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An oral presentation causes stress and memory impairments

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ABSTRACT

Laboratory experiments revealed the stress hormone cortisol to decrease memory retrieval of emotional material, but a translation to real-life settings is missing so far. In this study, 51 students encoded a list of neutral, positive, and negative words as well as two neutral, biographical notes one day before attendance at a seminar at the university. In the stress condition, students gave a graded oral presentation, whereas they just attended the same seminar in the control condition immediately before retrieval took place. Measures of state anxiety, salivary cortisol and alpha-amylase confirmed the oral presentation to constitute a potent stressor. Importantly, stress significantly impaired retrieval of negative words, but not retrieval of the biographical notes. These results indicate that a real-life stressor decreases memory retrieval for negative items. In contrast, delayed memory retrieval of neutral information and interrelated details of biographical notes seems to be less prone to stress effects. These results have critical implications for educational settings.

1. Introduction

'The oral presentation was so stressful for me! I forgot so many things I wanted to say!' Such a student's statement can often be heard in defense of a not optimal performance during a university course. But can field studies really support a relationship between stress and memory retrieval impairments?

In addition to subjective reports of stress symptoms and state anxiety (Merz and Wolf, 2015), salivary cortisol or alpha-amylase represent established objective stress markers, which can easily be applied in field research (Kudielka et al., 2012). Cortisol is a glucocorticoid, constitutes the end product of the hypothalamus-pituitary-adrenocortical axis and is slowly released into the bloodstream in response to acute stress (Joëls and Baram, 2009). Alpha-amylase has been proposed to reflect activation of the sympathetic nervous system leading to the release of (nor)epinephrine within seconds (Nater and Rohleder, 2009).

In the laboratory, many experimentally controlled stress induction protocols have been developed such as the Trier Social Stress Test (Kirschbaum et al., 1993), the Socially Evaluated Cold-Pressor Test (Schwabe et al., 2008), the Maastricht Acute Stress Test (Smeets et al., 2012) or the Montreal Imaging Stress Task (Dedovic et al., 2005). This laboratory-based research revealed that situations involving a strong component of social evaluation are able to substantially increase cortisol concentrations (Dickerson and Kemeny, 2004). In the field, such stress-associated increases in cortisol and/or (nor)epinephrine were observed in various situations: parachute jumping (Deinzer et al., 1997), competitive ballroom dancing (Rohleder et al., 2007), anticipation of a surgical intervention (Fell et al., 1985), written (Lovallo et al., 1986; Preuß et al., 2010) or oral examinations (Herbert et al., 1986; Lacey et al., 2000; Merz and Wolf, 2015; Schoofs et al., 2008). In some field studies, sex differences were reported with men showing higher cortisol increases compared to women (Frankenhaeuser et al., 1978; Khaksari et al., 2005; Merz and Wolf, 2015; Weekes et al., 2006); thus, participants' sex should be taken as a possible moderator (cf. Merz and Wolf, 2017 for an overview of sex differences in laboratory studies also regarding learning and memory processes).

Acute stress typically decreases memory retrieval (Wolf, 2009, 2017), particularly emotionally arousing material (e.g., Aerni et al., 2004) as well as words (relative to pictures) are affected (see Shields et al., 2017 for a recent meta-analysis). Importantly, glucocorticoids mediate these impairing effects of stress on memory retrieval (de Quervain et al., 1998) and an administration of glucocorticoids is sufficient to initiate this effect (de Quervain et al., 2000). Generally, it is assumed that stress leads to decreased activation of the hippocampus and the prefrontal cortex hampering retrieval performance (de Quervain et al., 2003; Gagnon et al., in press; Li et al., 2014; Oei et al., 2007). In addition to unrelated material such as lists of words or series of slides, the impact of stress on ecologically more valid and coherent material has been investigated with more mixed results (Hupbach and Fieman, 2012; Merz et al., 2010; Stock and Merz, 2018). Possibly, coherent material consisting of interrelated details is better consolidated

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and less prone to the impairing effects of stress.

While it has been recently shown that cortisol responses to acute stress in the laboratory and in the field are associated with each other (Henze et al., 2017), it remains unknown, if these stress-induced memory decreases observed in the laboratory can also be translated to the field. Such a translation is crucial, since findings from laboratory and field studies do not necessarily converge. Reduced standardization and controllability of confounders, but increased ecological validity characterize field research and might lead to quite different conclusions than research conducted with more restricted laboratory conditions. For example, a different time course of the stress reaction can be assumed to underlie an oral presentation (higher anticipatory anxiety, negative affect, cortisol levels and a longer duration of the cortisol stress response) compared to relatively short laboratory stressors. In addition, social self-preservation theory (Dickerson and Kemeny, 2004) would predict the potential threat to the social self to be much higher in a real-life situation such as during a graded presentation in front of classmates (also in terms of the cortisol stress reaction) in comparison to an artificial laboratory situation, in which a failed performance has no real consequences for the future. While the core result of stress impairing memory retrieval might be identical for field and laboratory studies, differences between both approaches might occur regarding the affected material. For example, differences in the time course of the stress response due to an oral presentation might also affect memory retrieval more generally in contrast to emotional material, which is typically and selectively impaired in laboratory stress studies (Shields et al., 2017).

In the current study, students' retrieval performance was tested after having given an oral presentation at a university course serving as a stress condition and after simple attendance in the same course as a control condition. We hypothesize the oral presentation to represent an effective real-life stressor leading to higher state anxiety, alpha-amylase and cortisol concentrations compared to the control condition. Moreover, we assume that the stress condition impairs memory retrieval, in particular retrieval of emotional words. In addition to the translation from findings obtained in the laboratory to the field, a direct comparison between an unrelated list of words with varying emotional content and coherent biographical notes will give us novel insights how the material itself contributes to impairing stress effects on memory retrieval.

2. Material and methods

2.1. Participants

The required sample size was derived from G*Power 3.1 (Faul et al., 2007) for a repeated-measures analysis of variance (ANOVA), assuming a small-sized effect of stress on memory retrieval ($g+ = 0.215$) as reported in a recent meta-analysis (Shields et al., 2017). In order to detect a significant day × valence (scale) interaction for the words (or the different scales; see 2.6) with a 90% power and an α-level of .05, a sample size of 49 participants was required.

Students at the Ruhr University Bochum participating in a seminar were asked via flyers, social media or personal address if they would like to voluntarily participate in a real-life stress study. Inclusion criteria consisted of an age between 18 and 40 years, a body mass index between 18 and 27 kg/m^2 and the enrollment in a seminar at the university, in which course credits are obtained solely via giving an oral presentation. Exclusion criteria comprised current or a history of psychiatric or neurological treatment, somatic diseases, particularly endocrine diseases known to influence endogenous hormone levels (e.g., hyper-/hypothyroidism), the intake of regular medication and drugs as well as smoking more than five cigarettes/month.

In total, 56 students (38 women) volunteered to participate in this study. After description of the purpose and all procedures, they provided written informed consent. Five women had to be excluded because of extraordinarily high (above the detection limit of the assay, 87 nmol/l) or non-detectable cortisol concentrations. Thus, the final sample consisted of 51 students (33 women; 19 women took hormonal contraceptives), 70% studied psychology in the bachelor degree course. The mean age was 20.9 years (SD = 2.77) and the mean body-mass-index was 21.82 kg/m^2 (SD = 2.25).

Students did not receive any reimbursement for participation. The study was approved by the ethics committee of the Faculty of Psychology at the Ruhr University Bochum and conducted in accordance with the Declaration of Helsinki.

2.2. Procedure

Students were randomly assigned to start the study either with the stress or the control condition (counterbalanced order) with identical and parallelized procedures (within-subjects design). The stress condition encompassed giving a graded oral presentation in a seminar at the university, which was performed in front of the students' classmates and the lecturer in groups of two to four presenters. The individual oral presentation lasted on average 21.7 min ($SE = 1.4$), whereas the presentation of the whole group of presenters lasted on average 64.4 min ($SE = 3.0$). Please note that the lecturer fills the remaining time, since a usual seminar session is designed for 90 min. The control condition consisted of the simple attendance in the same seminar (usually a week later or before) listening to their classmates' presentation and without giving an oral presentation by themselves.

About 24 (± 2) hours before the seminar, participants gave written informed consent and filled out a questionnaire on demographic variables (including age, weight or height). After that, they were asked to encode a word list and two biographical notes (see 2.5). On the next day, participants rated their state anxiety (see 2.3) and provided a saliva sample (see 2.4) immediately before the beginning of the seminar (up to ten minutes before seminar start). After the seminar (immediately or up to ten minutes later due to possible lecturer feedback), state anxiety and a second saliva sample were assessed before memory retrieval started (see 2.5) and further details were obtained (including information regarding course credits of the seminar). Testings on both days took place between 8am and 6pm to cover the whole range of possible seminar times and since stress effects on memory retrieval were reported to be independent of time of day (Smeets, 2011).

2.3. State anxiety

State anxiety was assessed via the German version (Laux et al., 1981) of the State-Trait-Anxiety Inventory (STAI; Spielberger et al., 1970) immediately before and after the seminar in the stress as well as the control condition. The state questionnaire consisted of 20 items referring to statements such as 'I am nervous' or 'I am worried', which had to be answered on a four-point Likert scale ranging from 'not at all' to 'very much'. The mean of these items for each time of measurement was used as the dependent variable.

2.4. Salivary cortisol and alpha-amylase

Concurrent with the assessment of state anxiety, saliva was collected using Salivette collection devices (Sarstedt, Nümbrecht, Germany). All participants must refrain from smoking, eating, and drinking anything but water for at least 30 min before each saliva sample was collected.

All four saliva samples (obtained immediately before and after the seminar in the stress and the control condition respectively) were stored at −20 °C until assayed. Free cortisol concentrations were analyzed using commercially available enzyme-linked immunosorbent assays (ELISA; Demeditec, Kiel, Germany). A quantitative enzyme kinetic method was used to determine salivary alpha-amylase levels (substrate: CNP-G3). Intra-assay and inter-assay coefficients of variations were all

below 10%.

2.5. Memory tests

Two parallel versions of two memory tests were used and handed to the participants in the stress and the control condition in a counterbalanced order. About 24 (± 2) hours prior to the start of the seminar at the university, intentional encoding took place at the same location during both conditions to avoid context-related effects.

The first memory test consisted of a word list presented on a piece of paper and contained ten neutral (e.g., symbol, object), ten positive (e.g., warmth, angel), and ten negative (e.g., terror, horror) German nouns (adapted from Kuhlmann et al., 2005b), which were randomized within each list. As previously shown, the neutral, positive, and negative words did not differ regarding word frequency, word length, or semantic cohesion (cf. Kuhlmann et al., 2005b). Participants were instructed to encode this list for subsequent immediate and delayed retrieval within two minutes. Immediately after encoding, participants were asked to write down as many words as they could remember within five minutes maximum. This procedure (two minutes encoding + five minutes subsequent retrieval) was repeated once to facilitate encoding and consolidation (Roediger and Butler, 2011) and to facilitate comparisons with previous laboratory work on the effects of stress and cortisol administration on memory retrieval using the identical approach (Kuhlmann and Wolf, 2005, 2006; Kuhlmann et al., 2005a, 2005b).

The second memory test was the Memory subtask taken from the Wilde-Intelligence-Test (WIT; Jäger and Althoff, 1994). Participants had to encode two biographical notes (from a woman and a man) in succession including photos, birth dates, telephone numbers, hometowns, and parts of their life stories. For each note, they had five minutes encoding time.

After the seminar, about 24 (± 2) h after encoding, retrieval of the words and the biographical notes was tested. Just like before, participants had to write down as many words as they could remember from the word list within a total of five minutes. We accounted for possible within- and between-subject variances in initial encoding by using the percentage of words remembered during retrieval after the seminar in relation to the second retrieval on the day before (cf. Kuhlmann et al., 2005b; Merz, 2017). Descriptive data and results concerning memory retrieval on day one and two are summarized in Table 1.

Retrieval of the biographical notes was tested with three scales via standardized answering sheets provided in the WIT. Scales included recognition (selection of the correct item out of five alternatives; score range: 0–13; time limit: six minutes), correction (selection of the incorrect item out of five alternatives; score range: 0–11; time limit: 5.5 min), and reproduction (writing down the correct answer in a semi-open answering format; score range: 0–16; time limit: seven minutes). In order to compare the performance between these three scales, the percentage of correct answers was calculated in relation to the possible maximum of correct answers within each scale.

2.6. Statistical analyses

Statistical analyses were performed in IBM SPSS Statistics for Windows 21.0 with the statistical significance level set to $\alpha = .05$; all post hoc tests were Bonferroni-corrected according to the number of comparisons. Analyses of variance (ANOVA) always included the between-subjects factor sex (men vs. women). For separate analyses of state anxiety, salivary cortisol and alpha-amylase, ANOVA were conducted with the repeated measurement factors day (stress vs. control) and time (pre vs. post seminar). For each memory test, retrieval performance was analyzed using repeated measures ANOVA with the repeated measures factors day and valence (neutral vs. positive vs. negative for the word list) or scale (recognition, correction, reproduction for the biographical notes). A direct comparison between overall percentage memory performance between both tasks (not separated by valence or scale) was conducted via an ANOVA with the repeated measures factor day and material (word lists vs. biographical notes).

This project has been preregistered at the Open Science Framework (DOI 10.17605/OSF.IO/M42WC).

3. Results

3.1. State anxiety

Fig. 1a shows that mean state anxiety varied between days and time (day x time interaction: $F_{(1, 49)} = 83.82$, $p < .001$, $\eta_p^2 = .63$; main effect day: $F_{(1, 49)} = 30.82$, $p < .001$, $\eta_p^2 = .39$; main effect time: $F_{(1, 49)} = 92.03$, $p < .001$, $\eta_p^2 = .65$). Post hoc tests indicated higher mean state anxiety before the stress compared to the control condition ($F_{(1, 49)} = 78.33$, $p < .001$, $\eta_p^2 = .62$), but not afterwards ($p > .90$). Furthermore, mean state anxiety was higher before compared to after the stress condition ($F_{(1, 49)} = 136.40$, $p < .001$, $\eta_p^2 = .74$), whereas no significant differences were observed in the control condition ($p > .70$).

3.2. Cortisol concentrations

Cortisol concentrations also varied as a function of day and time (day x time interaction: $F_{(1, 49)} = 7.78$, $p = .007$, $\eta_p^2 = .14$; main effect day: $F_{(1, 49)} = 33.38$, $p < .001$, $\eta_p^2 = .41$; main effect time: $F_{(1, 49)} = 4.80$, $p = .033$, $\eta_p^2 = .09$, Fig. 1b). Whereas cortisol levels declined in the control condition ($F_{(1, 49)} = 33.61$, $p < .001$, $\eta_p^2 = .41$), indicating the typical circadian rhythm, this was not the case for the stress condition ($p > .90$). Moreover, cortisol concentrations were substantially higher after the stress relative to the control condition, right before memory retrieval started ($F_{(1, 49)} = 26.93$, $p < .001$, $\eta_p^2 =$

Table 1
Mean (± SEM) retrieval performance for neutral, positive and negative words (maximum: 10 each) during first and second retrieval on day one and during delayed retrieval on day two are depicted separately for the control and the stress condition.

	Day One, First Retrieval		Day One, Second Retrieval		Day Two, Retrieval	
	Control	Stress	Control	Stress	Control	Stress
Neutral Words	3.29 ± 0.25	3.39 ± 0.25	5.71 ± 0.33	5.80 ± 0.33	3.63 ± 0.35	3.24 ± 0.39
Positive Words	4.39 ± 0.21	4.45 ± 0.23	7.08 ± 0.23	6.59 ± 0.27	4.55 ± 0.29	4.02 ± 0.36
Negative Words	4.69 ± 0.23	4.92 ± 0.22	6.88 ± 0.24	6.75 ± 0.25	4.69 ± 0.30	3.61 ± 0.34

On day one, only a main effect of valence was found (first retrieval: $F_{(2, 98)} = 19.64$, $p < .001$, $\eta_p^2 = .29$; second retrieval: $F_{(2, 98)} = 14.45$, $p < .001$, $\eta_p^2 = .23$). Post hoc tests revealed that participants remembered both positive and negative words better than neutral words (all $p \leq .001$).
On day two, without considering possible pre-existing within- and between-subject variances in initial encoding, largely comparable results to the main findings could be obtained: the factors day and valence modulated memory retrieval (day x valence interaction: $F_{(2, 98)} = 2.65$, $p = .076$, $\eta_p^2 = .51$; main effect day: $F_{(1, 49)} = 5.18$, $p = .027$, $\eta_p^2 = .10$; main effect valence: $F_{(2, 98)} = 7.64$, $p = .001$, $\eta_p^2 = .14$). As in the main analysis, post hoc tests indicated stress to impair memory retrieval of negative words only (negative: $F_{(1, 49)} = 13.56$, $p = .001$, $\eta_p^2 = .22$; positive: $p > .25$; neutral: $p > .30$).

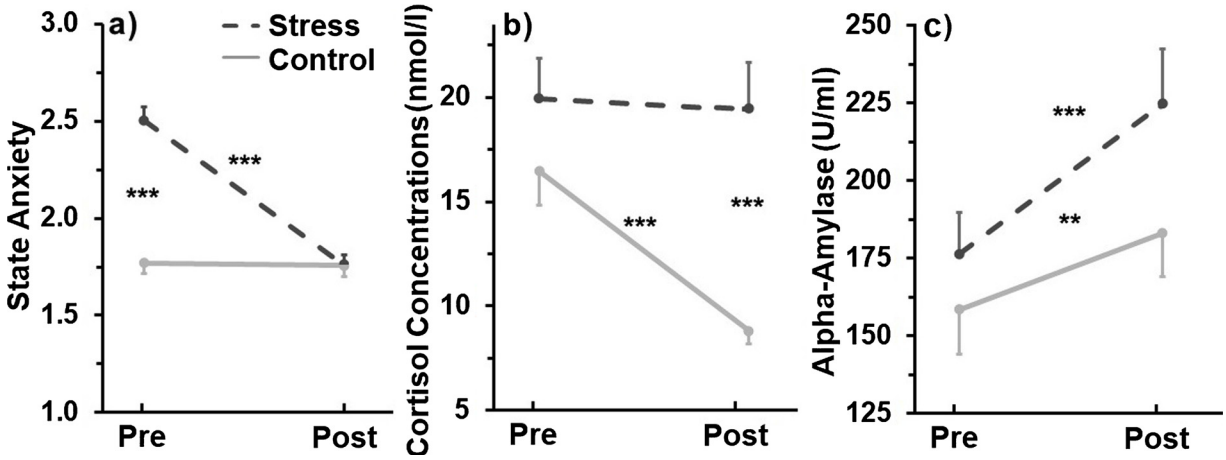

Fig. 1. Verification of the stress induction is shown before (pre) and after (post) an oral presentation was given at the university (stress) relative to a control condition in the same course. Data represent mean and standard errors of the mean. *** $p < .001$; ** $p < .005$.
a) State anxiety was significantly higher before the stress compared to the control condition and dropped afterwards to levels of the control condition.
b) Cortisol concentrations were significantly higher after the stress in comparison to the control condition. Additionally, cortisol concentrations declined in the control condition only.
c) Alpha-amylase levels were significantly higher during the stress relative to the control condition and increased during both conditions.

.36), but not before ($p > .08$). Additionally, a main effect of sex emerged revealing men having overall higher cortisol levels compared to women, independent of day and time ($F_{(1, 49)} = 4.79$, $p = .033$, $\eta_p^2 = .09$).

3.3. Alpha-amylase

Salivary alpha-amylase was generally higher during the stress compared to the control condition (main effect day: $F_{(1, 49)} = 9.85$, $p = .003$, $\eta_p^2 = .17$). In addition, higher alpha-amylase concentrations were found at the end relative to the beginning of the experimental day (main effect time: $F_{(1, 49)} = 14.08$, $p < .001$, $\eta_p^2 = .22$, Fig. 1c).

3.4. Memory retrieval

As shown in Fig. 2a, memory retrieval of the word lists was subject to a modulation by day and valence (day x valence interaction: $F_{(2, 98)} = 3.56$, $p = .032$, $\eta_p^2 = .07$; main effect day: $F_{(1, 49)} = 7.99$, $p = .007$, $\eta_p^2 = .14$; see Table 1 for descriptive statistics and results concerning memory retrieval on day one and uncorrected results regarding day two). Importantly, post hoc tests revealed that participants only had difficulties when retrieving previously learned negative words after the stress compared to the control condition (negative: $F_{(1, 49)} = 19.27$, $p < .001$, $\eta_p^2 = .28$; positive: $p > .68$; neutral: $p > .10$).

In contrast, memory retrieval of the biographical notes was only affected by the retrieval type (main effect scale: $F_{(2, 98)} = 19.13$, $p < .001$, $\eta_p^2 = .28$), but not by day or time (all $p > .23$, Fig. 2b). Overall, items from the reproduction scale were retrieved to a lesser extent in comparison to items from the recognition and the correction scale (both $p < .001$).

In line with these findings, a direct comparison between overall percentage memory performance in both tasks (not separated by valence or scale) revealed that retrieval was better for the biographical notes relative to the word lists (main effect material: $F_{(1, 49)} = 6.43$, $p = .014$, $\eta_p^2 = .12$). In addition, stress modulated this effect (day x material interaction: $F_{(1, 49)} = 4.74$, $p = .034$, $\eta_p^2 = .09$): whereas stress did not affect overall retrieval performance of the biographical notes ($p > .44$), overall retrieval of the word lists decreased in the stress compared to the control condition ($F_{(1, 49)} = 6.82$, $p = .024$ (after Bonferroni-correction), $\eta_p^2 = .12$, cf. above).

4. Discussion

This field study supports the notion that giving an oral presentation at the university represents a potent stressor and leads to memory retrieval impairments. More specifically, stress reduced the retrieval of

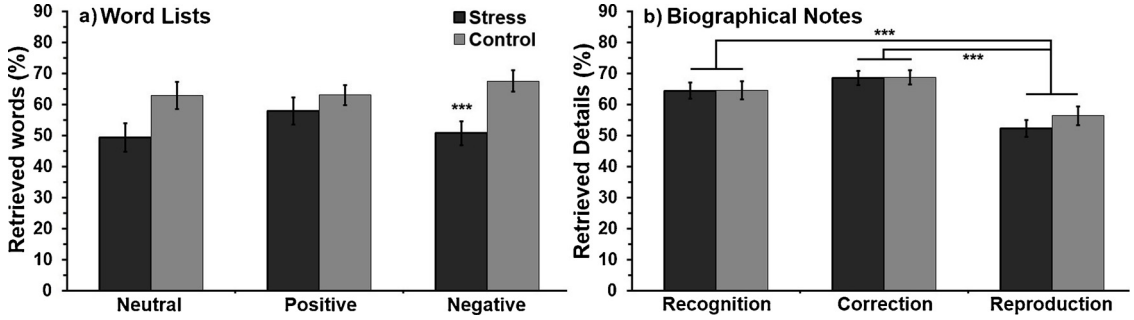

Fig. 2. Memory retrieval is shown after an oral presentation was given at the university (stress) relative to a control condition in the same course. Encoding took place 24 (± 2) hours before under neutral conditions. Data represent mean and standard errors of the mean. *** $p < .001$.
a) Percentage retrieval of neutral, positive and negative words of a previously encoded word list. Stress significantly impaired retrieval of negative words relative to the control condition.
b) Percentage retrieval of details of previously encoded biographical notes, separated by the scales recognition, correction and reproduction. Memory retrieval was significantly decreased for the reproduction compared to the recognition and the correction scale, but no stress effect occurred.

negative words only, but not of positive or neutral information.

Findings from subjective measures indicate an anticipatory rise in state anxiety towards the upcoming oral presentation (cf. Merz and Wolf, 2015). In the stress condition, higher initial state anxiety was observed, which declined afterwards to levels found in the control condition. Furthermore, concentrations of alpha-amylase were higher in the stress in comparison to the control condition as observed in a field study before (Schoofs et al., 2008), indicating oral presentations to be associated with a higher activation of the sympathetic nervous system (Herbert et al., 1986; Nater and Rohleder, 2009).

Declining cortisol levels over the course of the day due to the typical circadian rhythm can explain the pattern in the control condition (Young et al., 2004). In contrast, the cortisol levels remained high in the stress condition, but did not increase in response to the oral presentation. Since the second saliva sample was taken after the seminar (between 90 and 110 min after the first saliva sample and between 90 and 100 min after seminar start), the peak cortisol response (typically occurring 20–40 min after stress onset of laboratory stressors; Dickerson and Kemeny, 2004; Goodman et al., 2017) could not be captured. On the one hand, the definition of stress onset for an oral presentation is difficult, since the beginning of the oral presentation or seminar start are both not necessarily valid. Instead, stress might begin for students much earlier when already anticipating the oral presentation, this point in time cannot be assessed reliably and varies widely on an individual level. On the other hand, students would not agree to give one or more additional saliva samples during their graded, oral presentation. Thus, we could not evaluate the cortisol stress response in its beginning, peak and recovery in a more fine-grained manner comparable to laboratory studies, which can be conceived as a limitation of the current approach, but inherent to this field stressor. Generally, results on cortisol concur with prior research in the university setting (e.g., Herbert et al., 1986; Lovallo et al., 1986; Merz and Wolf, 2015; Preuß et al., 2010; Schoofs et al., 2008). Altogether, our findings confirm that an oral presentation depicts an effective real-life stressor, which is suited to investigate memory processes in the field. Importantly, cortisol concentrations were higher in the stress compared to the control condition, especially after the oral presentation when retrieval testing took place.

Stress substantially reduced memory retrieval for negative words, which could be driven by a stress-induced decreased activation and interplay between the hippocampus and the prefrontal cortex necessary for successful memory retrieval (de Quervain et al., 2003; Gagnon et al., in press; Li et al., 2014; Oei et al., 2007). For neutral words, a reduction in memory retrieval was also observed in the stress condition, however, only at a descriptive level. Furthermore, acute stress exerted neither an effect on positive words nor on the information contained in the biographical notes. Positive words might have been perceived as less emotionally arousing compared to negative words, thus, not highly susceptible to the impairing effects of stress hormones typically restricted to emotionally arousing material (Shields et al., 2017). It might be advisable to use individualized material in future studies to guarantee a comparable emotional arousal for positive and negative stimuli. The biographical notes consisted of neutral information, accordingly, the lacking stress effect on the biographical notes might also be due to the non-emotionality of the testing material. Besides, in contrast to the word lists including unrelated nouns, coherent stories with interrelated details were presented in the biographical notes, which might be more immune to the detrimental stress effects on memory retrieval. Relational associations and the possible imagined interaction of the different details of the biographical notes (cf. Bower, 1970) might lead to a more elaborated or deeper level of semantic processing (Craik and Lockhart, 1972), which could be less prone to the impairing influence of stress. In addition, the answer format of the biographical notes mostly included recognition items, whereas the remembrance of the word lists was tested with a free retrieval test. It has already been shown that stress effects on memory retrieval are stronger for free retrieval compared to recognition tasks (Gagnon and Wagner, 2016; Wolf, 2017), our results thus concur with these observations. Indeed, identifying specific circumstances under which stress does not impair memory retrieval is highly relevant for the educational system or testimonies (cf. Smith and Thomas, 2018).

Regarding word lists, it could be argued that the repeated encoding-retrieval cycle on day one might preserve memory retrieval from the detrimental effects of stress as shown before (Smith et al., 2016). However, this previous study compared two repetitions of encoding (stress effects on memory retrieval were present) with two repetitions of retrieval (stress effects on memory retrieval were absent) after encoding. In contrast, we used both, one repetition of encoding and retrieval, respectively and still found stress to significantly impair memory retrieval for negative words. Possibly, the effect of repeated encoding outweighs the effect of repeated retrieval in terms of subsequent susceptibility to stress hormones during memory retrieval, which needs to be directly tested in future studies.

In our previous experiment however (Merz et al., 2010), stress reduced memory retrieval of the same biographical notes used in the current study. However, it has to be noted that this prior experiment did not test retrieval performance 24 h after encoding, but only 50 min later. Hence, the consolidation period could be critically involved in stress effects to unfold or not: possibly, stress effects on the biographical notes are more likely to occur when the memory trace has not been consolidated yet in contrast to a consolidated memory trace of this coherent and interrelated material present in the current design. In addition, memory retrieval was tested in our previous laboratory study during peak cortisol concentrations (around 35 min after stress onset), whereas the present study tested memory retrieval at least 90 min after seminar start (cf. Schwabe and Wolf, 2014; please note that stress onset cannot be defined in the current field study as noted above). Thus, different results might be explained by the difference between stress onset and memory testing alluding to the contribution of genomic and non-genomic cortisol effects on the brain (Hermans et al., 2014; Wolf, 2017).

Additional saliva samples and anxiety ratings obtained during the encoding session would have been beneficial for interpretation purposes, since these data could have served as a further baseline independent of the seminar context. Since cortisol also affects encoding processes (Shields et al., 2017), future studies should also take saliva samples during encoding to verify similar cortisol concentrations between conditions. Moreover, the neutral, positive and negative words were randomized within each list, but not for each participant. Thus, possible primacy and recency effects cannot be excluded, however, they cannot account for the observed stress effect due to the counterbalanced assignment of lists and conditions across participants.

5. Conclusions

Taken together, the stress-induced memory impairments of negative material observed in the laboratory (Shields et al., 2017; Wolf, 2009, 2017) were translated to the field for the first time. Stress did not reduce retrieval of ecologically more valid material as depicted in the biographical notes, potentially due to their neutral and coherent content. Important implications of these results encompass educational settings, in which retrieval performance might be indeed compromised during an oral presentation as exemplified in the beginning, at least as far as negative material is concerned. Similar stress effects on memory retrieval can be assumed in further academic settings such as oral or written examinations (also leading to substantial cortisol increases; Herbert et al., 1986; Lacey et al., 2000; Lovallo et al., 1986; Merz and Wolf, 2015; Preuß et al., 2010; Schoofs et al., 2008). Importantly, the translation of the current findings to student-relevant material such as details of lectures or textbooks should be realized in future studies.

Declaration of interest

None.

Conflict of interest

All authors declare no conflict of interest.

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