How does stress affect working memory consolidation?

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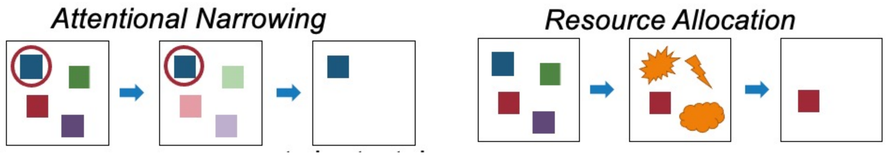
Stress has mixed effects on working memory performance.

Previous research suggests that stress may improve[1], impair[2], or have no effect[3] on working memory performance, and the impacts on specific processes like working memory consolidation have not been investigated.

Two theories to explain stress effects

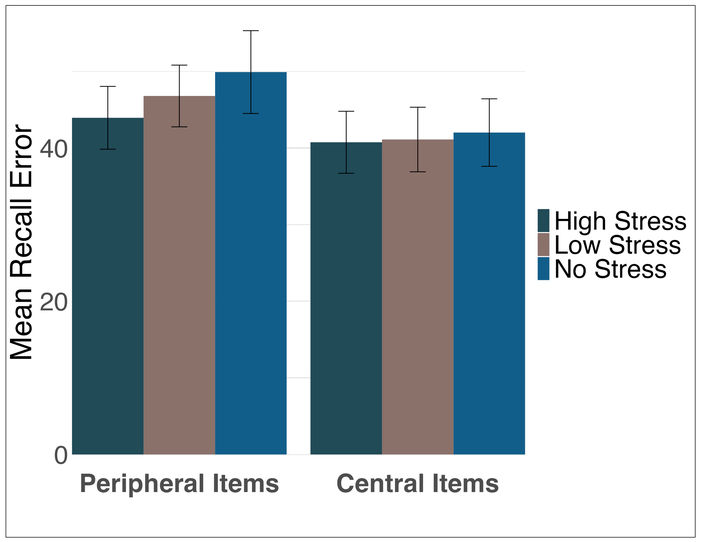


	Attentional Narrowing	Resource Allocation
Stress Effect on Quality		
Stress Effect on Speed		

Recall error may be weakly affected by item type, but not stress or consolidation time.

Stress & Item Type and Recall Error

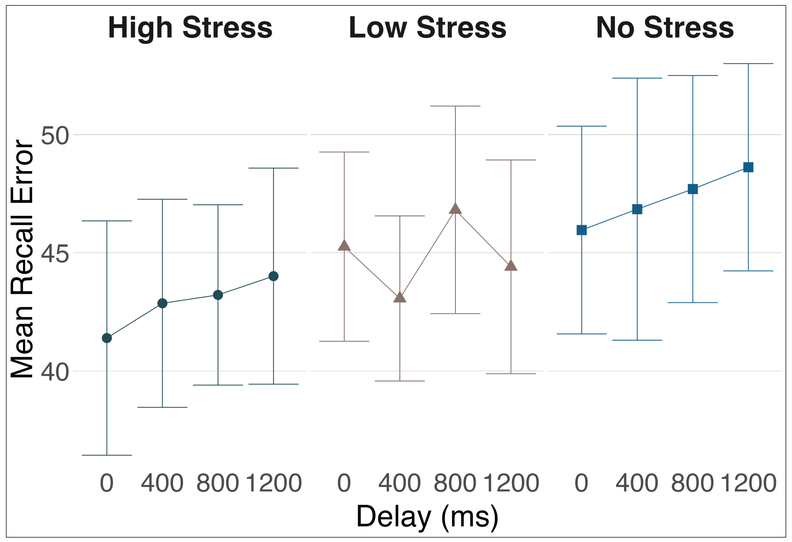
- No main effects of stress (BF_{10} = .09) or item type (BF_{10} = .55)
- No interaction effect (BF_{10} = .01)



Error bars represent standard error.

Stress & Delay and Recall Error

- No main effects of stress (BF_{10} = .09) or delay (BF_{10} = .02)
- No interaction effect (BF_{10} = 1.6 x 10^{-5})

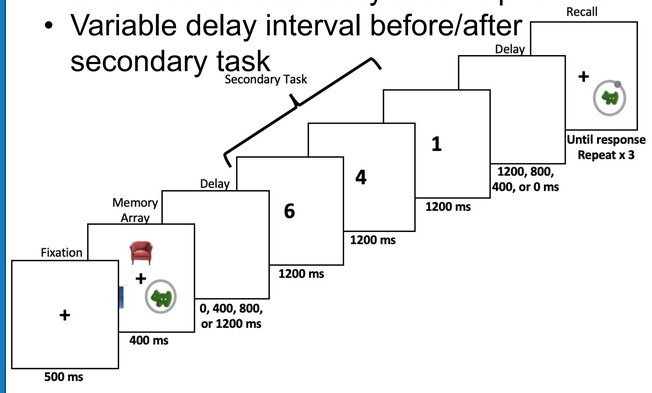


Error bars represent standard error.

Methods

Procedure

- High Stress (n = XX) /Low Stress (n = XX) /No Stress (n = XX) Task
- Working Memory Color Recall task
  - One item in visual array cued to prioritize
  - Variable delay interval before/after secondary task



References

1. Lai et al., 2014
2. (Schoofs et al., 2008)
3. Pulopulos et al., 2015)

Secondary task response times decrease with increased consolidation time and stress may speed up working memory consolidation.

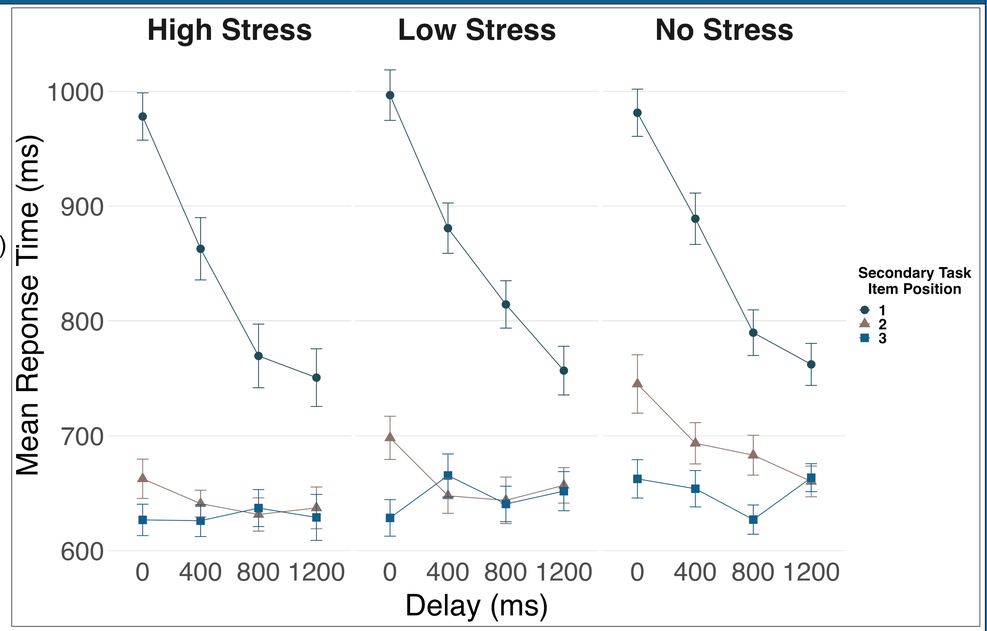
Stress & Delay and Secondary Task Response Time

- Main effect of stress (BF_{10} = 3.9)
- Strong main effect of delay (BF_{10} = 3029)
- No interaction effect (BF_{10} = .01)

Stress and Secondary Task Response Failure

- High Stress: 6.6%
- Low Stress: 8.3%
- No Stress: 7.8%

BF_{10} = .14



Error bars represent standard error.

Stress has different impact on the efficacy and speed of working memory consolidation.

Working memory recall error is not more affected by attentional narrowing under stressful conditions.

- Working memory recall error: central < peripheral items
- Effect not stronger after stress

Increased time for working memory consolidation did not lead to differences in working memory accuracy.

- No effect of delay length on recall error
- No differences across stress conditions

Stress may lead to faster working memory consolidation.

- More consolidation time = faster response time for first item
- Stress groups show faster response time at shortest delay compared to no stress group

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How and when does stress affect working memory?

Previous research suggests that stress may improve[1], impair[2], or have no effect[3] on working memory performance.

Stress may impact working memory at different timepoints: encoding, consolidation, maintenance, or retrieval.

Does stress specifically impact working memory consolidation? If so, does it affect the quality or speed of consolidation?

Two theories to explain stress effects

Attentional Narrowing

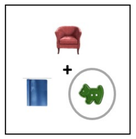
Resource Allocation

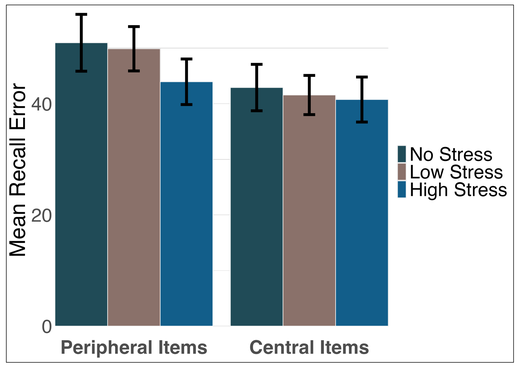
	Attentional Narrowing	Resource Allocation
Effect on Quality	↑ for central items, ↓ for peripheral items	↓ for all items
Effect on Speed	↑ speed (faster response time to secondary task)	↓ speed (slower response time to secondary task)

Effect on quality: no evidence of stress effect, yet

Stress & Item and Recall Error

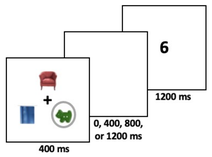
- No main effect of stress (BF_{10} = .10)
- Ambiguous main effect of item type (BF_{10} = 1.0)
- No interaction effect (BF_{10} = .01)

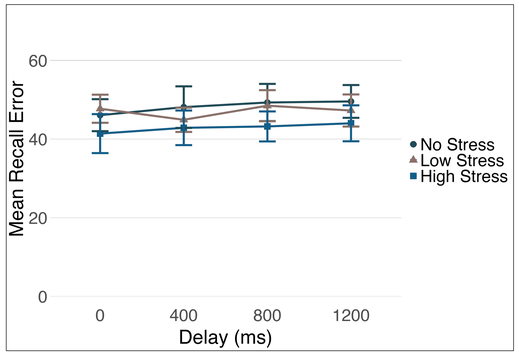




Stress & Delay and Recall Error

- No main effect of stress (BF_{10} = .16)
- No main effect of delay (BF_{10} = .02)
- No interaction effect (BF_{10} = 2.3 x 10^{-5})





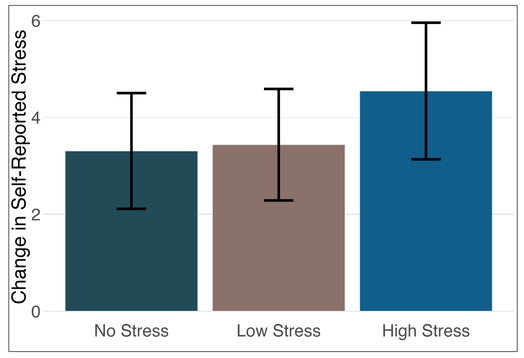
Error bars represent standard error.

Stress induction effectiveness

Subjective stress response measure

- 6-item State-Trait Anxiety Inventory
- Possible range 6 – 24

	Timepoint 1	Timepoint 2
No Stress	9.15 (SD = 2.8)	12.5 (SD = 2.8)
Low Stress	10.9 (SD = 3.0)	14.3 (SD = 5.2)
High Stress	11.7 (SD = 1.7)	16.3 (SD = 4.9)



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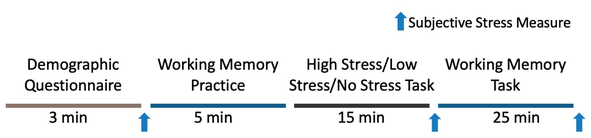
Methods

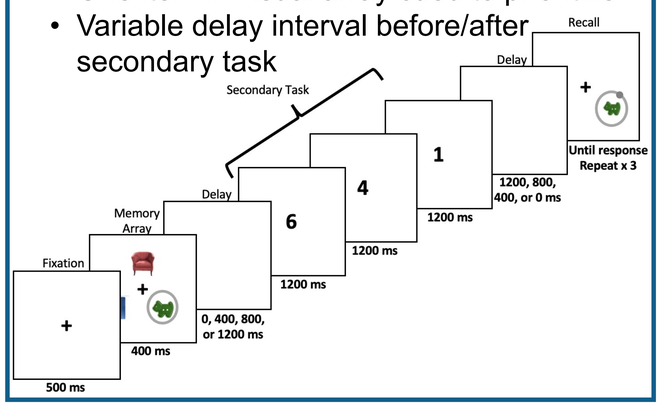
3 Stress Conditions:

High (n = 14) Low (n = 16) No (n = 14)



Working Memory Color Recall task

- One item in visual array cued to prioritize
- Variable delay interval before/after secondary task



Effect on speed: stress increases consolidation speed

Stress & Delay and Secondary Task Response Time

Item 1

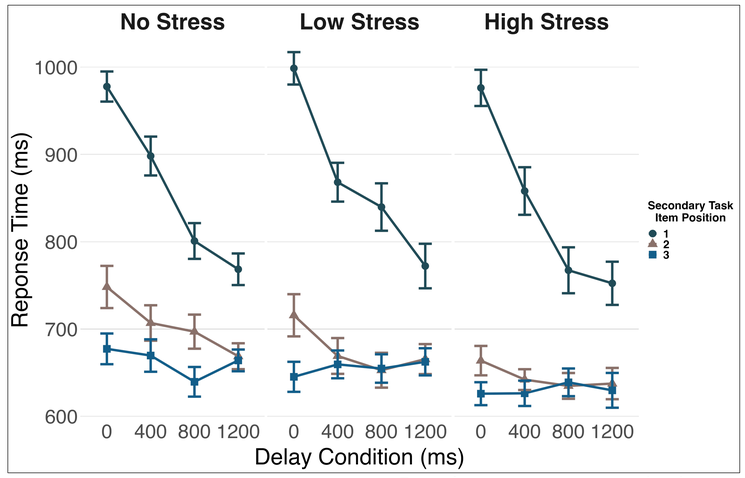
- **Main effect of delay (BF_{10} = 5.29 x 10^{20})**
- No main effect of stress (BF_{10} = .20)
- No interaction effect (BF_{10} = .01)

Item 2

- **Main effect of delay (BF_{10} = 5.8)**
- **Main effect of group (BF_{10} = 153)**
- No interaction effect (BF_{10} = .02)

Item 3

- No main effect of stress (BF_{10} = .01)
- Ambiguous main effect of stress (BF_{10} = 1.4)
- No interaction effect (BF_{10} = .0004)



Error bars represent standard error.

Secondary Task Failure to Respond Rate

Item 1

- High Stress: 5.1%
- Low Stress: 8.6%
- No Stress: 6.7%

Item 2

- High Stress: 1.2%
- Low Stress: 2.0%
- No Stress: 1.4%

Item 3

- High Stress: 0.8%
- Low Stress: 1.4%
- No Stress: 0.5%

Stress primarily affects consolidation speed, not quality

Preliminary results found no evidence that working memory recall error is affected by acute stress.

- Recall is slightly improved for central items compared to peripheral items
- Effect not stronger after stress
- No difference in recall error related to amount of consolidation time

Stress may lead to faster working memory consolidation.

- More consolidation time = faster response time, particularly for first item
- Response times for second item suggest that consolidation is faster in high stress group compared to no stress group

Neither theory fully accounts for present results.

- Increased speed supports Attentional Narrowing, but there was no predicted effect on quality

1. Lai et al., 2014 2. (Schoofs et al., 2008) 3. Pulopulos et al., 2015)

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Previous research suggests that stress may improve[1,2], impair[3], or have no effect[4,5] on working memory performance.

Stress may impact working memory at different timepoints[6]: encoding, consolidation, maintenance, or retrieval.

Does stress specifically impact working memory consolidation? If so, does it affect the quality or speed of consolidation?

Two theories to explain stress effects

Attentional Narrowing

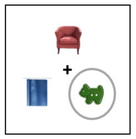
Resource Allocation

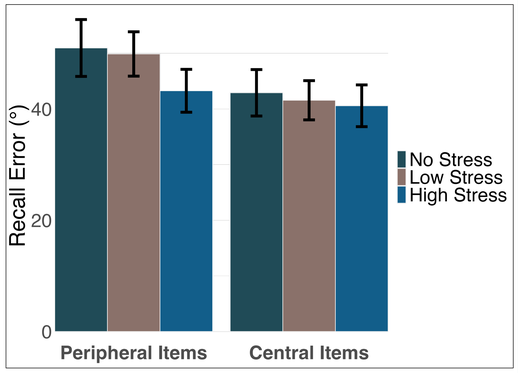
	Attentional Narrowing	Resource Allocation
Effect on Quality	↑ for central items, ↓ for peripheral items	↓ for all items
Effect on Speed	↑ speed (faster response time to secondary task)	↓ speed (slower response time to secondary task)

Effect on quality: no evidence of stress effect, yet

Stress & Item and Recall Error

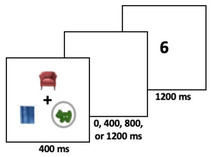
- No main effect of stress (BF_{10} = .11)
- Ambiguous main effect of item type (BF_{10} = .95)
- No interaction effect (BF_{10} = .01)

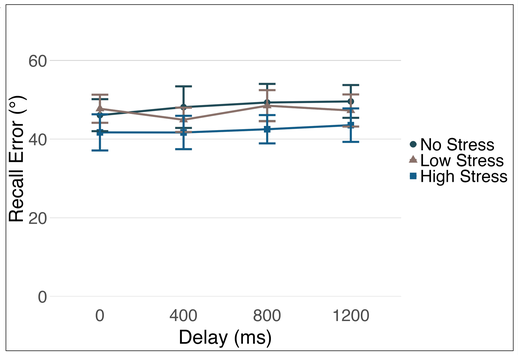




Stress & Delay and Recall Error

- No main effect of stress (BF_{10} = .26)
- No main effect of delay (BF_{10} = .02)
- No interaction effect (BF_{10} = 3.3 x 10^{-5})





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Subjective Stress Response

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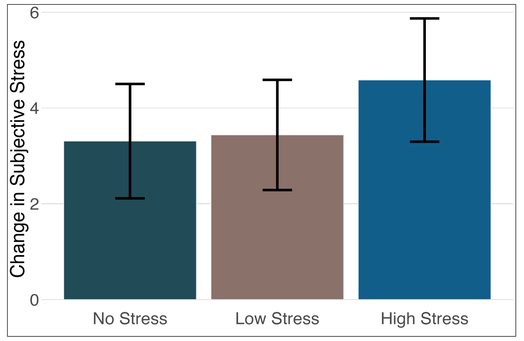

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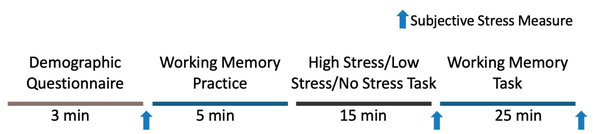
Methods

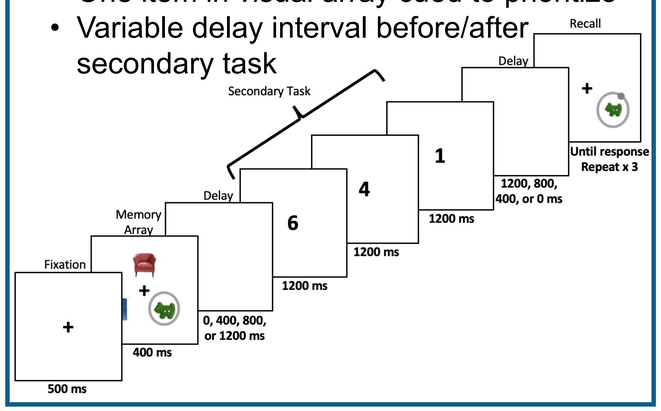
3 Stress Conditions:

No (n = 14) Low (n = 16) High (n = 14)



Working Memory Color Recall task

- One item in visual array cued to prioritize
- Variable delay interval before/after secondary task



1. Lai et al. (2014). *International Journal of Industrial Ergonomics* 2. Edwards et al. (2015). *Anxiety, Stress, & Coping*. 3. Shields et al. (2016). *Neuroscience & Biobehavioral Reviews*. 4. Pulopulos et al. (2015). *Stress*. 5. Sorg, B. & Whitney P. (1992) *Journal of Research in Personality*. 6. Stauble et al. (2013). *Stress*.

Effect on speed: stress increases consolidation speed

Stress & Delay and Secondary Task Response Time

Item 1

- **Main effect of delay (BF_{10} = 3.7 x 10^{20})**
- Ambiguous main effect of stress (BF_{10} = .74)
- No interaction effect (BF_{10} = .02)

Item 2

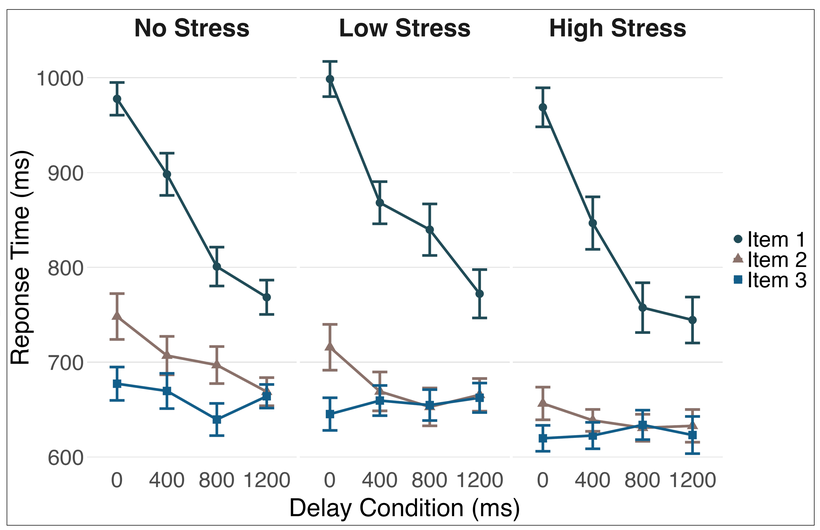
- **Main effect of delay (BF_{10} = 4.7)**
- **Main effect of stress (BF_{10} = 929)**
- No interaction effect (BF_{10} = .02)

Item 3

- No main effect of delay (BF_{10} = .01)
- **Main effect of stress** (BF_{10} = 7.3)
- No interaction effect (BF_{10} = .0004)

1st Item Response Failure

- High Stress: 5.1%
- Low Stress: 8.6%
- No Stress: 6.7%



Error bars represent standard error.

Contact: kcotton@gradcenter.cuny.edu

Stress primarily affects consolidation speed, not quality

Preliminary results found no evidence that stress affected recall error.

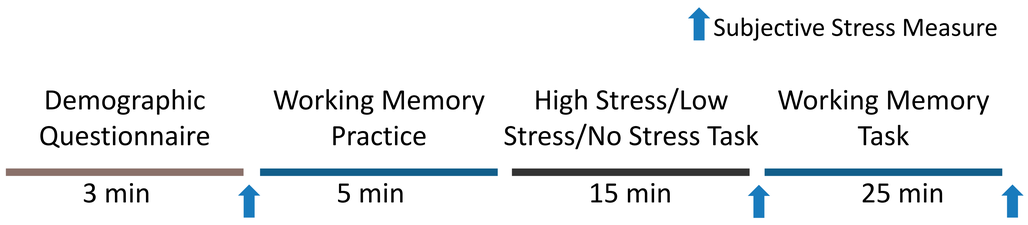
- Slightly better recall for central compared to peripheral items, but no stress effect
- No difference related to amount of consolidation time

Stress may lead to faster working memory consolidation.

- More consolidation time = faster response time, particularly for first item
- Response times for second item suggest that consolidation is faster in high stress group compared to no stress group

Neither theory fully accounts for results.

- Increased consolidation speed supports Attentional Narrowing, but no evidence of the predicted effect on quality


Subjective Stress Measure
Demographic Questionnaire
Working Memory Practice
High Stress/Low Stress/No Stress Task
Working Memory Task
3 min
5 min
15 min
25 min

- 3 item visual array of colored objects (400 ms)
  ↳ 1 item cued to prioritize
- Parity Judgment task (3 items, 3600 ms total)
- 4 delays (time before/after secondary task):
  ↳ 0/1200, 400/800, 800/400, 1200/0 ms
- Continuous recall for each item

- Stress groups ↓ working memory error, even at shortest delays
- Central item ↓ working memory error, peripheral items ↑ working memory error
  - Stronger effect in stress groups
- Stress groups ↓ secondary task response time
- Stress groups ↑ working memory error, even at longest delays
- No difference between central item and peripheral items across stress groups
- Stress groups ↑ secondary task response time, even at longest delays

- **Stress and Secondary Task Response Failure**
- High Stress: 6.6%
- Low Stress: 8.3%
- No Stress: 7.8%
- BF_{10} = .14