Supplementary Methods and Results to Accompany:

Individual Variation in Working Memory is Associated with Fear Extinction Performance

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Psychiatric Symptom Measures

Clinician Administered PTSD SCALE (CAPS). The CAPS (Blake et al., 1995) is a gold-standard structured clinical interview used to assess for the presence of posttraumatic stress disorder. The CAPS total score has a range from 0 to 136, using DSM-IV criteria. In the full sample, CAPS total mean = 9.86 (SD=9.42; range=0-55). The difference between high and low WM was not significant, $t(396.01)=0.70, p=.49$.

Beck Anxiety Inventory (BAI). Anxiety symptomatology was assessed using the BAI (Beck & Steer, 1993). The BAI is a well-validated measure of general anxiety symptoms present within the past week. The BAI was used to dissociate from depressive symptoms (Clark, Watson, & Mineka, 1994). A cut-off score of >15 was used to categorize participants into moderate or severe anxiety levels. In the full sample, the BAI had a mean of 3.06 (SD=3.77; range=0-15). There was no difference between high and low WM ability on BAI scores, $t(396.6)=0.69, p=.49$ (see Table 1).

Beck Depression Inventory-II (BDI-II). The BDI-II was used to assess depressive symptoms over the past two weeks (Beck, Steer, Ball, & Ranieri, 1996). Participants were classified as moderately to severely depressed if they scored > 19 on the BDI-II. In the current study, the full sample mean=3.96 (SD=4.24; range=0-19), with no difference between high and low WM ability, $t(396.6)=1.18, p=.24$ (see Table 1 in main report).

Analysis and results for baseline startle activity

Fear acquisition. The final 4 presentations of the startle stimulus in the absence of any stimuli (noise alone or "NA" trials) which measured baseline startle, were averaged together to create an index of baseline startle over "late acquisition." To examine group differences in working memory (WM) and attention ability on baseline startle reactivity, two separate independent t-tests were performed on baseline startle during acquisition. Both WM and attention ability were not related to baseline startle reactivity, $ts < -1.61$, $ps > .11$.

Fear Extinction. The 16 baseline, or NA trials, were averaged into 4 Extinction blocks titled Early Extinction (trials 1-4), Mid Extinction 1 (trials 5-8), Mid Extinction 2 (trials 9-12) and Late Extinction (trials 13-16). These scores were entered into two separate WM Group (Low vs. High ability) × Block (Early, Middle, Late) repeated measures ANOVAs (Greenhouse-Geisser corrected). Only the main effect of block was significant, $F = 158.45$, $ps < .0001$, where startle reactivity decreased over the course of the four phases (linear trend: $Fs > 236.69$, $ps < .0001$. The main effects of group, and the group X block interaction were non-significant, $Fs < 1.04$, $ps > .35$. This suggest that there were no group differences in habituation to the startle probe throughout extinction learning.

This supports the hypothesis that individual differences in WM ability influence fear extinction learning, and is not simply due to a general response to startle probes or to habituation.

Reanalysis of startle Using T-scores

To compare these data with studies that use differential startle amplification and other factors that could affect the baseline startle signal, we reanalyzed the FPS data using T-scores instead of the index scores used in the primary analyses. The results of this analysis were similar to the primary analyses. Using the extreme group approach, the main effect of group (p=.008) and the group × block interaction was significant (p=.008). High WM ability was associated with greater extinction scores at the late block (p=.001), but not the early and middle blocks (ps > .12).

Analysis of CS- trials during fear extinction

Using raw FPS responses (after subtraction from NA baseline) we computed extinction learning scores on the CS- trials. Like the CS+ trials in the main report, these scores reflect the change in response across extinction learning using the first block as a baseline (see Method in main report). These scores were then entered into a Group × Block ANOVA. WM ability did not influence FPS learning scores for CS- trials: group effect and interaction $Fs < .105$, $ps > .31$. This pattern was corroborated using the full sample (n=788), $Fs < 1.89$, $ps > .17$. In contrast, US expectancy learning scores revealed a significant Group × Block interaction, $F(1.67, 648.59) = 4.45$, $p = .017$. However, none of the pairwise comparisons were significantly different, $ps > .15$. The main effect of group was not significant, $p = .61$.

Comparing CS+ and CS- discrimination during fear extinction

Using raw FPS responses (after subtraction from NA baseline) *we compared the influence of WM ability on CS+ versus CS- discrimination during extinction via a Group × CS type × Block ANOVA.* The 3-way interaction was marginally significant, $F(2.75, 1211.22)=2.68$, $p = .051$. There was also a significant Group × CS type interaction, $F(1,441)=4.28$, $p=.04$. As shown in Supplementary Figure 4, for individuals with low WM ability, CS+ was significantly different from CS- responses during the second ($p=.001$) and fourth blocks ($p<.001$), but not the first and third blocks ($ps>.17$). In contrast, in individuals with high WM ability, CS+ versus CS- responses were significantly different at all four blocks ($ps<.006$). The difference of CS+ and CS- discrimination between high and low WM ability was significantly different in the first block ($p=.005$) but not the other three blocks ($ps > .12$).

Analysis of trial x trial US expectancy

To facilitate the interpretation of the effect of WM ability on US expectancy ratings for both the CS+ trials (see main report) and CS- trials, a Group (Low ability vs. High ability) × Trial (16 trials) repeated measures ANOVA was computed for CS+ and CS- trials separately. For violations of sphericity, Greenhouse-Geisser corrections are reported.

For CS+ trials, expectancy ratings decreased over time, $F(7.07, 2672.44) = 149.233$, $p < .0001$, partial $\eta^2 = .28$, however individuals with high WM ability were quicker to expect the absence of the US than individuals in the low WM group, Group X Trial interaction, $F(7.07, 2672.44) = 2.09$, $p = .041$, partial $\eta^2 = .006$ (Supplementary Figure 5a).

Lower expectancy ratings were most pronounced in the second (i.e., averaging trials 5-8; p = .029) and third block of trials (i.e. averaging trials 9-12; p = .013).

For CS- trials, the Group X Trial interaction was not significant, p = .31. However, there was a main effect for group, $F(1, 389) = 8.02$, p = .005, partial η^2 = .02. Individuals with high WM ability reported lower US expectancy (*Mean* = -.72, *SE* = .032) compared to individuals with low WM ability (*Mean* = -.60, *SE* = .032), see Supplementary Figure 5b.

To examine the influence of WM ability *on CS+ versus CS- US discrimination during extinctio* , we computed a Group × CS type × Trial ANOVA. Individuals with high WM ability expected the US less than individual with low WM ability (Group main effect: $F(1,391)=9.061$, p=.003). There was also a significant Group × Trial interaction (p=.036), but no other interactions (ps>.37), where individuals with high WM ability had lower US expectancy ratings during the middle portions of extinction learning.

Effect of WM ability on extinction learning at 2-back and 3-back trials

We examined whether the effect of WM ability on extinction learning was influenced by performance at 2-back and 3-back separately. To test this, we ran two separate GLMs on the full sample (n=788 for extinction) using individual differences on 2-back and 3-back trials as the continuous between subject variable and the extinction learning scores for the 3 blocks (see Method in main report for details) as the within-subject variables. For the 2-back trials, the main effect of WM ability and the WM ability × block interaction was not significant, ps > .11. For the 3-back trials, the main effect of WM ability was not significant (p =.23), but the WM ability × block interaction was significant (p < .05). WM ability continued to predict extinction learning at the late block (p=.001). However, the interaction

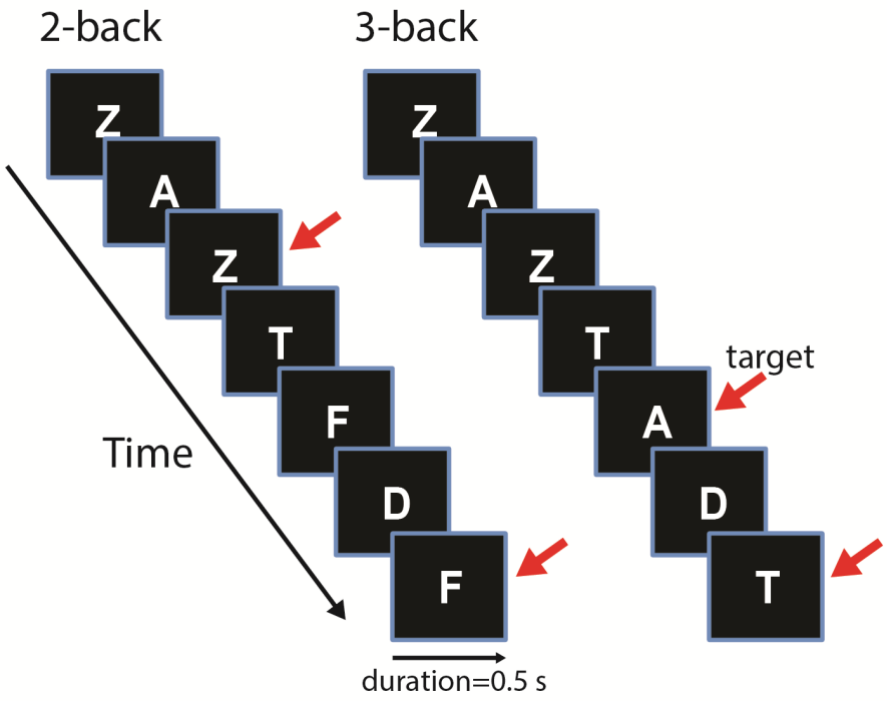
effect between 2-back and 3-back was not significantly different (p=.82). These results suggest that individual differences in WM ability at higher cognitive loads are potentially driving the relationship to extinction learning, but performance at the 2-back trials are also important. Future work will need to test the contribution of 0-back and 1-back trials to extinction learning performance, conditions not used in the current investigation.

Working memory analyses including non-responders in full continuous sample

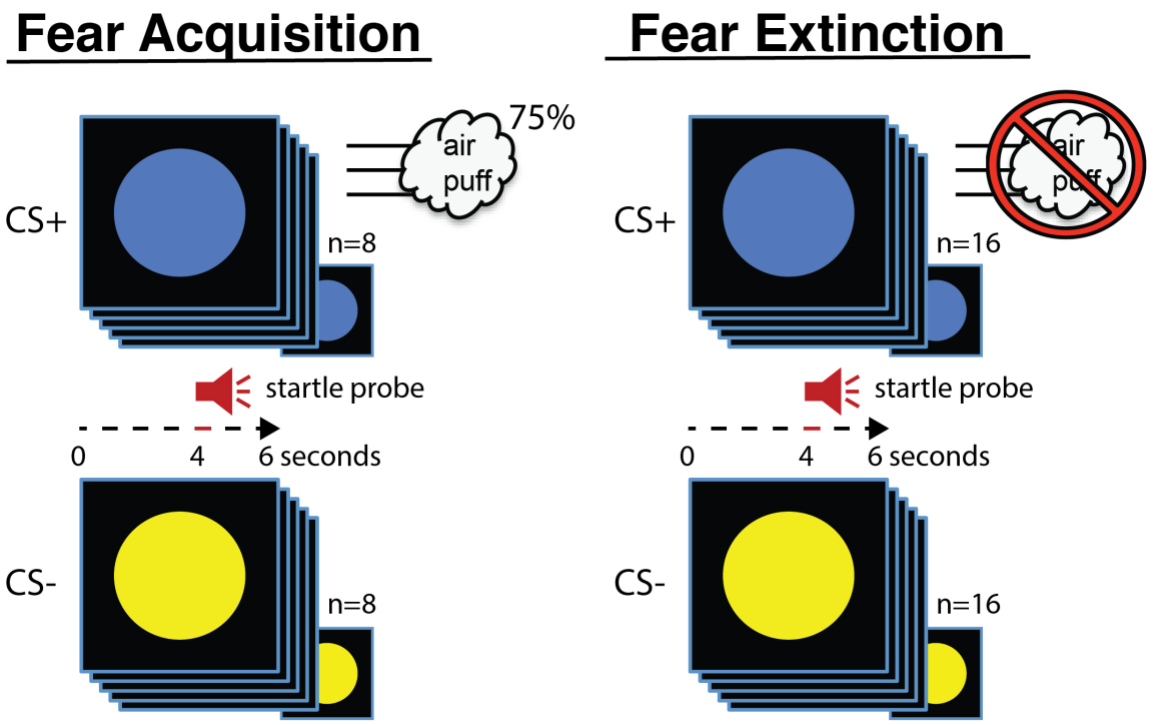
We examined whether WM ability still influenced extinction learning when including the non-responders in the full continuous sample (n=905). We observed a trend for main effect of block (p=.06), no WM ability x block interaction, p=.35. But a significant main effect of WM ability, p=.007. A follow up regression analysis confirmed that WM significantly predicted extinction success at early (p=.06), mid (p=.006), and late (p=.002), although when each block was entered simultaneously in the model, partial correlations were not significant, suggesting WM ability didn't affect any single extinction learning block exclusively.

Responders and non-responders did not differ on CS+ US expectancy ratings. The main effect of group (responder vs. non-responder) and the group x block interaction were not significant, Fs < 0.90, ps>.34. When including the non-responders in our primary analyses, the results for CS+ US expectancy ratings with the full sample were similar to that reported in the main report. With increasing levels of WM ability, US expectancy decreased (main effect of group: F=5.55, p=.019). There was also a significant group × block interaction, F=6.99, p=.008. Post-hoc analyses show that WM ability predicted US expectancy at middle (p=.013) and late (p=.003) blocks.

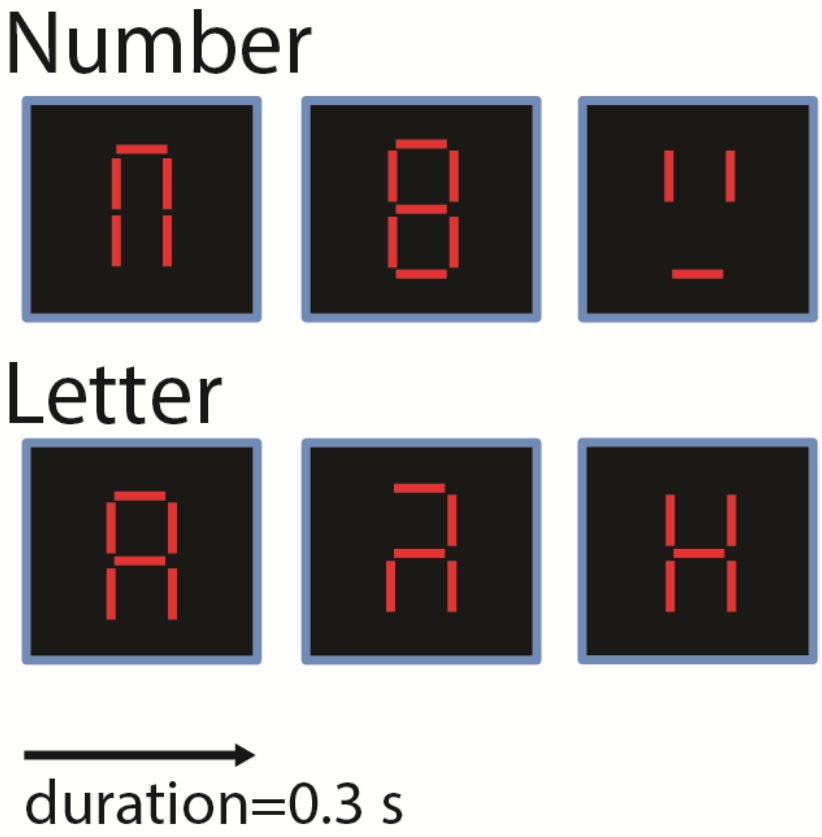
Supplemental Figure 1. The Penn WebCNB N-Back Task. As detailed in the main report Methods section, the N-back task consisted of 2-back and 3-back trials. In each block of trials, a single letter was presented at the center of the screen for 0.5 seconds. Letters were considered targets if the letter matched 2 letters back, or 3 letters back (see red arrows for illustrative purposes).



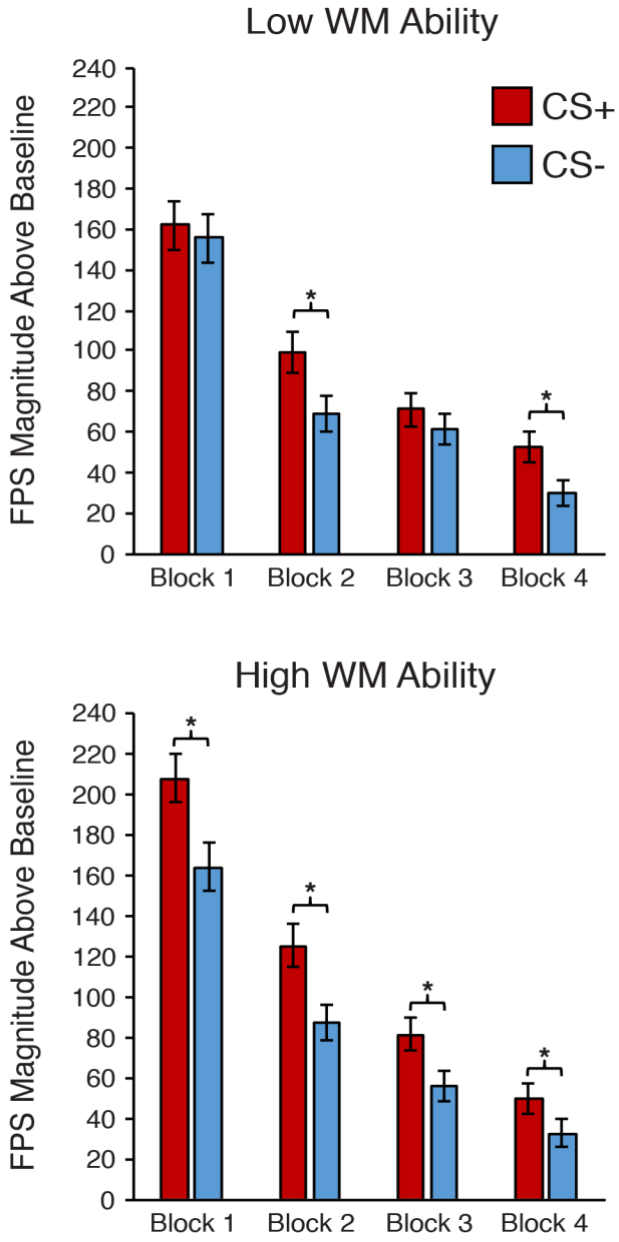
Supplemental Figure 2. Conditioned fear potentiated startle paradigm. The task consisted of an acquisition phase (left) and an extinction phase (right). During acquisition, subjects viewed one of two colored circles. One of the colored circles was paired (CS+) with an aversive air-puff (US; 75% reinforcement), while the other colored circle was never paired with the US (CS-; colors counter-balanced across subjects). The extinction phase was completed 10 minutes later, and was identical to acquisition except no US was delivered with the CS+. A startle-probe was administered 4 seconds into each CS presentation during both the acquisition and extinction phases. See Methods in the main report for more details.



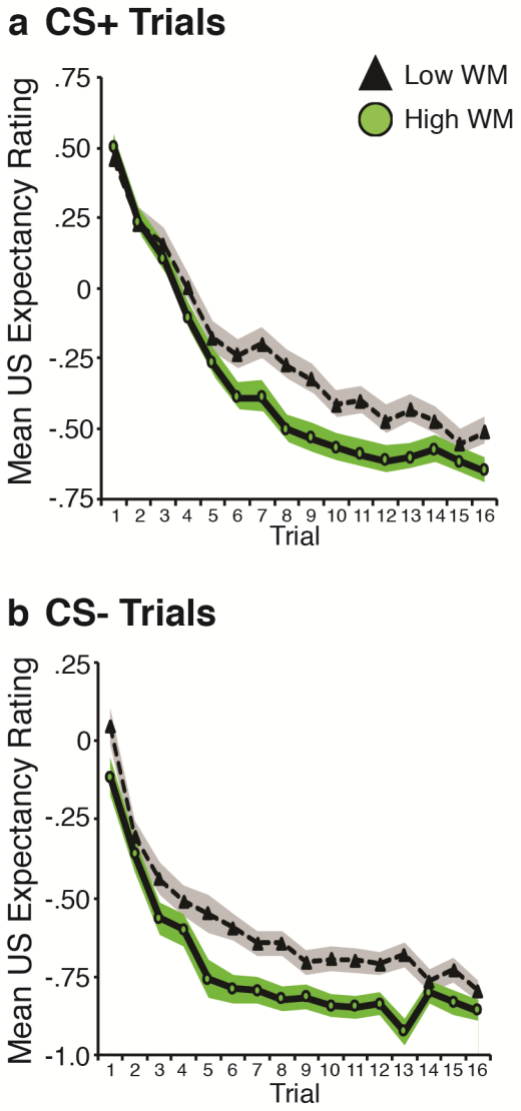
Supplemental Figure 3. Rows depict the two trials types from the Penn WebCNB CPT Task. As described in the main report Methods section, the CPT task consisted a series of red-lines appearing on the screen. A keyboard response was required when the red-lines formed a number (middle panel top-row), or a letter (first and last panel bottom-row). Number and letter trials were separated into separate blocks.



Supplemental Figure 4. WM Ability association with change in CS+ versus CS- discrimination during extinction training. Results for the WM Ability x CS type x Block interaction. Top panel shows the comparison between CS+ and CS- responses after baseline subtraction for each block for individuals with low WM ability. Bottom panel shows the comparison between CS+ and CS- responses after baseline subtraction for each block for individuals with high WM ability. Error bars reflect S.E.M. *p<.05 for pairwise comparison.



Supplemental Figure 5. WM ability and extinction trial-by-trial US expectancy ratings. (a) Mean US expectancy ratings during CS+ trials. Individuals with high WM ability (green circles) are quicker to expect the absence of the US compared to individuals with low WM ability (black triangles). (b) Mean US expectancy ratings during CS- trials. Individuals with high WM ability overall report the absence of the US compared to individuals with low WM ability (main effect of group). Expectancy responses were re-coded as: expect air puff = 1, unsure = 0, do not expect air puff = -1. Error ribbons reflect S.E.M.



Supplementary References

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