.1007/s00127-003-0622-7.

Het, S., Rohleder, N., Schoofs, D., Kirschbaum, C., & Wolf, O. T. (2009). Neuroendocrine and psychometric evaluation of a placebo version of the 'Trier Social Stress Test.' *Psychoneuroendocrinology*, *34*, 1075–1086. https://doi.org/10.1016/j.psyneuen.2009.02.008.

Hox, J. (2002). *Multilevel analysis: Techniques and applications*. Mahwah, NJ: Lawrence Erlbaum.

Humpston, C. S., Evans, L. H., Teufel, C., Ihssen, N., & Linden, D. E. J. (2017) Evidence of absence: No relationship between behaviourally measured prediction error response and schizotypy, *Cognitive Neuropsychiatry*, *22*, 373–390. https://doi.org/10.1080/13546805.2017.1348289.

Izquierdo, A., Brigman, J. L., Radke, A. K., Rudebeck, P. H., & Holmes, A. (2017). The neural basis of reversal learning: An updated perspective. *Neuroscience*, *345*, 12–26. https://doi.org/10.1016/j.neuroscience.2016.03.021.

Jaya, E. S., Ascone, L., & Lincoln, T. M. (2017). Social adversity and psychosis: The mediating role of cognitive vulnerability. *Schizophrenia Bulletin*, *43*, 557–565. https://doi.org/10.1093/schbul/sbw104.

Johns, L. C., & van Os, J. (2001). The continuity of psychotic experiences in the general population. *Clinical Psychology Review*, *21*, 1125–1141. https://doi.org/10.1016/S0272-7358(01)00103-9.

Juarez-Ramos, V., Rubio, J. L., Delpero, C., Mioni, G., Sablum, F., & Gomez-Milan, E. (2014). Jumping to conclusions bias, BADE and feedback sensitivity in schizophrenia and schizotypy. *Consciousness and Cognition*, *26*, 133–144.

Kay, S. R., Opler, L. A., & Lindenmayer, J. P. (1989). The positive and negative syndrome scale (PANSS): Rationale and standardisation. *British Journal of Psychiatry*, *155*, 59–65. https://doi.org/10.1093/schbul/13.2.261.

Keefe, K. M., & Warman, D. M. (2011). Reasoning, delusion proneness and stress: An experimental investigation. *Clinical Psychology and Psychotherapy*, *18*, 138–147. https://doi.org/10.1002/cpp.683.

Kesting, M. L., Bredenpohl, M., Klenke, J., Westermann, S., & Lincoln, T. M. (2013). The impact of social stress on self-esteem and paranoid ideation. *Journal of Behavior Therapy and Experimental Psychiatry*, *44*, 122–128. https://doi.org/10.1016/j.jbtep.2012.07.010.

Kirschbaum, C., Pirke, K. M., & Hellhammer, D. H. (1993). The 'Trier Social Stress Test' – a tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology*, *28*, 76–81. https://doi.org/119004.

Konings, M., Bak, M., Hanssen, M., Van Os, J., & Krabbendam, L. (2006). Validity and reliability of the CAPE: A self-report instrument for the measurement of psychotic experiences in the general population. *Acta Psychiatrica Scandinavica*, *114*, 55–61. https://doi.org/10.1111/j.1600-0447.2005.00741.x.

Kramer, I., Simons, C. J. P., Wigman, J. T. W., Collip, D., Jacobs, N., Derom, C., … Wichers, M. (2014). Time-lagged moment-to-moment interplay between negative affect and paranoia: New insights in the affective pathway to psychosis. *Schizophrenia Bulletin*, *40*, 278–286. https://doi.org/10.1093/schbul/sbs194.

Krkovic, K., Clamor, A., Schlier, B., & Lincoln, T. M. (2020). Emotions and persecutory ideation in daily life: On the trail of the 'chicken and egg' problem. *Journal of Abnormal Psychology*, *129*, 215–223. https://doi.org/10.1037/abn0000495.

Krkovic, K., Krink, S., & Lincoln, T. M. (2018). Emotion regulation as a moderator of the interplay between self-reported and physiological stress and paranoia. *European Psychiatry*, *49*, 43–49. https://doi.org/10.1016/j.eurpsy.2017.12.002.

Lataster, T., Valmaggia, L., Lardinois, M., van Os, J., & Myin-Germeys, I. (2013). Increased stress reactivity: A mechanism specifically associated with the positive symptoms of psychotic disorder. *Psychological Medicine*, *43*, 1389–1400. https://doi.org/10.1017/S0033291712002279.

Laws, K. R., Kondel, T. K., Clarke, R., & Nillo, A. M. (2011). Delusion-prone individuals: Stuck in their ways? *Psychiatry Research*, *2–3*, 219–224. https://doi.org/10.1016/j.psychres.2010.09.018.

Le, T. P., Fedechko, T. L., Cohen, A. S., Allred, S., Pham, C., Lewis, S., & Barkus, E. (2019). Stress and cognitive biases in schizotypy: A two-site study of bias against disconfirmatory evidence and jumping to conclusions. *European Psychiatry*, *62*, 20–27. doi: 10.1016/j.eurpsy.2019.08.006.

Leeson, V. C., Robbins, T. W., Matheson, E., Hutton, S. B., Ron, M. A., Barnes, T. R. E., & Joyce, E. M. (2009). Discrimination learning, reversal, and set-shifting in first-episode schizophrenia: Stability over six years and specific associations with medication type and disorganization syndrome. *Biological Psychiatry*, *66*, 586–593. https://doi.org/10.1016/j.biopsych.2009.05.016.

Lehrl, L. (2005). *MWT-B – Mehrfachwahl-Wortschatz-Intelligenztest [multiple choice vocabulary test, MWT-B]*. Balingen: Spitta.

Lincoln, T. M., Lange, J., Burau, J., Exner, C., & Moritz, S. (2010). The effect of state anxiety on paranoid ideation and jumping to conclusions. An experimental investigation. *Schizophrenia Bulletin*, *36*, 1140–1148. https://doi.org/10.1093/schbul/sbp029.

Lincoln, T. M., Peter, N., Schäfer, M., & Moritz, S. (2009). Impact of stress on paranoia: An experimental investigation of moderators and mediators. *Psychological Medicine*, *39*, 1129–1139. https://doi.org/10.1017/S0033291708004613.

Livet, A., Navarri, X., Potvin, S., & Conrod, P. (2020). Cognitive biases in individuals with psychotic-like experiences: A systematic review and a meta-analysis. *Schizophrenia Research*, *222*, 10–22. https://doi.org/10.1016/j.schres.2020.06.016.

Lüdtke, T., Kriston, L., Schröder, J., Lincoln, T. M., & Moritz, S. (2017). Negative affect and a fluctuating jumping to conclusions bias predict subsequent paranoia in daily life: An online experience sampling study. *Journal of Behavior Therapy and Experimental Psychiatry*, *56*, 106–112. https://doi.org/10.1016/j.jbtep.2016.08.014.

Moritz, S., Burnette, P., Sperber, S., Köther, U., Hagemann-Goebel, M., Hartmann, M., & Lincoln, T. M. (2011). Elucidating the black box from stress to paranoia. *Schizophrenia Bulletin*, *37*, 1311–1317. https://doi.org/10.1093/schbul/sbq055.

Moritz, S., Köther, U., Hartmann, M., & Lincoln, T. M. (2015). Stress is a bad advisor. Stress primes poor decision making in deluded psychotic patients. *European Archives of Psychiatry and Clinical Neuroscience*, *265*, 461–469. https://doi.org/10.1007/s00406-015-0585-1.

Moritz, S., Scheunemann, J., Lüdtke, T., Westermann, S., Pfuhl, G., Balzan, R.P., & Andreou, C. (2020). Prolonged rather than hasty decision-maker in schizophrenia using the box task. Must we rethink the jumping to conclusions account of paranoia? *Schizophrenia Research*, *222*, 202–208. doi: 10.1016/j.schres.2020.05.056.

Moritz, S., & Woodward, T. S. (2006). A generalized bias against disconfirmatory evidence in schizophrenia. *Psychiatry Research*, *142*, 157–165. https://doi.org/10.1016/j.psychres.2005.08.016.

Murray, G. K., Cheng, F., Clark, L., Barnett, J. H., Blackwell, A. D., Fletcher, P. C., … Jones, P. B. (2008). Reinforcement and reversal learning in first-episode psychosis. *Schizophrenia Bulletin*, *34*, 848–855. https://doi.org/10.1093/schbul/sbn078.

Nuechterlein, K. H., & Dawson, M. E. (1984). A heuristic vulnerability/stress model of schizophrenic episodes. *Schizophrenia Bulletin*, *10*, 300–312. https://doi.org/10.1093/schbul/10.2.300.

Pot-Kolder, R., Veling, W., Counotte, J., & Van Der Gaag, M. (2018). Self-reported cognitive biases moderate the associations between social stress and paranoid ideation in a virtual reality experimental study. *Schizophrenia Bulletin*, *44*, 749–756. https://doi.org/10.1093/schbul/sbx119.

Pytlik, N., Soll, D., Hesse, K., Moritz, S., Bechdolf, A., Herrlich, J., & …Mehl, S. (2020). Problems in measuring the JTC-bias in patients with psychotic disorders with the fish task: A secondary analysis of a baseline assessment of a randomized controlled trial. *BMC Psychiatry*, *20*, 1–10. https://doi.org/10.21203/rs.3.rs-18581/v1.

R Core Team (2020). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/.

Reddy, L. F., Waltz, J. A., Green, M. F., Wynn, J. K., & Horan, W. P. (2016). Probabilistic reversal learning in schizophrenia: Stability of deficits and potential causal mechanisms. *Schizophrenia Bulletin*, *42*, 942–951. https://doi.org/10.1093/schbul/sbv226.

Reininghaus, U., Kempton, M. J., Valmaggia, L., Craig, T. K. J., Garety, P., Onyejiaka, A., … Morgan, C. (2016). Stress sensitivity, aberrant salience, and threat anticipation in early psychosis: An experience sampling study. *Schizophrenia Bulletin*, *42*, 712–722. https://doi.org/10.1093/schbul/sbv190.

Sanford, N., Veckenstedt, R., Moritz, S., Balzan, R. P., & Woodward, T. S. (2014). Impaired integration of disambiguating evidence in delusional schizophrenia patients. *Psychological Medicine*, *44*, 2729–2738. https://doi.org/10.1017/S0033291714000397.

Schlagenhauf, F., Huys, Q. J. M., Deserno, L., Rapp, M. A., Beck, A., Heinze, H. J., … Heinz, A. (2014). Striatal dysfunction during reversal learning in unmedicated schizophrenia patients. *NeuroImage*, *89*, 171–180. https://doi.org/10.1016/j.neuroimage.2013.11.034.

Schlier, B., Jaya, E. S., Moritz, S., & Lincoln, T. M. (2015). The Community Assessment of Psychic Experiences measures nine clusters of psychosis-like experiences: A validation of the German version of the CAPE. *Schizophrenia Research*, *169*, 274–279. https://doi.org/10.1016/j.schres.2015.10.034.

Schlier, B., Moritz, S., & Lincoln, T. M. (2016). Measuring fluctuations in paranoia: Validity and psychometric properties of brief state versions of the Paranoia Checklist. *Psychiatry Research*, *241*, 323–332. https://doi.org/10.1016/j.psychres.2016.05.002.

Schwabe, L., & Wolf, O. T. (2009). Stress prompts habit behavior in humans. *Journal of Neuroscience*, *29*, 7191–7198. https://doi.org/10.1523/JNEUROSCI.0979-09.2009.

Schwabe, L., & Wolf, O. T. (2011). Stress increases behavioral resistance to extinction. *Psychoneuroendocrinology*, *36*, 1287–1293. https://doi.org/10.1016/j.psyneuen.2011.02.002.

Shechner, T., & Bar-Haim, Y. (2016). Threat monitoring and attention-bias modification in anxiety and stress-related disorders. *Current Directions in Psychological Science*, *25*, 431–437. doi:10.1177/0963721416664341.

Shields, G. S. (2020). Stress and cognition: A user's guide to designing and interpreting studies. *Psychoneuroendocrinology*, *112*, 104475. https://doi.org/10.1016/j.psyneuen.2019.104475.

Shields, G. S., Sazma, M. A., & Yonelinas, A. P. (2016). The effects of acute stress on core executive functions: A meta-analysis and comparison with cortisol. *Neuroscience and Biobehavioral Reviews*, *68*, 651–668. https://doi.org/10.1016/j.neubiorev.2016.06.038.

So, S. H., Siu, N. Y., Wong, H. L, Chan, W., & Garety, P. A. (2016). 'Jumping to conclusions' data-gathering bias in psychosis and other psychiatric disorders – Two meta-analyses of comparisons between patients and healthy individuals. *Clinical Psychology Review*, *46*, 151–167. https://doi.org/10.1016/j.cpr.2016.05.001.

https://doi.org/10.1017/S0033291721003524 Published online by Cambridge University Press

Stefanis, N. C., Hanssen, M., Smirnis, N. K., Avramopoulos, D. A., Evdokimidis, I. K., Stefanis, C. N., … van Os, J. (2002). Evidence that three dimensions of psychosis have a distribution in the general population. *Psychological Medicine*, *32*, 347–358.

Stemmler, G., Heldmann, M., Pauls, C. A., & Scherer, T. (2001). Constraints for emotion specificity in fear and anger: The context counts. *Psychophysiology*, *38*, 275–291. https://doi.org/10.1111/1469-8986.3820275.

Sundag, J., Ascone, L., de Matos Marques, A., Moritz, S., & Lincoln, T. M. (2016). Elucidating the role of early maladaptive schemas for psychotic symptomatology. *Psychiatry Research*, *238*, 53–59. https://doi.org/10.1016/j.psychres.2016.02.008.

Tabachnick, B. G., & Fidell, L. S. (2019). *Using multivariate statistics* (7th ed.). Boston: Pearson.

Van Der Steen, T., Gimpel-Drees, J., Lataster, T., Viechtbauer, W., Simons, C. J. P., Lardinois, M., … Myin-Germeys, I. (2017). Clinical high risk for psychosis: The association between momentary stress, affective and psychotic symptoms. *Acta Psychiatrica Scandinavica*, *136*, 63–73. https://doi.org/10.1111/acps.12714.

Van Os, J., Linscott, R., Myin-Germeys, I., Delespaul, P., & Krabbendam, L. (2009). A systematic review and meta-analysis of the psychosis continuum: Evidence for a psychosis proneness–persistence–impairment model of psychotic disorder. *Psychological Medicine*, *39*, 179–195. doi:10.1017/S0033291708003814.

Veckenstedt, R., Randjbar, S., Vitzthum, F., Hottenrott, B., Woodward, T. S., & Moritz, S. (2011). Incorrigibility, jumping to conclusions, and decision threshold in schizophrenia. *Cognitive Neuropsychiatry*, *16*, 174–192. https://doi.org/10.1080/13546805.2010.536084.

Veling, W., Pot-Kolder, R., Counotte, J., Van Os, J., & Van Der Gaag, M. (2016). Environmental social stress, paranoia and psychosis liability: A virtual reality study. *Schizophrenia Bulletin*, *42*, 1363–1371. https://doi.org/10.1093/schbul/sbw031.

Waltz, J. A., & Gold, J. M. (2007). Probabilistic reversal learning impairments in schizophrenia: Further evidence of orbitofrontal dysfunction James. *Schizophrenia Research*, *93*, 296–303 https://doi.org/10.1016/j.schres.2007.03.010.

Wittchen, H.-U., Zaudig, M., & Fydrich, T. (1997). *Strukturiertes klinisches Interview für DSM-IV: SKID; eine deutschsprachige, erweiterte Bearbeitung der amerikanischen Originalversion des SCID*. Göttingen: Hogrefe.

Woodward, T. S., Buchy, L., Moritz, S., & Liotti, M. (2007). A bias against disconfirmatory evidence is associated with delusion proneness in a nonclinical sample. *Schizophrenia Bulletin*, *33*, 1023–1028. https://doi.org/10.1093/schbul/sbm013.

Woodward, T. S., Moritz, S., & Chen, E. Y. H. (2006a). The contribution of a cognitive bias against disconfirmatory evidence (BADE) to delusions: A study in an Asian sample with first episode schizophrenia spectrum disorders. *Schizophrenia Research*, *83*, 297–298. https://doi.org/10.1016/j.schres.2006.01.015.

Woodward, T. S., Moritz, S., Cuttler, C., & Whitman, J. C. (2006b). The contribution of a cognitive bias against disconfirmatory evidence (BADE) to delusions in schizophrenia. *Journal of Clinical and Experimental Neuropsychology*, *28*, 605–617. https://doi.org/10.1080/13803390590949511.

Zhu, C., Sun, X., & So, S. H. (2017). Associations between belief inflexibility and dimensions of delusions: A meta-analytic review of two approaches to assessing belief flexibility. *British Journal of Clinical Psychology*, *57*, 59–81. https://doi.org/10.1111/bjc.12154.

https://doi.org/10.1017/S0033291721003524 Published online by Cambridge University Press