Stress affects the prediction of others' behavior

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Abstract

Predicting behavior of other people is vital for successful social interactions. We tested whether a stress-induced cortisol increase affects healthy young men's prediction of another individual's behavior. Forty-two participants were randomly assigned to a stress or a control condition. Afterwards they participated in a modified false-belief task that not only tests false-belief understanding but also the tendency to predict another person's future behavior based on his former behavior. Subjective ratings and salivary cortisol concentrations revealed a successful stress induction. Stress did not affect participants' attribution of false beliefs but it increased the probability to predict that a protagonist would act according to his former behavior. Recognizing that stress fosters the interpretation of others' behavior following their former behavior and not their current goals extends previous research showing that stress fosters our own habitual behavior.

Keywords: stress; social cognition; behavior prediction; false-belief attribution; socially evaluated cold pressor test

1. Introduction

To form and maintain social relationships, we frequently rely on social cognitive skills. But how do these skills work under stressful circumstances? In the present study we examined whether stress-induced cortisol elevations affect participants' performance in a false-belief task.

Stress arises when individuals perceive a threat to their physiological or psychological well-being (Lazarus and Folkman, 1984). A large body of literature demonstrates that stress affects our thoughts and feelings through a series of physiological processes and hormonal changes. Controlled laboratory experiments revealed that stress or glucocorticoid hormones affect cognitive functions like memory (for a review, see Wolf, 2009), learning (Joëls et al., 2006), and decision making (Pabst et al., 2013). However, while a large body of research on stress effects on memory and learning exists, only a few studies focused on social cognition. This is surprising since social cognitive skills may help to succeed in social interactions. Theory of Mind, the ability to attribute mental states to oneself and others (Premack and Woodruff, 1978), is one of the most widely studied social cognitive skills. A functional Theory of Mind enables humans to explain and predict others' behavior, thereby maintaining social relationships. But, until now, we do not know how Theory-of-Mind competencies work under stressful circumstances.

There are a few studies that investigated the effect of stress on social cognition so far. One study (Smeets et al., 2009) revealed a stress-induced effect on the interpretation of the Movie for the Assessment of Social Cognition (MASC; Dziobek et al., 2006). While the correlation between cortisol responses and MASC scores was positive among men, it was negative among women. Thus, the stress-induced effect on mental state reasoning was sex specific (Smeets et al., 2009). Sex differences were also found for the effect of stress on self-other distinction, a prerequisite for reasoning about others' mental states. Women showed

higher self-other distinction in the stress compared to the control condition. However, men showed reduced self-other distinction in the stress compared to the control condition (Tomova et al., 2014). A placebo-controlled study revealed that increases in cortisol concentrations per se did not influence emotion recognition. But they interacted with variables like sex, emotion, and task difficulty (Duesenberg et al., 2016). Given these results there are several reasons to assume that stress affects Theory of Mind.

First, there is a very high density of glucocorticoid and mineralocorticoid receptors in the prefrontal cortex (PFC) indicating that this area is highly stress sensitive (Roosendaal et al., 2004). In line with these findings, there is evidence that some cognitive functions mediated by the PFC are affected by high glucocorticoid levels after stress (Plessow et al., 2012; Scholz et al., 2009). Furthermore, the PFC is known for its important role in social aspects of cognition (Gallagher and Frith, 2003; Iacoboni et al., 2004). Taken together, the stress-induced reduction of PFC capacity might affect social reasoning.

Second, coping with stressful events includes a shift towards less demanding cognitive processes (Schwabe and Wolf, 2013). For example, stress favored less demanding strategies in a spatial learning task (Schwabe et al., 2007) and an instrumental learning task (Schwabe and Wolf, 2009). These studies revealed that stressed participants used less demanding strategies like stimulus-response learning or habitual behavior compared to control participants who used more demanding strategies like spatial learning or goal-directed behavior.

A stress-related shift towards less (PFC-) demanding processes may also occur in regard to social cognition. False-belief tasks are frequently used as a measure of Theory-of-Mind performance (e.g., Wimmer and Perner, 1983). It is necessary to suppress one's own knowledge to correctly infer the protagonist's knowledge. Therefore, reasoning about others' mental states in this scenario is likely more resource demanding than relying on one's own

mental states. In an adapted version of a false-belief task, even adults were biased by their own knowledge when reasoning about someone else's mental states (Birch and Bloom, 2007). In this study, participants observed a scenario where a protagonist placed a violin in a blue container. The violin was transferred from that container to another container in the absence of the protagonist and the containers switched locations afterwards. Overall, there were four differently designed containers. Participants were asked to predict where the protagonist would look for the violin on his return. It was manipulated which container the violin was transferred to and whether the participants were informed about this outcome. Participants were particularly likely to attribute their own knowledge about the violin's location to the protagonist when there was a plausible explanation for the protagonist not to act according to his acquired false belief about the violin's location. For example, when the violin was in the container that occupied the location where the violin had originally been participants were particularly cursed by their own knowledge. Put differently, adults did not consistently predict others to perform goal-directed behavior (i.e., looking for an object in a container where the other person thought it was) but instead sometimes predicted others to perform on the basis of their former behavior (i.e., returning to the location where the other person had gone to in the past). The likelihood of using such a cognitive shortcut might increase under stress.

To examine whether a stress-induced cortisol increase affects the prediction of others' behavior, we exposed participants to an acute stressor or a control condition prior to conducting a false-belief procedure based on Birch and Bloom's (2007) work. We hypothesized that stressed participants would show an increased tendency to predict another person's future behavior being based on previous behavior. Specifically, we predicted that compared to their non-stressed counterparts, stressed participants would be more likely to

assume the protagonist's search to be guided by location (i.e., considerations where he stored the violin before) rather than container identity.

We also hypothesized that stressed participants would be biased by their own knowledge in a false-belief task more often than control participants. That is, they would be more likely to predict that the protagonist would look for the violin at its current location than participants in the control condition.

2. Material and methods

2.1 Participants and Design

Forty-two healthy men between 19 and 33 years of age ($M = 24.14$, $SD = 3.52$) and with a body-mass-index between 18 and 28 kg/m² participated in this study. Screening questionnaires were used to check exclusion criteria like regular smoking, past or current psychiatric, neurological, or endocrine disorders, and medication intake. We used a between-subjects design in which participants were randomly assigned to either a control condition ($n = 21$) or a stress condition ($n = 21$). Four additional participants from the stress group were excluded from further analysis. They stopped the stress induction prematurely and did not show a considerable cortisol response.

Participants were instructed not to do physical exercises or drink caffeine or alcohol on the day of their participation. Furthermore, they were asked not to eat or drink anything except water within 90 minutes prior to the experiment. All participants provided written informed consent and received a small monetary compensation for participation (10 €). The experiment was approved by the local ethics committee (2017-2).

2.2 Procedure

To control for the circadian rhythm of cortisol secretion all sessions took place in the afternoon. Participants underwent either the socially evaluated cold pressor test (SECPT; Schwabe et al., 2008) or a non-stressful control procedure. During the SECPT participants

had to immerse their right hand into ice water (0-2 °C). Within this three-minute period, participants were video-recorded and monitored by a reserved female experimenter. In the control condition, participants immersed their right hand into warm water (35-37 °C). Within this three-minute period, they were neither video-recorded nor observed by an experimenter. Immediately after the SECPT or control procedure, participants used a scale ranging from 0 (“not at all”) to 100 (“very much”) to rate how difficult it was to keep their hand immersed, and how unpleasant, stressful, and painful they experienced the treatment.

Twenty minutes after the stress or control manipulation, participants completed a false-belief task (adapted from Birch and Bloom, 2007). The participants listened to a story told by a second female experimenter while pictures were presented to illustrate the storyline. On the first picture there was a boy standing in a room and holding a violin. Four containers (blue, yellow, black, and white) were distributed around a sofa in the middle of the room (Figure 1a). Participants were told that the boy called Niklas finishes playing his violin and puts it in the blue container. The second picture showed Niklas leaving the room to play outside. The third picture depicted another boy in the room who puts the violin in the yellow container. The participants were told that this was Niklas' brother transferring the violin from the blue to the yellow container while Niklas is still playing outside. At this point, two control questions were asked to ensure that the participants correctly remembered the different positions of the violin throughout the story: “Where did Niklas put the violin?” and “Where did his brother put the violin?”. The fourth picture showed the brother relocating the containers. The next picture showed the final set-up of the containers (Figure 1b). The violin is neither in the blue container where Niklas put it, nor in the location where the blue container was originally placed. Finally, the participants were asked to rate the probability of Niklas looking for his violin in each of the containers first.

To assess salivary cortisol concentrations, three saliva samples were collected throughout the experiment. Salivettes (Sarstedt, Nümbrecht, Germany) were used to take samples before (baseline), as well as 20 and 35 minutes after the onset of the treatment. Samples were stored at -20°C until biochemical analysis. The fraction of free cortisol was assessed using an immunoassay (IBL, Hamburg). Mean intra- and inter-assay coefficients of variance were below 9 %.

Figure 1. Pictures of the false-belief task show the set-up of the containers before the protagonist left the room (a) and after his return (b).

3. Results

3.1 Stress induction

Analyses of subjective stress ratings and salivary cortisol concentrations revealed a successful stress induction. The SECPT was rated as more unpleasant ($t(30.98) = -6.30, p < .001, d = 1.94$), more stressful ($t(27.07) = -5.84, p < .001, d = 1.80$), and more painful ($t(30.36) = -10.93, p < .001, d = 3.38$) than the control condition. Furthermore, participants from the stress group found it more difficult to keep their hand immersed in the water compared to participants from the control group ($t(30.41) = -6.71, p < .001, d = 2.07$; see Table 1 for descriptive data).

Table 1

Mean (SD) subjective ratings and salivary cortisol in the stress and control condition

	control	stress
subjective ratings		
difficult	4.76 (15.37)	52.86 (29.01)
unpleasant	7.62 (14.46)	49.05 (26.44)
stressful	4.29 (10.28)	37.62 (24.06)
painful	2.38 (10.91)	58.10 (20.64)
salivary cortisol (nmol/l)		
baseline	5.57 (2.72)	5.61 (3.97)
+20 minutes	7.49 (5.04)	12.22 (5.78)
+35 minutes	6.78 (5.27)	9.65 (3.64)

Due to skewness, cortisol data were log-transformed for use in further analyses.

A repeated-measures ANOVA conducted on salivary cortisol revealed significant main effects of condition ($F(1, 39) = 4.47, p = .041, \eta_p^2 = .10$) and time ($F(1.33, 51.79) = 33.04, p < .001, \eta_p^2 = .46$), as well as a significant condition $\times$ time interaction ($F(1.33, 51.79) = 11.94, p < .001, \eta_p^2 = .23$). Figure 2 shows that conditions differed in cortisol concentrations 20 minutes ($t(40) = -3.08, p = .004, d = 0.95$) and 35 minutes ($t(39) = -2.77, p = .009, d = 0.86$) after the SECPT or the control procedure, respectively. However, baseline cortisol levels did not differ between conditions ($t(40) = 0.24, p = .815, d = -0.07$). This indicates that the SECPT induced a physiological stress response, which was present throughout task performance.

Figure 2. Mean salivary cortisol concentrations of participants from the control and stress group throughout the experiment. Error bars represent standard errors.

3.2 False-belief task

Mean probability ratings for the containers from the false-belief task are shown in Figure 3. The black container occupied the former location of the blue container where Niklas put the violin into. To test the hypothesis that stress increases the likelihood of predicting behavior based on a person's former actions, we analyzed how likely participants thought it was for Niklas to look in the black container first. Participants in the stress condition rated the probability for Niklas to look into the black container first significantly higher than participants from the control condition ($t(30.58) = -1.84, p = .038$ (one-sided), $d = 0.567$). To test the hypothesis that stress influences the ability to suppress one's own knowledge and to correctly attribute a false belief to another person, we analyzed the likelihood that participants ascribed to Niklas looking in the blue container first. The participants' ratings of the probability that Niklas would look into the blue container first did not differ between conditions ($t(40) = 0.81, p = .212$ (one-sided), $d = -0.25$). The probability ratings for the yellow container, which included the violin at the end of the story did not differ between groups ($t(21.84) = 1.22, p = .237, d = -0.375$). The ratings of the probability

that Niklas would look into the white container first did not differ between groups, ($t(24.48) = 1.57, p = .131, d = -0.48$) either.

Figure 3. Mean ratings of the probability that Niklas would look into the black, white, yellow, or blue container first. Error bars represent standard errors.

4. Discussion

The present study investigated the effect of acute stress on the performance in a false-belief task. The SECPT resulted in a cortisol increase compared to the non-stressful control procedure. Participants from both conditions did not differ in their tendency to attribute their own knowledge to the protagonist. Thus, stressed participants were not any more cursed by their own knowledge when reasoning about the protagonist's false belief than were their non-stressed counterparts. However, stressed participants did show a stronger tendency to assume that the protagonist's future behavior would be a repetition of his former behavior compared to non-stressed participants. Specifically, compared to the control condition, participants in the stress condition rated it more likely that the protagonist would look for his object at the original location. This finding ties in with studies suggesting that stress causes a shift from goal-directed to habitual behavior (Schwabe et al., 2007; Schwabe and Wolf, 2009). The present study shows that a shift from goal-directed behavior to actions based on former

behavior does not only occur for a person's own behavior but also when reasoning about others' behavior. However, it should be noted, that the present study refers to one-time behavior shown in the past, while others referred to behavior repeated throughout several trials (Schwabe and Wolf, 2009). Therefore, future studies should examine how stress affects the prediction of others' habitual behavior.

Habitual behavior is less resource demanding and allows fast reactions which are often needed in stressful situations (Schwabe and Wolf, 2013). Regarding the false-belief task, it might be efficient to take the former location of the relevant container into consideration. Since the protagonist as well as the participants knew where this location was, deciding upon this option did not require to differentiate between their different states of knowledge. Furthermore, suppressing salient information (i.e., the original location of the violin) requires additional resources. Habitual behavior under stress allows to respond immediately and might be beneficial on the one hand. On the other hand, a lack of flexibility might have negative outcomes in social conflicts like fostering stereotypes and prejudice.

In contrast to our hypothesis, stress did not affect the attribution of a false belief. Participants from the stress condition did not show a stronger bias towards their own knowledge compared to participants from the control condition. This is surprising because of the high stress-sensitivity of the PFC (Roosendaal et al., 2004) and its important role in false-belief attribution (Gallagher and Frith, 2003). One way to explain these null results is that the task was possibly too easy for adults. However, previous studies using more sophisticated mindreading tasks did not provide straightforward effects of stress on social cognition (e.g., Smeets et al., 2009). Stressed adults might have enough cognitive resources available to infer false beliefs correctly when they are explicitly asked to do so. This might change in the context of implicit Theory-of-Mind tasks in which processing a protagonist's belief is not essential to answer the test questions (e.g., Buttelmann and Buttelmann, 2017). Another

explanation of the null results is that we did not measure potential mediators such as executive functions. Executive functions like inhibitory control are mainly controlled by prefrontal regions of the brain. Moreover, they are essential for solving false-belief tasks. However, previous studies on the effect of stress on inhibition revealed inconsistent findings. While some studies indicated a stress-induced impairment of inhibitory control (Sänger et al., 2014; Scholz et al., 2009), others revealed that stress (Schwabe et al., 2013) or cortisol administration (Shields et al., 2015) enhances inhibition. Future research should address the question if more implicit Theory-of-Mind tasks are affected by stress and if or how executive functions mediate effects of stress on social cognition.

Salivary cortisol concentrations are influenced by menstrual cycle phases or the use of oral contraceptives (Kirschbaum et al., 1999). To eliminate this confounding variable, the sample of the present study was restricted to male participants. Nevertheless, future studies should involve female subjects while systematically controlling for the use of oral contraceptives and cycle phases on the day of participation. Previous studies investigating mixed samples found sex differences in mental state reasoning (Smeets et al., 2009) as well as self-other distinction (Tomova et al., 2014). However, results of these studies were contradictory. In Smeets et al.'s (2009) study stress enhanced mental state reasoning in men and reduced it in women. In Tomova et al.'s (2014) study stress reduced self-other distinction in men and enhanced it in women. Since self-other distinction is a prerequisite for mental state reasoning, further research is needed to clarify these opposite effects. In addition, investigating sex differences in the context of effects of stress on social cognition may contribute to the debate on sex-specific behavior under stress. The male tendency to show a “fight-or-flight response” to stress and the female tendency to show a “tend and befriend” response to stress (Taylor et al., 2000; Turton and Campbell, 2005) may be underlying social-cognitive performances.

Laboratory stressors typically induce acute and temporary responses. Ethical considerations do not allow inducing chronic stress. However, questionnaires or interviews could be used to investigate the association between chronic stress and social cognition. Chronic stress is associated with structural changes in the PFC (de Kloet et al., 2005). Therefore, it should be clarified if people who consistently suffer from stress show deficits in social cognition.

In sum, stress did not affect participants' attributions of false beliefs but it increased the probability to predict others' behavior by referring to their former actions. Previous research focused on the influence of stress on the own habitual behavior. Addressing the influence of stress on the interpretation of others' behavior as habitual might be a promising avenue for further research in social cognition and social relationships.

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Conflict of interest

The authors declare that they have no conflict of interest.

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