SUPPLEMENTAL MATERIAL

Fear Without Context: Acute Stress Modulates the Balance of Cue-Dependent and

Contextual Fear Learning

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## Supplementary results

**Explorative analysis of gender differences in the influence of stress on cued and contextual fear learning**

In an explorative analysis, we investigated whether the stress-induced changes in the balance of cued and contextual fear learning differ in men and women. In order to rule out that potential gender differences in the impact of stress on the mode of fear learning were due to differential stress responses, we first analyzed whether there were gender differences in the subjective and physiological response to the TSST. This analysis showed that the subjective, autonomic, and endocrine responses to the stressor were comparable in men and women (all group × gender and group × gender × time point of measurement interactions: all $F < 1.55$, all $p > .247$, all $\eta_p^2 < 0.02$). Next, we assessed the influence of stress on indicators of cued and contextual fear during acquisition and extinction.

For cue-dependent fear acquisition, expressed as SCR, there was a trend for a gender × group × CStype interaction ($F(1, 68) = 3.76$, $p = .057$, $\eta_p^2 = 0.05$), suggesting that men in the control group showed higher SCRs to the CS+ ($F(1, 14) = 19.61$, $p = .001$, $\eta_p^2 = 0.58$), whereas there was only a trend in that direction in stressed men ($F(1, 15) = 3.33$, $p = .088$, $\eta_p^2 = 0.18$; CStype × group interaction for men: $F(1, 29) = 5.70$, $p = .024$, $\eta_p^2 = .164$; CStype × group interaction for women: $F(1, 39) = 0.06$, $p = .80$, $\eta_p^2 < 0.01$). Furthermore, there was a significant gender × CStype interaction ($F(1, 68) = 5.81$, $p = .019$, $\eta_p^2 = 0.08$) showing that whereas men did overall show stronger SCRs to the CS+ than to the CS- ($F(1, 29) = 21.61$, $p < .001$, $\eta_p^2 = 0.43$), this difference was only a trend in women ($F(1, 39) = 2.46$, $p = .125$, $\eta_p^2 = 0.06$). In terms of subjective indices of cue-dependent fear acquisition, there were no gender differences in the stress effect on subjective arousal (all $F < 2.56$, all $p > .114$, all $\eta_p^2 < .037$). For shock expectancy ratings, however, there was a CStype × gender interaction ($F(1, 68) = 6.41$, $p = .014$, $\eta_p^2 = 0.09$)

suggesting that women differentiated better between CStypes ($F(1, 39) = 6.57$, $p = .014$, $\eta_p^2 = 0.14$) than did men ($F(1, 29) = 1.43$, $p = .241$, $\eta_p^2 = 0.05$).

Stress effects on context-related SCRs and shock expectancy ratings during acquisition did not differ between men and women (all $F < 2.52$, all $p > .100$, all $\eta_p^2 < 0.04$). With respect to subjective arousal, however, there was a trend for a three-way interaction of gender, group, and context ($F(1.53, 104.09) = 2.948$, $p = .070$, $\eta_p^2 = 0.04$), suggesting that whereas men in both the stress and control group showed higher arousal in the risk vs. safe contexts (both $p < .018$; context × group interaction for men: $F(1.594, 46.219) = 0.369$, $p = .649$, $\eta_p^2 = 0.01$), only women in the control group showed this differentiation ($F(1.244, 24.879) = 20.40$, $p < .001$, $\eta_p^2 = 0.51$) but not those in the stress group ($F(2, 38) = 2.31$, $p = .113$, $\eta_p^2 = 0.11$).

During extinction, there were no gender differences in the effect of stress on cue-related SCRs or arousal ratings (all $F < 2.29$, all $p > .105$, all $\eta_p^2 < 0.04$). For expectancy ratings, however, there was a gender × group × CS type interaction ($F(1, 68) = 5.20$, $p = .026$, $\eta_p^2 = 0.07$), which suggested that women in the control group tended to show higher shock expectancy ratings for the CS+ than for the CS- ($F(1, 20) = 3.88$, $p = .063$, $\eta_p^2 = 0.16$), while women in the stress group tended to show the opposite pattern ($F(1, 19) = 2.86$, $p = .107$, $\eta_p^2 = 0.13$; group × CS type interaction in women: $F(1, 39) = 6.68$, $p = .014$, $\eta_p^2 = 0.15$; group × CS type interaction in men: $F(1, 29) = 0.64$, $p = .431$, $\eta_p^2 = 0.02$).

Finally, although there was a significant interaction between gender, group, context, and block for context-related SCRs during extinction ($F(4, 272) = 2.91$, $p = .022$, $\eta_p^2 = 0.04$), none of the follow-up tests reached statistical significance (all $F < 1.90$, all $p > .112$, all $\eta_p^2 < 0.05$). Likewise, there were no significant gender differences in the influence of stress on context-related arousal or shock expectancy ratings (all $F < 0.66$, all $p > .582$, all $\eta_p^2 < 0.01$).

In sum, these analyses revealed no convincing evidence for systematic gender differences in the influence of stress on the balance of contextual and cued fear learning. For the few effects that reached statistical significance, it is important to note that we did not have any a-priori hypothesis regarding gender differences and this study was therefore not adequately powered for analyses of differences between men and women. Thus, although some of the observed gender differences may seem interesting, they need to be interpreted with great caution and future studies are required to explicitly test for possible gender differences in the impact of stress on the balance of cued and contextual fear learning.

Supplementary Table S1

*Subjective stress ratings.*

|  | Control | | Stress | |
| --- | --- | --- | --- | --- |
|  | M | SD | M | SD |
| Stressfulness | 20.83 | 16.45 | 62.78 | 23.50 |
| Unpleasantness | 25.83 | 25.23 | 64.44 | 23.96 |
| Difficulty | 21.39 | 21.67 | 67.50 | 21.43 |
| Good vs. bad mood |  |  |  |  |
| Before manipulation | 34.69 | 3.72 | 34.14 | 4.20 |
| After manipulation | 34.44 | 3.48 | 30.22 | 6.70 |
| Calmness vs restlessness |  |  |  |  |
| Before manipulation | 32.92 | 4.34 | 32.39 | 4.20 |
| After manipulation | 31.89 | 3.94 | 26.06 | 6.29 |
| Alertness vs. tiredness |  |  |  |  |
| Before manipulation | 31.31 | 7.11 | 29.64 | 5.90 |
| After manipulation | 31.28 | 5.75 | 29.28 | 5.10 |

Stressfulness, unpleasantness, and difficulty were rated on a scale from 0 ("not at all") to 100 ("very much").

Supplementary Table S2

*Data from the exploration phase.*

|  | Control | | Stress | |
| --- | --- | --- | --- | --- |
|  | M | SD | M | SD |
| Time in risk context (sec) | 52.22 | 20.62 | 47.00 | 17.47 |
| Time in safe context 1 (sec) | 51.10 | 15.57 | 48.19 | 16.67 |
| Time in safe context 2 (sec) | 45.94 | 16.10 | 52.36 | 15.64 |
| SCR to risk context (µS) | 0.15 | 0.19 | 0.16 | 0.21 |
| SCR to safe context 1 (µS) | 0.14 | 0.20 | 0.22 | 0.32 |
| SCR to safe context 2 (µS) | 0.17 | 0.27 | 0.16 | 0.24 |
| Valence rating risk context | 2.11 | 0.75 | 1.89 | 0.68 |
| Valence rating safe context 1 | 2.22 | 0.72 | 1.89 | 0.78 |
| Valence rating safe context 2 | 1.94 | 0.67 | 2.14 | 0.76 |
| Arousal rating risk context | 0.42 | 0.55 | 0.49 | 0.56 |
| Arousal rating safe context 1 | 0.58 | 0.69 | 0.50 | 0.56 |
| Arousal rating safe context 2 | 0.44 | 0.56 | 0.50 | 0.56 |

Valence and arousal ratings were given on a scale from 0 ("very negative"/"not arousing") to

3 ("very positive"/"very arousing").

Supplementary Table S3

*Subjective arousal and shock expectancy ratings during acquisition.*

|  | Control | | Stress | |
|---|---|---|---|---|
|  | M | SD | M | SD |
| Cue-related subjective arousal |  |  |  |  |
| CS+ block 1 | 1.00 | 0.74 | 1.07 | 0.65 |
| CS+ block 2 | 1.29 | 0.83 | 1.07 | 0.63 |
| CS+ block 3 | 1.35 | 0.95 | 1.01 | 0.74 |
| CS+ block 4 | 1.47 | 0.97 | 0.88 | 0.74 |
| CS- block 1 | 1.15 | 0.68 | 1.10 | 0.70 |
| CS- block 2 | 1.33 | 0.91 | 1.10 | 0.74 |
| CS- block 3 | 1.28 | 0.92 | 1.06 | 0.76 |
| CS- block 4 | 1.26 | 1.01 | 1.04 | 0.74 |
| Cue-related shock expectancy |  |  |  |  |
| CS+ block 1 | 1.89 | 0.60 | 1.83 | 0.67 |
| CS+ block 2 | 2.46 | 0.75 | 2.04 | 0.79 |
| CS+ block 3 | 2.36 | 0.65 | 2.33 | 0.72 |
| CS+ block 4 | 2.13 | 0.90 | 2.08 | 0.86 |
| CS- block 1 | 1.97 | 0.64 | 1.90 | 0.57 |
| CS- block 2 | 2.21 | 0.66 | 2.28 | 0.62 |
| CS- block 3 | 1.92 | 0.91 | 2.04 | 0.90 |
| CS- block 4 | 2.17 | 0.90 | 2.25 | 0.69 |

Supplementary Table S3 (continued)

| | Control | | Stress | |
|---|---|---|---|---|
| | M | SD | M | SD |
| Context-related subjective arousal | | | | |
| Risk context block 1 | 0.85 | 0.67 | 0.81 | 0.55 |
| Risk context block 2 | 0.93 | 0.73 | 0.68 | 0.61 |
| Risk context block 3 | 1.07 | 0.90 | 0.68 | 0.61 |
| Risk context block 4 | 0.97 | 0.86 | 0.56 | 0.62 |
| Safe context 1 block 1 | 0.90 | 0.70 | 0.79 | 0.59 |
| Safe context 1 block 2 | 0.61 | 0.62 | 0.49 | 0.45 |
| Safe context 1 block 3 | 0.42 | 0.51 | 0.32 | 0.45 |
| Safe context 1 block 4 | 0.28 | 0.44 | 0.24 | 0.37 |
| Safe context 2 block 1 | 0.86 | 0.82 | 0.74 | 0.58 |
| Safe context 2 block 2 | 0.64 | 0.63 | 0.56 | 0.61 |
| Safe context 2 block 3 | 0.35 | 0.53 | 0.38 | 0.44 |
| Safe context 2 block 4 | 0.35 | 0.48 | 0.22 | 0.35 |
| Context-related shock expectancy | | | | |
| Risk context block 1 | 1.71 | 0.64 | 1.60 | 0.75 |
| Risk context block 2 | 1.63 | 0.97 | 1.58 | 1.12 |
| Risk context block 3 | 1.61 | 1.12 | 1.38 | 1.09 |
| Risk context block 4 | 1.44 | 1.07 | 1.29 | 1.07 |
| Safe context 1 block 1 | 1.32 | 0.78 | 1.43 | 0.75 |
| Safe context 1 block 2 | 0.82 | 0.81 | 0.86 | 0.76 |
| Safe context 1 block 3 | 0.51 | 0.84 | 0.42 | 0.64 |

| | | | | |
|---|---|---|---|---|
| Safe context 1 block 4 | 0.42 | 0.69 | 0.39 | 0.71 |
| Safe context 2 block 1 | 1.40 | 0.78 | 1.44 | 0.71 |
| Safe context 2 block 2 | 0.82 | 0.82 | 0.79 | 0.69 |
| Safe context 2 block 3 | 0.54 | 0.80 | 0.51 | 0.72 |
| Safe context 2 block 4 | 0.47 | 0.76 | 0.42 | 0.71 |

Valence and arousal ratings were given on a scale from 0 ("very negative"/"not arousing") to

3 ("very positive"/"very arousing").

Supplementary Table S4

*Subjective arousal and shock expectancy ratings during extinction.*

|  | Control | | Stress | |
| --- | --- | --- | --- | --- |
|  | M | SD | M | SD |
| Cue-related subjective arousal | | | | |
| CS+ block 1 | 1.17 | 0.89 | 0.99 | 0.63 |
| CS+ block 2 | 0.71 | 0.80 | 0.64 | 0.63 |
| CS+ block 3 | 0.42 | 0.62 | 0.53 | 0.73 |
| CS- block 1 | 1.08 | 0.82 | 0.93 | 0.69 |
| CS- block 2 | 0.61 | 0.72 | 0.61 | 0.56 |
| CS- block 3 | 0.26 | 0.42 | 0.57 | 0.75 |
| Cue-related shock expectancy | | | | |
| CS+ block 1 | 2.01 | 0.77 | 1.72 | 0.75 |
| CS+ block 2 | 1.10 | 0.97 | 1.21 | 1.00 |
| CS+ block 3 | 0.72 | 0.95 | 0.88 | 0.90 |
| CS- block 1 | 1.82 | 0.84 | 1.81 | 0.76 |
| CS- block 2 | 1.00 | 0.98 | 1.17 | 0.93 |
| CS- block 3 | 0.58 | 0.90 | 0.83 | 0.85 |
| Context-related subjective arousal | | | | |
| Risk context block 1 | 0.83 | 0.68 | 0.63 | 0.53 |
| Risk context block 2 | 0.32 | 0.42 | 0.39 | 0.51 |
| Risk context block 3 | 0.14 | 0.31 | 0.28 | 0.50 |

Supplementary Table S4 (continued)

| | Control | | Stress | |
|---|---|---|---|---|
| | M | SD | M | SD |
| Safe context 1 block 1 | 0.51 | 0.62 | 0.49 | 0.51 |
| Safe context 1 block 2 | 0.31 | 0.54 | 0.38 | 0.45 |
| Safe context 1 block 3 | 0.18 | 0.43 | 0.29 | 0.44 |
| Safe context 2 block 1 | 0.51 | 0.55 | 0.46 | 0.48 |
| Safe context 2 block 2 | 0.17 | 0.38 | 0.26 | 0.37 |
| Safe context 2 block 3 | 0.08 | 0.25 | 0.22 | 0.37 |
| Context-related shock expectancy | | | | |
| Risk context block 1 | 1.25 | 0.87 | 1.28 | 0.93 |
| Risk context block 2 | 0.51 | 0.76 | 0.60 | 0.93 |
| Risk context block 3 | 0.40 | 0.83 | 0.38 | 0.71 |
| Safe context 1 block 1 | 0.92 | 0.92 | 0.75 | 0.74 |
| Safe context 1 block 2 | 0.63 | 0.88 | 0.57 | 0.70 |
| Safe context 1 block 3 | 0.47 | 0.86 | 0.32 | 0.63 |
| Safe context 2 block 1 | 0.65 | 0.74 | 0.56 | 0.70 |
| Safe context 2 block 2 | 0.32 | 0.69 | 0.43 | 0.63 |
| Safe context 2 block 3 | 0.25 | 0.72 | 0.33 | 0.61 |

Valence and arousal ratings were given on a scale from 0 ("very negative"/"not arousing") to 3 ("very positive"/"very arousing").

Supplementary Table S5

*Control variables.*

|  | Control | | Stress | |
| --- | --- | --- | --- | --- |
|  | M | SD | M | SD |
| Men/women | 15/21 | - | 16/20 | - |
| Age | 25.58 | 3.37 | 25.42 | 4.27 |
| School years | 12.29 | 1.10 | 12.43 | 0.70 |
| Academic education (years) | 4.18 | 1.73 | 4.75 | 2.24 |
| Depressive mood (BDI) | 6.42 | 6.90 | 5.42 | 3.58 |
| Chronic stress (TICS screening scale) | 13.17 | 9.08 | 12.94 | 7.68 |
| State anxiety | 35.44 | 7.09 | 34.92 | 5.74 |
| Trait anxiety | 34.67 | 9.65 | 36.08 | 7.36 |
| Gaming hours per week | 2.09 | 3.91 | 1.44 | 2.86 |
| Number of shocks received during acquisition | 12.42 | 2.10 | 12.47 | 1.81 |
| Shock intensity (in V) | 55.50 | 15.59 | 54.06 | 10.69 |

Supplementary Table S6

*Responses in the explicit knowledge questionnaire.*

|  | Control | Stress |
|---|---|---|
| Did you notice a certain rule that determined whether you receive a shock or not? | | |
| *No* | 2 | 4 |
| *Yes, correct rule mentioned* | 28 | 29 |
| *Yes, incorrect rule mentioned* | 6 | 3 |
| Did you notice that a light bulb it up? If so, in which color(s) did it lit up? | | |
| *Yes and both colors correctly mentioned* | 36 | 33 |
| *Yes but only one color correctly mentioned* | 0 | 3 |
| How many rooms did you visit during the task? | | |
| *Correct answer (3 rooms)* | 36 | 35 |
| *Incorrect answer* | 0 | 1 |
| Could the receipt of electric shocks be predicted? If so, how? | | |
| *Yes, only the light was relevant* | 6 | 9 |
| *Yes, only the room was relevant* | 3 | 4 |
| *Yes, both light and room were relevant* | 26 | 23 |
| Which color had the light the predicted a shock? | | |
| *CS+ color correctly indicated* | 31 | 29 |
| *CS+ color not correctly indicated* | 5 | 7 |

Supplementary Table S5 (continued)

|  | Control | Stress |
|---|---|---|
| In which room was the probability to receive an electric shock highest? | | |
| *Risk room correctly indicated* | 30 | 29 |
| *Risk room not correctly indicated* | 6 | 7 |
| Did you receive the electric shocks always in the same room? | | |
| *Yes* | 22 | 20 |
| *No* | 12 | 12 |
| *Don't know* | 2 | 4 |
| Did you notice any changes between the second and third phase of the task? | | |
| *Both, relocation of cues and absence of shocks   mentioned* | 8 | 6 |
| *Only absence of shocks mentioned* | 19 | 18 |
| *Only relocation of cues mentioned* | 1 | 0 |
| *Incorrect change mentioned* | 4 | 7 |
| *No change noticed* | 4 | 5 |

Data show the number of participants per group. Chosen response options per question indicated in italics.