Pre-learning Contextual States and Trait Anxiety Impact Learning from Error

Yume Choi
Adcock Lab (Dr. Alison Adcock)

Pre-Learning Contextual States and Trait Anxiety Impact Learning from Error

Yume Choi, Rachael Wright, Alyssa Sinclair, R. Alison Adcock
Center for Cognitive Neuroscience, Duke University

Research Questions

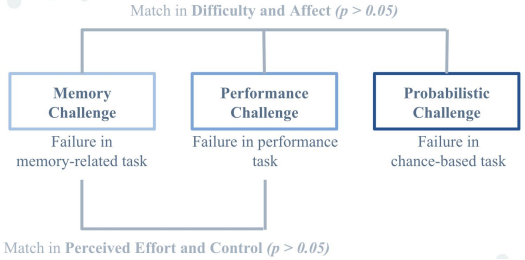
Pre-learning experiences can influence learning outcomes.[1]

1. **What specific pre-learning contextual states impact the subsequent prediction error-driven declarative learning?**

High trait anxiety can impair prediction error and learning.[2]

2. **Are there individual differences in trait anxiety that impact how people react to the pre-learning experiences?**

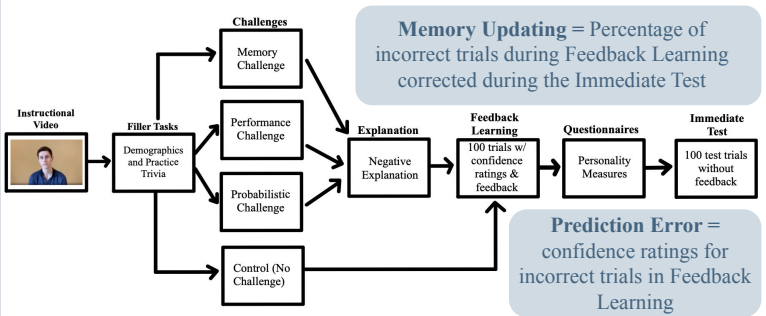
Pilot Studies



Hypotheses

1. The Memory Challenge group would demonstrate the **lowest** memory updating driven by prediction error, and the Control and Probabilistic Challenge group will demonstrate the **highest** amount.
2. Higher trait anxiety would shower **lower** levels of memory updating regardless of the condition presented.

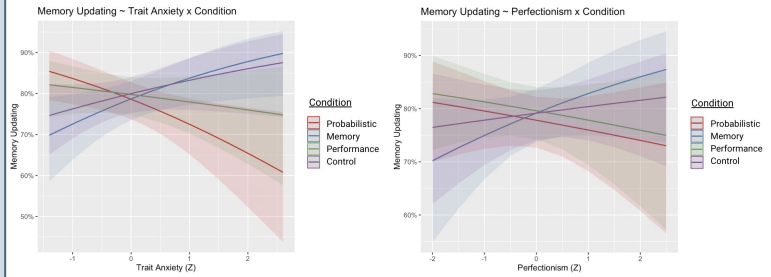
Main Study Design



Memory Updating = Percentage of incorrect trials during Feedback Learning corrected during the Immediate Test

Prediction Error = confidence ratings for incorrect trials in Feedback Learning

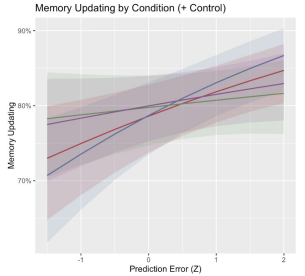
Results I



Significant interactions:
Probabilistic and Control: *(β = -0.55, z-ratio = -2.69, p = 0.04)*
Probabilistic and Memory: *(β = -0.66, z-ratio = -3.34, p = 0.0047)*

No main effect or interactions for perfectionism levels on memory updating

Results II



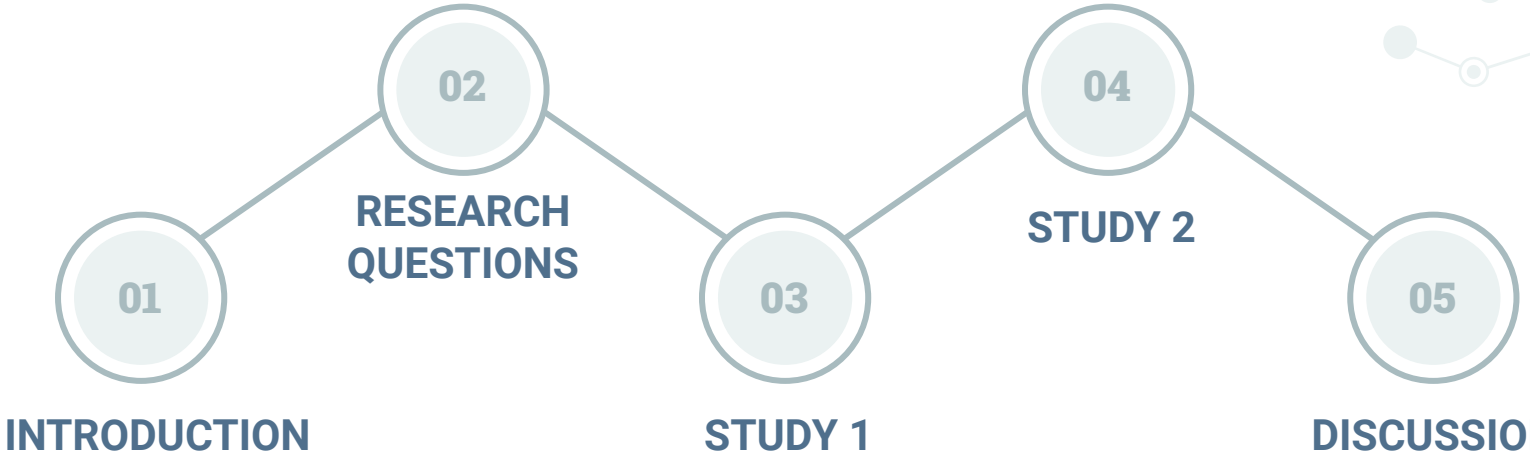
Hypercorrection Effect: Main effect of prediction error on memory updating *(β = 0.17, z = 5.09, p < 0.001)*

Conclusions

1. Those with higher trait anxiety primed with the Probabilistic Challenge felt a **lowered locus of control and adverse effects of their effort**, leading to impaired memory updating.[3]
2. Those with higher trait anxiety primed with the Memory Challenge were able to **leverage motivation in a memory-related task** for enhanced memory updating.
3. The observed effects of trait anxiety cannot be explained by that of perfectionism.
4. Implications on the necessity of research to hone in on specific behaviors of trait anxiety that impair learning.

1. Pine, A., Sadeh, N., Ben-Yakov, A., Dudai, Y. & Mendelsohn A. (2018). Knowledge acquisition is governed by striatal prediction errors. Nature Communications, 9(1), 1673. DOI: 10.1038/s41467-018-03992-5
2. Aylward, J., Valton, V., Ahn, W., Bond, R.L., Dayan, P, Roiser, J.P., & Robinson O.J. (2019). Altered learning under uncertainty in unmedicated mood and anxiety disorders. Nature Human Behavior, 3(10), 116-1123. DOI: 10.1038/s41562-019-0628-0
3. Eysenck, M.W. (1979). Anxiety, learning, and memory: A reconceptualization. Journal of Research in Personality, 13, 363-385. https://doi.org/10.1016/0092-6566(79)90001-1

Table of Contents



01

INTRODUCTION

Introduction To Learning

Declarative Learning: acquiring memory, recalling facts/events.

Non-declarative Learning: motor and cognitive skills (implicit/procedural)

Predictive Coding: Predictions about beliefs to make models of the world

Prediction Error: Learning to minimize errors about beliefs (expectation - reality)

Rao and Ballard, 1999; Pine et al., 2018.

Prediction Error in Declarative Learning

MULTIPLE - REPETITION APPROACH

General information questions repeated, take the difference between trial-specific confidence ratings and feedback

HYPERCORRECTION EFFECT

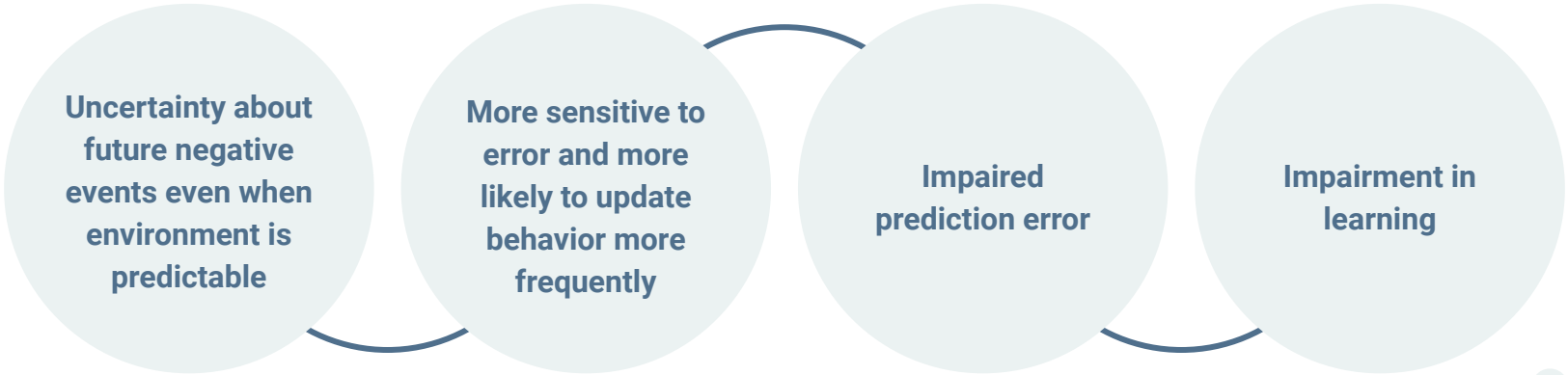
High-confidence errors are more likely to be corrected

PEARSON-HALL THEORY

Learning occurs when the outcome is surprising

Ergo et al., 2020; Pine et al., 2018

Trait Anxiety & **Prediction Error**



Grupe & Nitschke, 2013; Aylward et al., 2019

Initial Study: *Learning from Error*

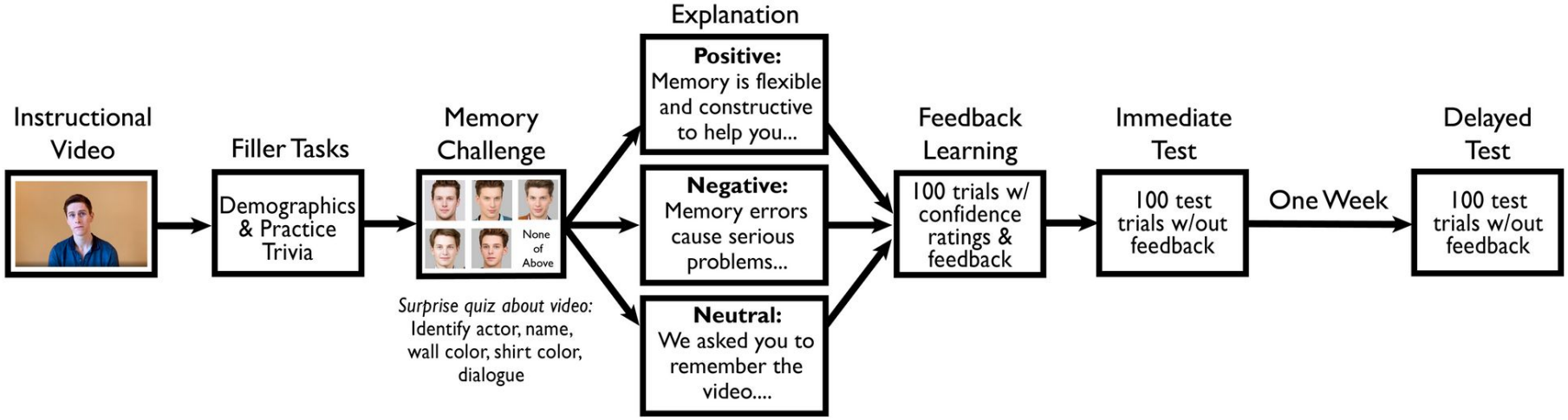
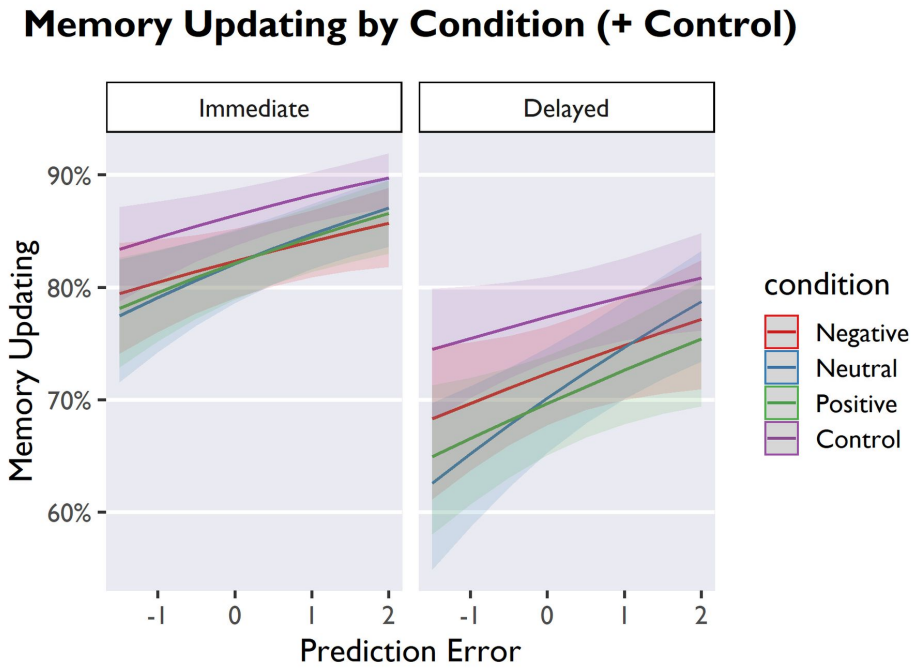


Figure 1. Overview of the paradigm. Participants in the three experimental conditions (*Positive, Negative, Neutral*) complete the memory challenge, explanation, and feedback learning. *Control group* (unpictured) only completes feedback learning.

Results



Follow-Up Questions:

Possible causes of reduced memory updating …

1. Memory Failure
2. Performance-based failure
3. Negative affect-based failure

Research Questions

1) What specific **pre-learning contextual states** impact the subsequent **prediction error**-driven declarative learning?
2) Are there individual differences in **trait anxiety** that impact how people react to the pre-learning experiences?

02

STUDY 1: PILOT

Pilot Studies Overview

Memory Challenge

Failure in memory-related task

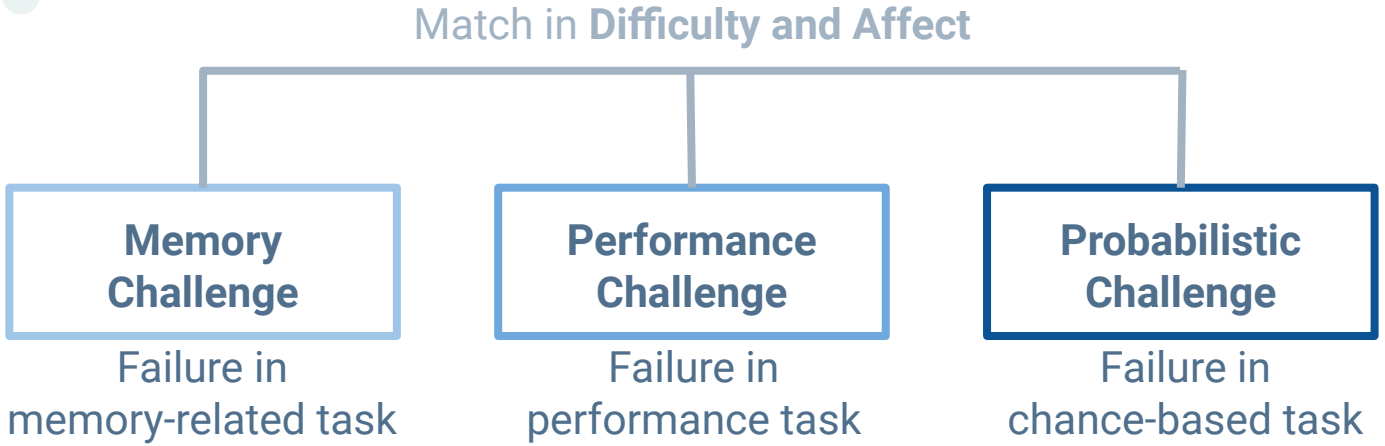
Performance Challenge

Failure in performance task

Probabilistic Challenge

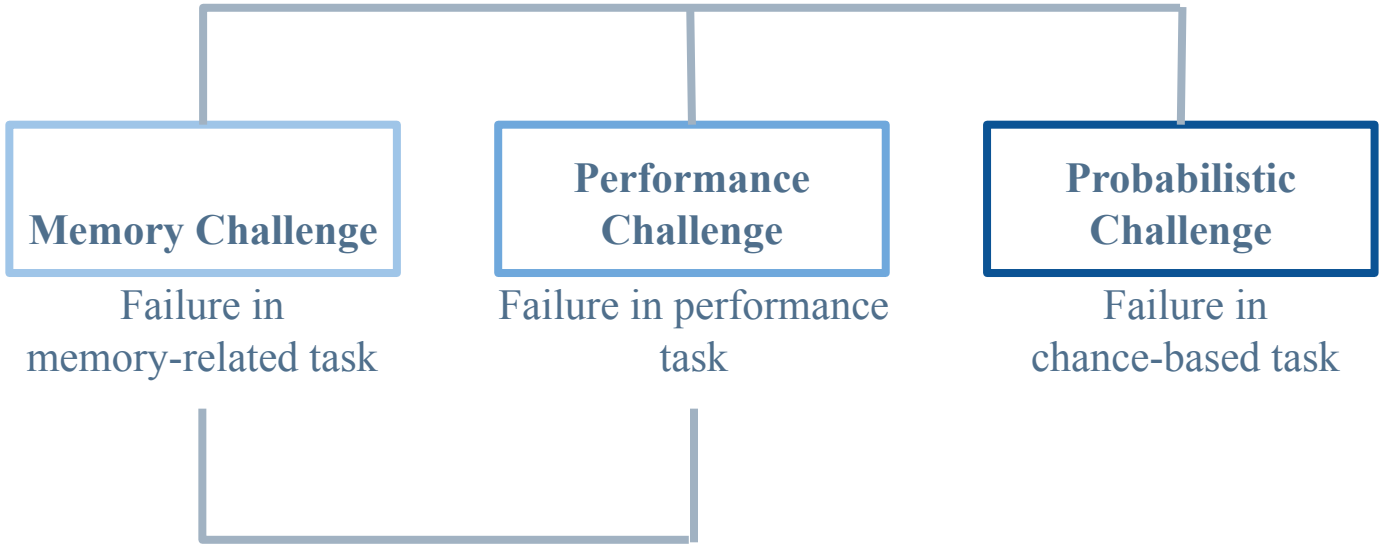
Failure in chance-based task

Pilot Studies Overview



Pilot Studies Overview

Match in **Difficulty and Affect** ***(p > 0.05)***



Match in **Perceived Effort and Control** ***(p > 0.05)***

FEEDBACK QUESTIONS

01

Effortful: How effortful was this task? (0: Not at all → 100: Extremely)

02

Difficulty: In general, how easy or difficult would it be for someone to do well on this task? (0: Easy → 100: Difficult)

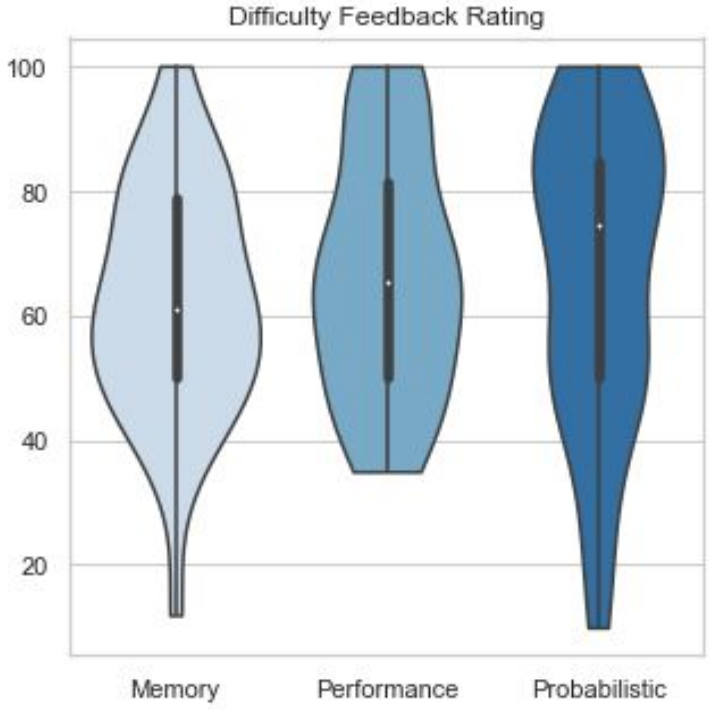
03

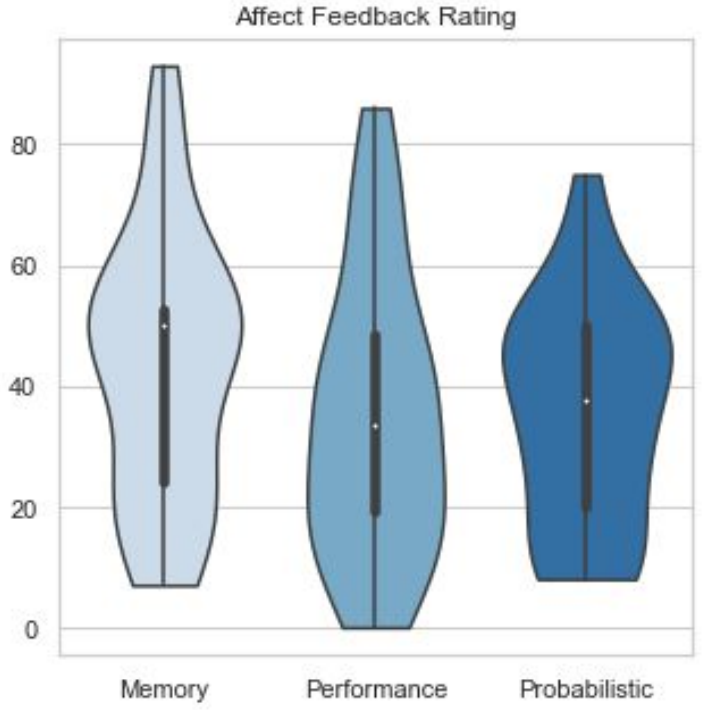
Affect: How do you feel after completing this task? (0: Negative → 100: Positive)

04

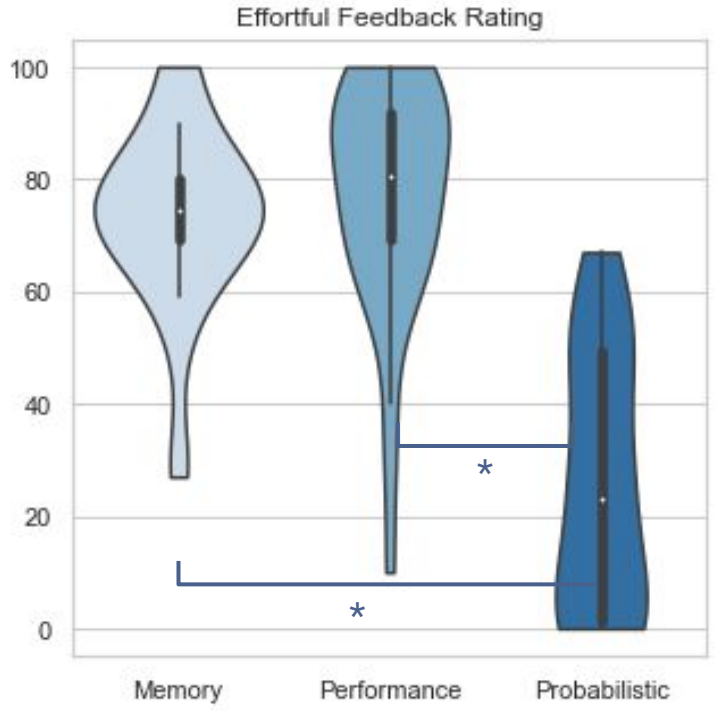
Control: What degree did you feel the results were in your control? (0: Completely out of my control → 100: Completely in my control)

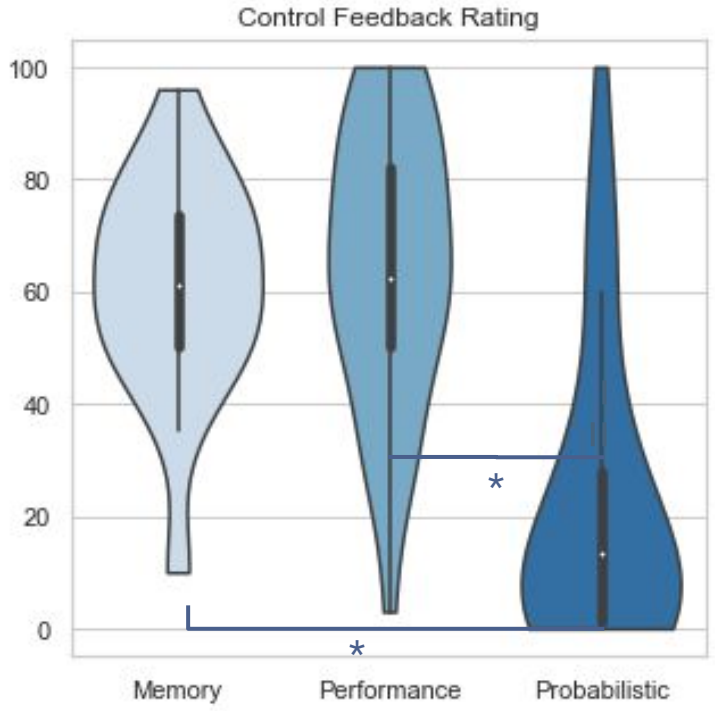
Pilot Study 3 Results





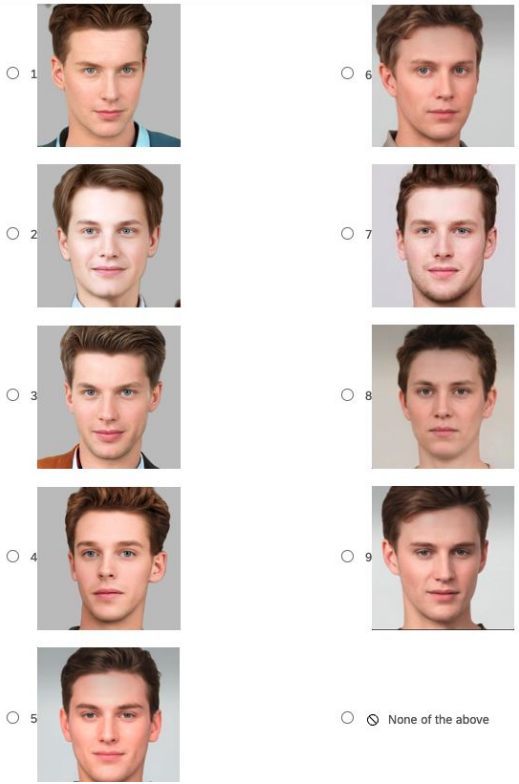
Pilot Study 3 Results





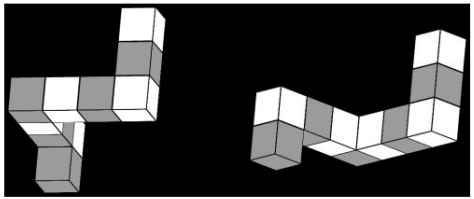
Condition 1: Memory Challenge

1. Look at the headshot **photos** and identify the actor who was shown in the instructional video.
2. What was the actor's **name**?
3. What was the color of the **shirt** that the actor wore?
4. What color was the background **wall**?
5. Which of the following **statements** did the actor say?

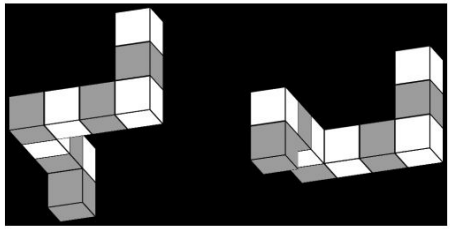


Condition 2: Performance Challenge

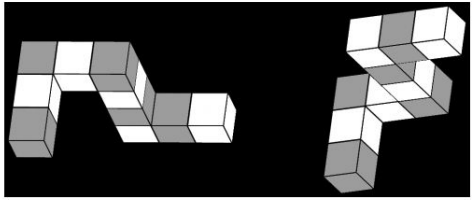
A.



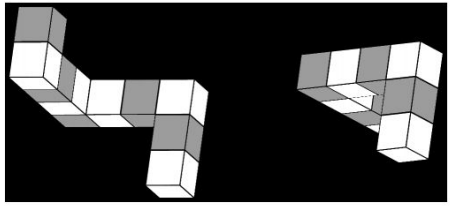
C.



B.



D.



Which of the following pairs is a match?

- A
- B
- C
- D
- None of the Above

Mental Rotation Test: Select which pair is a match (the same rotated version of each other).

Condition 3: Probabilistic Challenge

A marble is about to be selected from the container. What is your prediction for what color it will be?

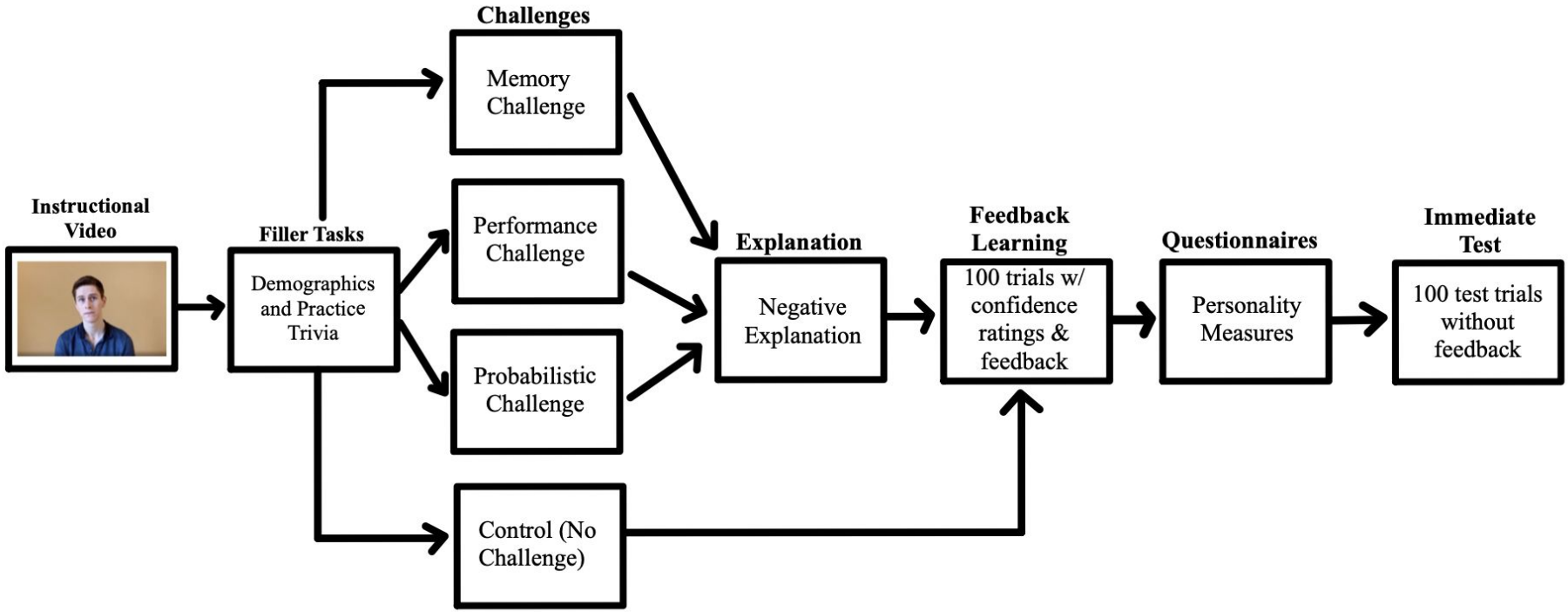
- Blue
- Orange
- Pink
- Green

Marble Prediction Test: Predict what color marble, at random, will be selected from the container. (7 Trials)

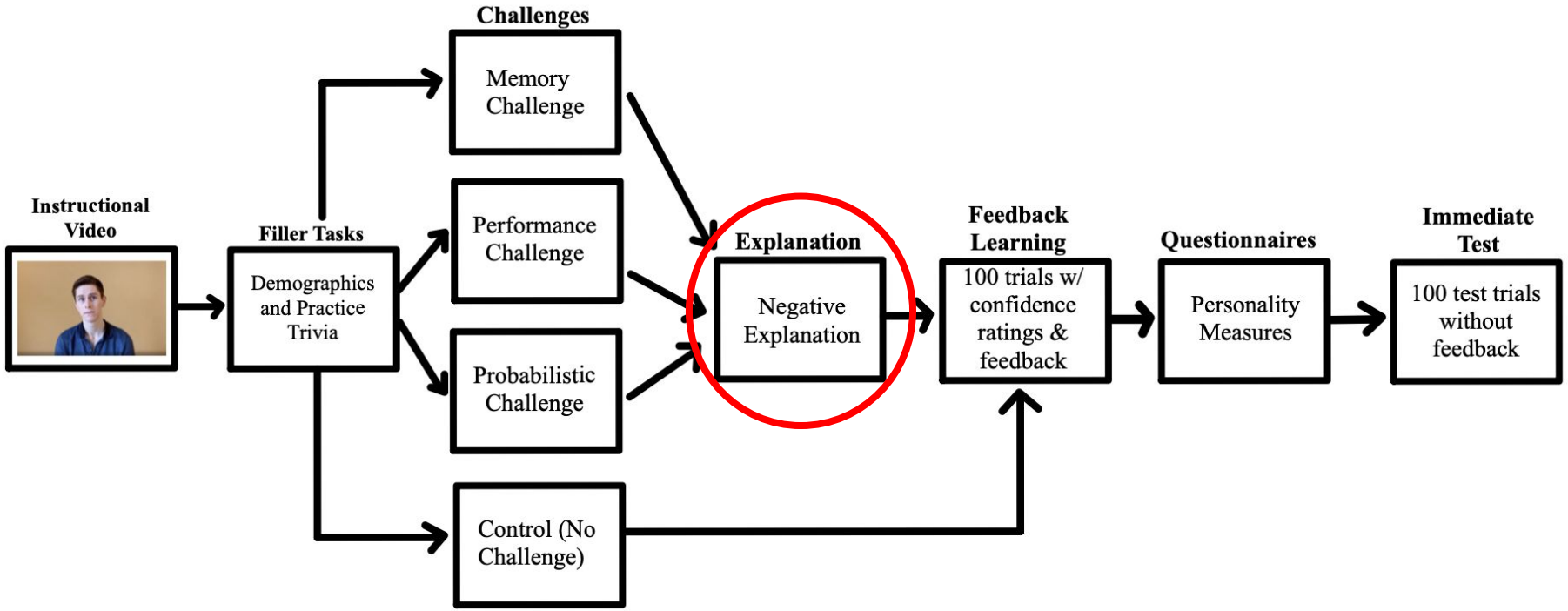
03

STUDY 2: EXPERIMENT

Our Study Design



Study Design



Negative Explanations

Memory Challenge

“Your brain can distort memories or lose important information. You have probably suffered memory failures before.“

“Memory failures can cause serious problems when one is faced with new situations and important decisions.“

Negative Explanations

Memory Challenge

“Your brain can distort memories or lose important information. You have probably suffered memory failures before.“

“Memory failures can cause serious problems when one is faced with new situations and important decisions.“

Performance Challenge

“Spatial reasoning is an important ability involved in math, navigation, and overall cognition. ”

“In some cases, the negative consequences of poor spatial reasoning can be severe, such as misjudging distances when driving and causing an accident.“

Negative Explanations

Memory Challenge

"Your brain can distort memories or lose important information. You have probably suffered memory failures before."

"Memory failures can cause serious problems when one is faced with new situations and important decisions."

Performance Challenge

"Spatial reasoning is an important ability involved in math, navigation, and overall cognition. "

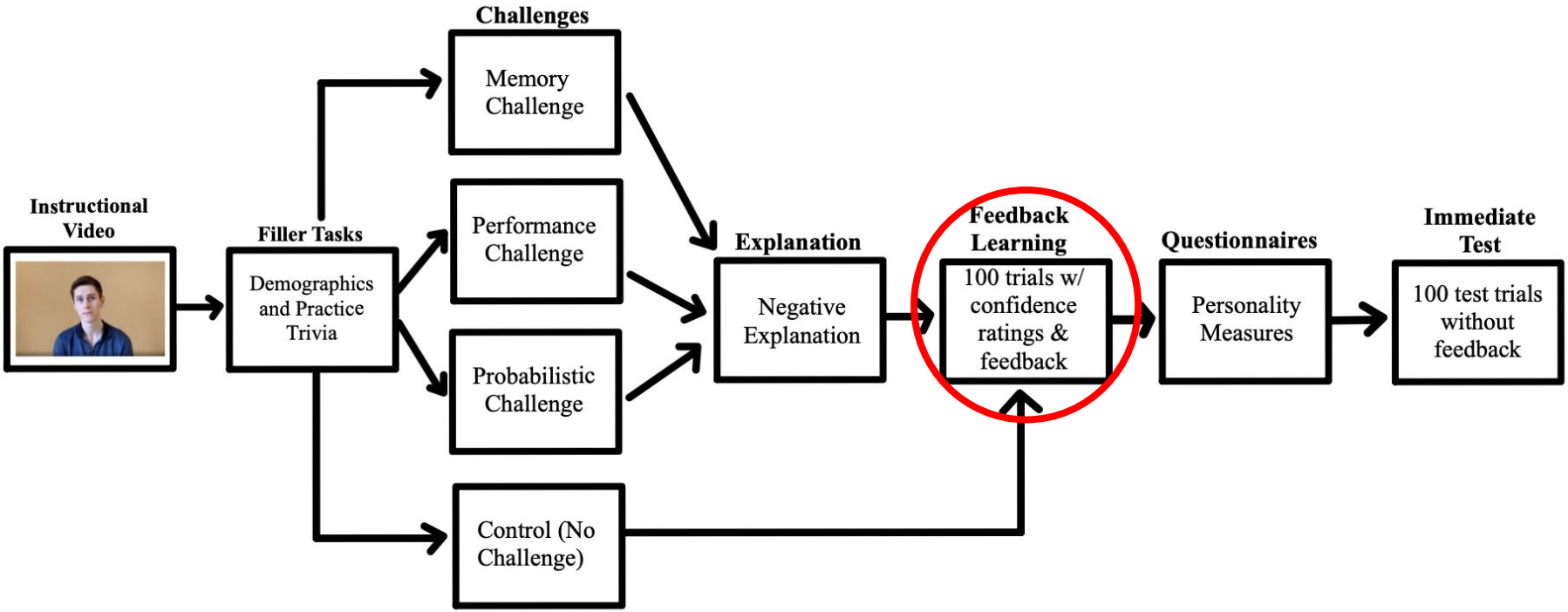
"In some cases, the negative consequences of poor spatial reasoning can be severe, such as misjudging distances when driving and causing an accident."

Probabilistic Challenge

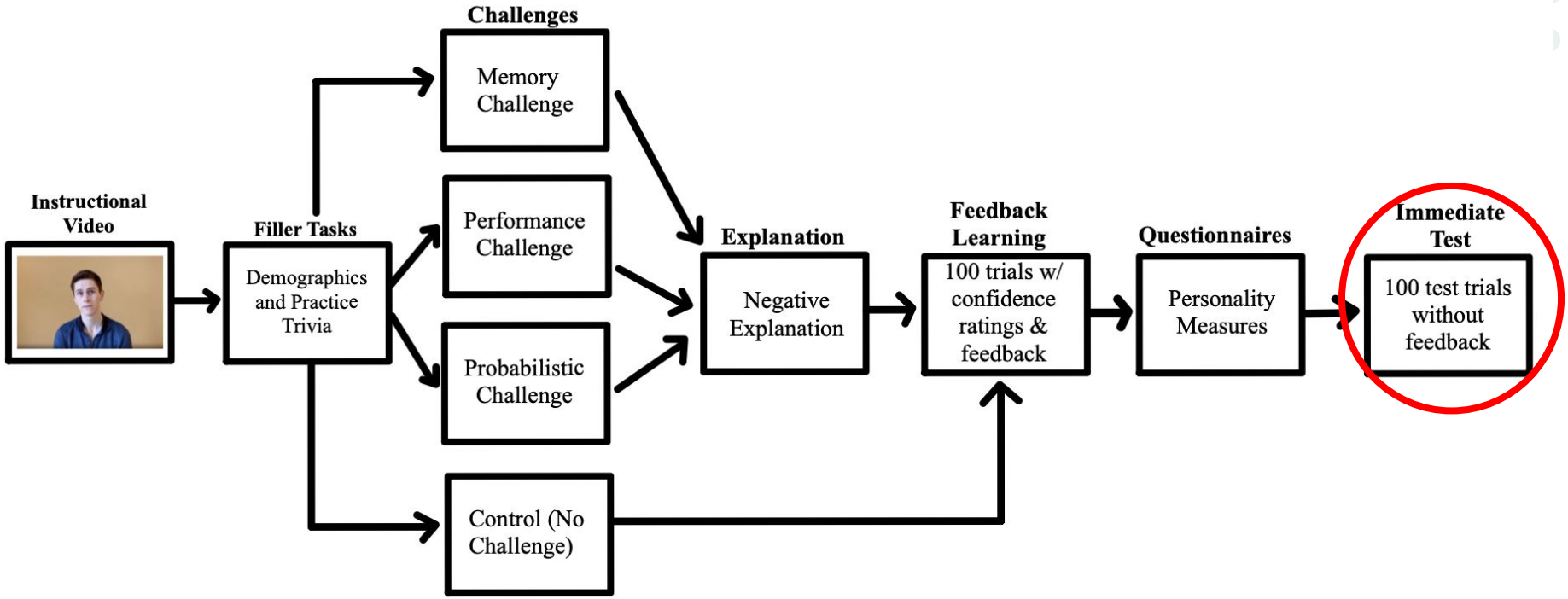
"Your final score on the marble prediction test is 1/7 (14%)."

"Although it's likely that you won't guess them all correctly, you performed worse than chance. Most people perform at around chance levels, and occasionally higher."

Study Design



Study Design



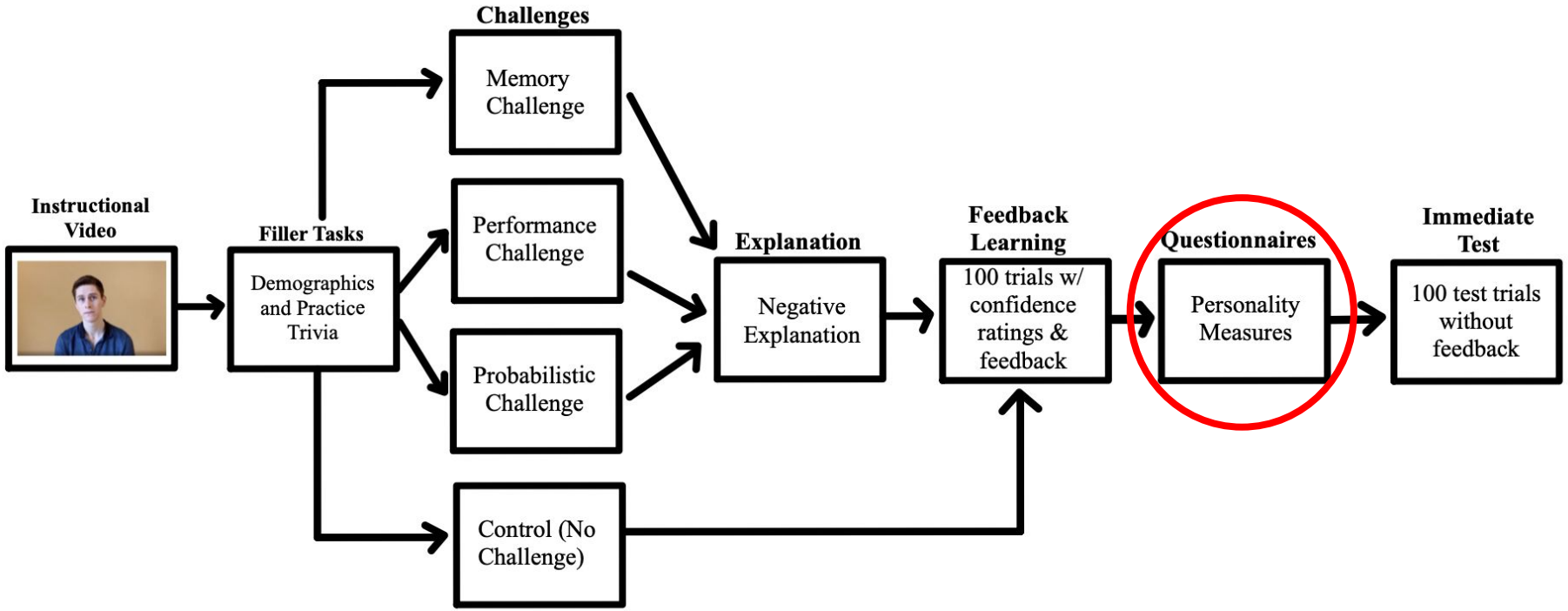
Feedback Learning and Immediate Test

Memory Updating = Percentage of incorrect trials during feedback learning that was corrected during the test

What season is it in Australia when it is summertime in the United States?

The **CORRECT** answer is: **Winter**

Study Design



Personality Measures

STICSA Trait Anxiety

- Rated on scale of 1 = *Not at all* → 4 = *Very much so*
- Cognitive subscale (i.e. *I worry that I cannot control my thoughts as well as I would like to).*
- Somatic subscale (i.e. *My heart beats fast).*

Frost Perfectionism

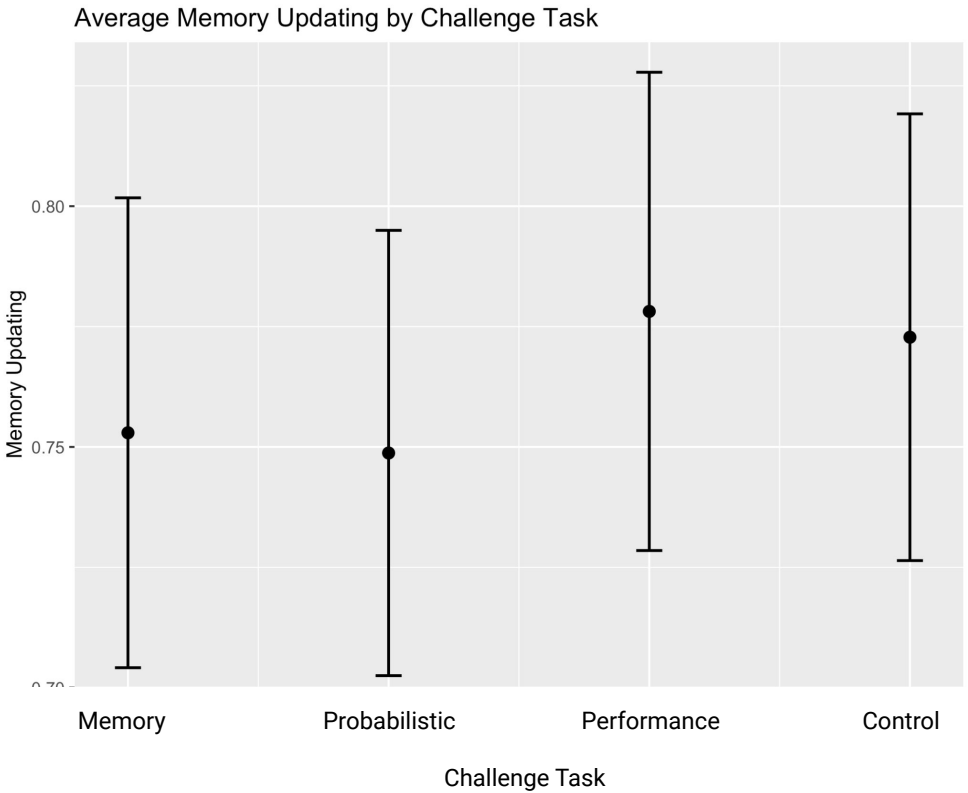
- Rated on scale of 1 = *Strongly Disagree* → 5 = *Strongly Agree*
- I.e. *Even when I do something very carefully, I often feel that it is not quite right.*

Grös et al., 2007; Stoeber, J., 1983

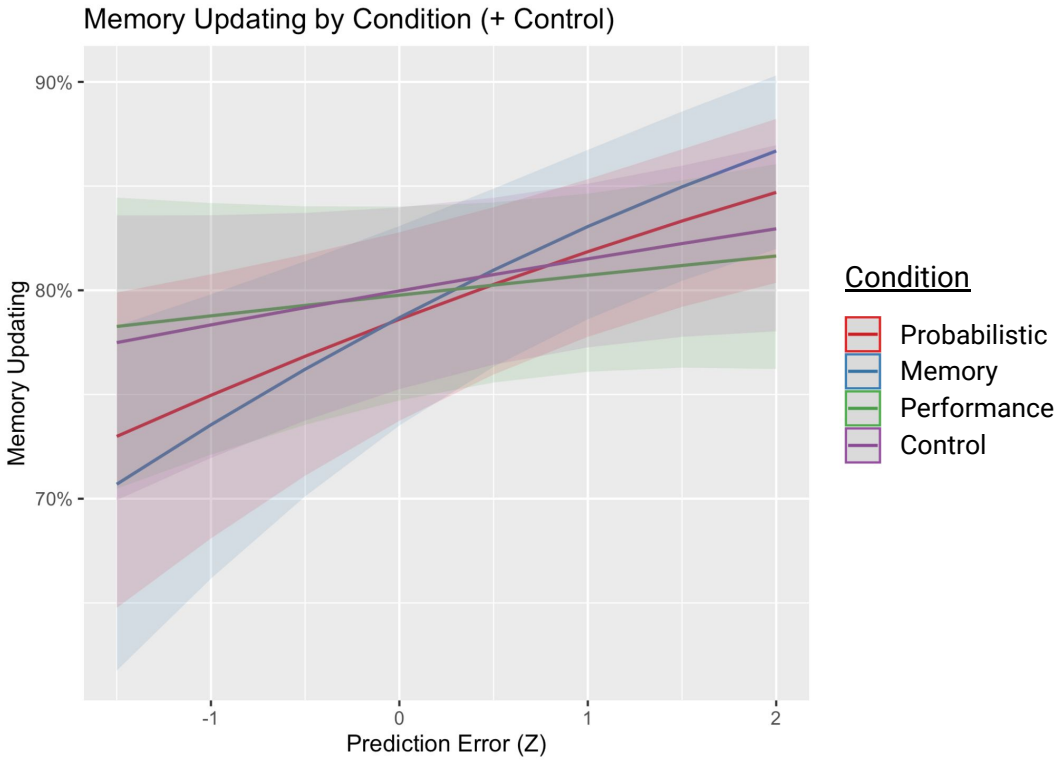
Hypotheses

1) The Memory Challenge group would demonstrate the **lowest** amount of memory updating driven by prediction error, and the Control and Probabilistic Challenge group will demonstrate the **highest** amount.
2) Higher Trait Anxiety would show **lower** levels of memory updating regardless of the condition presented

Memory Updating = Percentage of incorrect trials during feedback learning that was corrected during the test

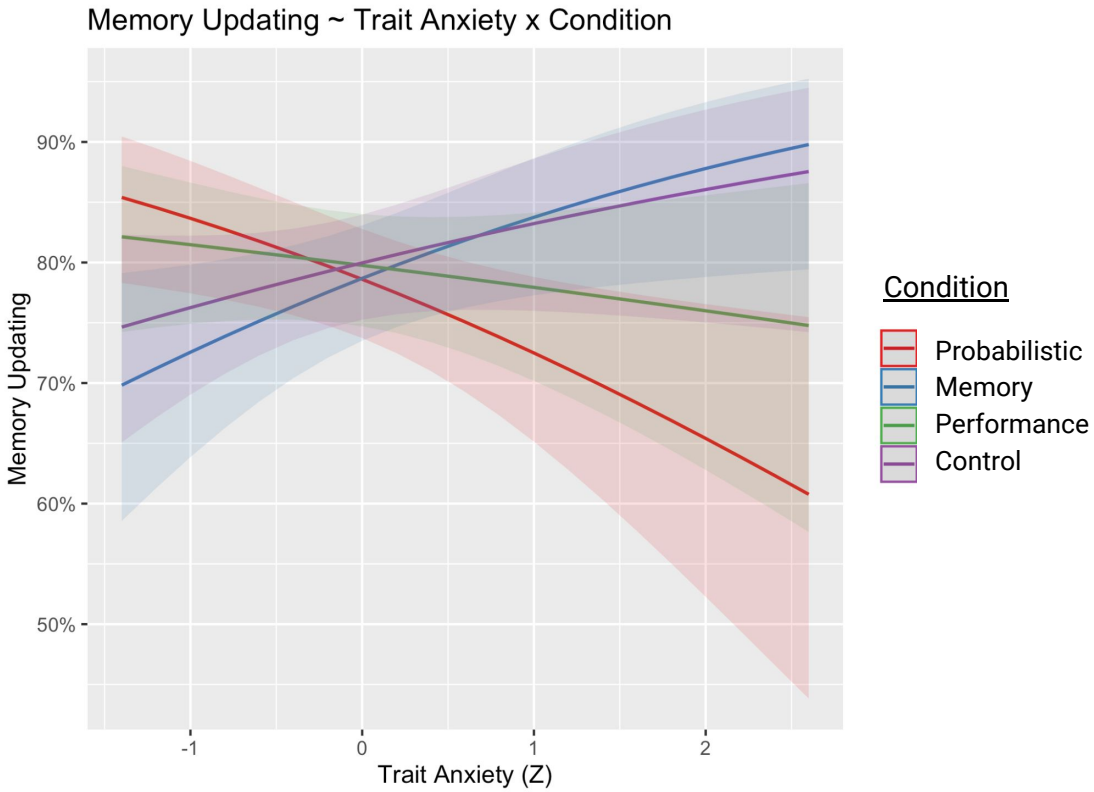


1. Main Effect of prediction error *(β = 0.17, z = 5.09, p < 0.001)*
2. No interaction between condition and prediction error

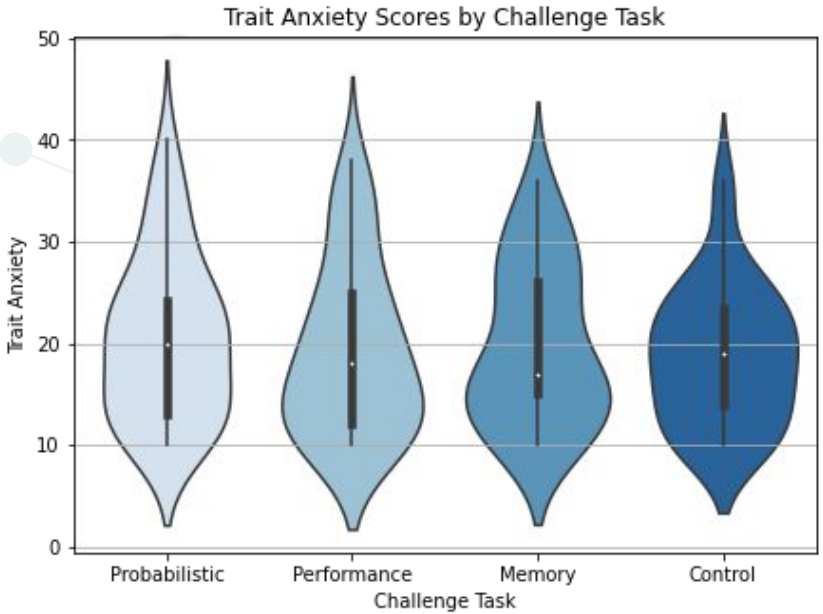


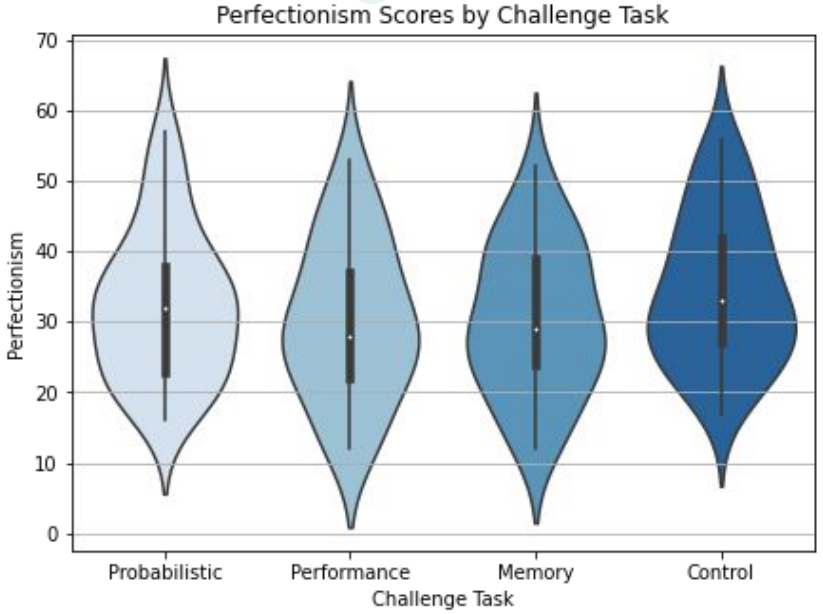
Interaction between conditions and trait anxiety *(X^2 = 13.859, p = 0.003)*

1. Probabilistic and Control: *(β = -0.55, z-ratio = -2.69, p = 0.04)*
2. Probabilistic and Memory: *(β = -0.66, z-ratio = -3.34, p = 0.0047)*



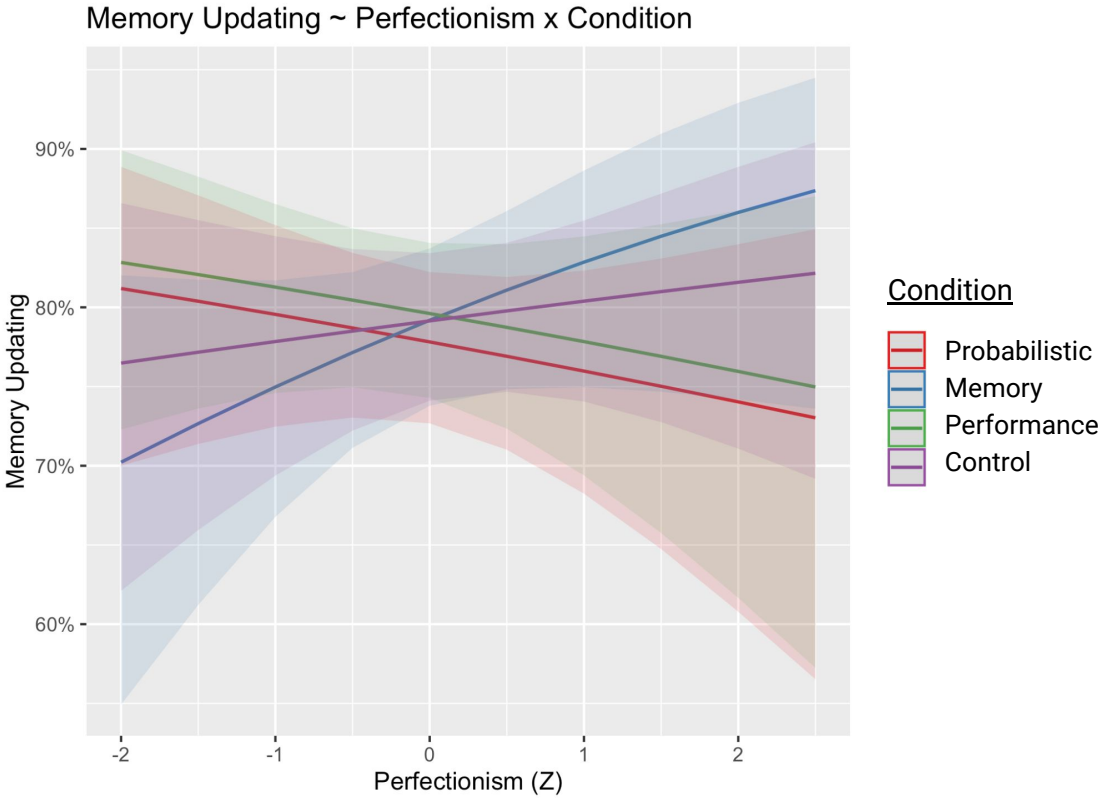
Distribution of Trait Anxiety and Perfectionism Scores





Correlation: $r^2 = 0.7, p < 0.001$

1. No significant main effects
2. No significant interactions



04

DISCUSSION

Hypotheses

1) The Memory Challenge group would demonstrate the **lowest** amount of memory updating driven by prediction error, and the Control and Probabilistic Challenge group will demonstrate the **highest** amount.
2) Higher Trait Anxiety would show **lower** levels of memory updating regardless of the condition presented

Summary of Results

01 Main effect of prediction error = **hypercorrection effect**

02 Higher trait anxiety subjects in the **Probabilistic Challenge** had lower memory updating

03 Higher trait anxiety subjects in the **Memory Challenge** and **Control** had higher memory updating

04 No significant interaction between perfectionism and the condition on memory updating

Interpretation of Results

01 **Probabilistic Challenge:** lowered locus of control and adverse effects of effort

02 **Memory Challenge:** leverages motivation in memory-related task

03 Observed effects of trait anxiety cannot be explained by **perfectionism**

04 Necessity of research to hone in on **specific behaviors** that impair learning

Why the Probabilistic Challenge?

Berggren & Derakshan, 2012; Eysenck, 1979; Cohen, Rothbart, & Philips, 1976

Main Takeaways for Trait Anxiety

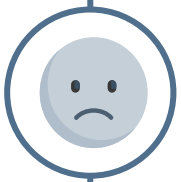
01

Increased Effort is adaptive to learning

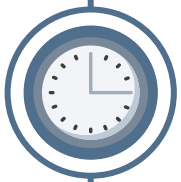
02

Decreased perception of control is maladaptive to learning

Limitations and Future Studies



- Distribution of trait anxiety levels (fewer people with high trait anxiety)
- Test was completed immediately after the feedback learning
- Not controlled setting



- Replicate for General Anxiety Disorder (GAD)
- Learning interventions on specific traits of anxiety that impair learning
- Distinguishing perfectionism and anxiety

Thank you!

References

Aylward, J., Valton, V., Ahn, W., Bond, R.L., Dayan, P., Roiser, J.P., & Robinson O.J. (2019). Altered learning under uncertainty in unmedicated mood and anxiety disorders. Nature Human Behavior, 3(10), 116-1123. DOI: 10.1038/s41562-019-0628-0

Berggren, N., & Derakshan, N. (2012). Attentional control deficits in trait anxiety: Why you see them and why you don't. Biological Psychology, 92, 440-446. doi:10.1016/j.biopsycho.2012.03.007

Cohen, S., Rothbart, M., & Philips, S. (1976). Locus of control and the generality of learned helplessness in humans. Journal of Personality and Social Psychology, 34, 1049-1056.

Ergo, K., De Loof, E., & Verguts, T. (2020). Reward prediction error and declarative memory. Trends in Cognitive Sciences, 24(5), 388-397. DOI: 10.1016/j.tics.2020.02.009

Eysenck, M.W. (1979). Anxiety, learning, and memory: A reconceptualization. Journal of Research in Personality, 13, 363-385. https://doi.org/10.1016/0092-6566(79)90001-1

Grös, D.F., Antony, M.M., Simms, L.J., & McCabe, R.E. (2007). Psychometric properties of the state-trait inventory for cognitive and somatic anxiety (STICSA): Comparison to the state-trait anxiety inventory (STAI). Psychological Assessment, 19(4), 369-381.

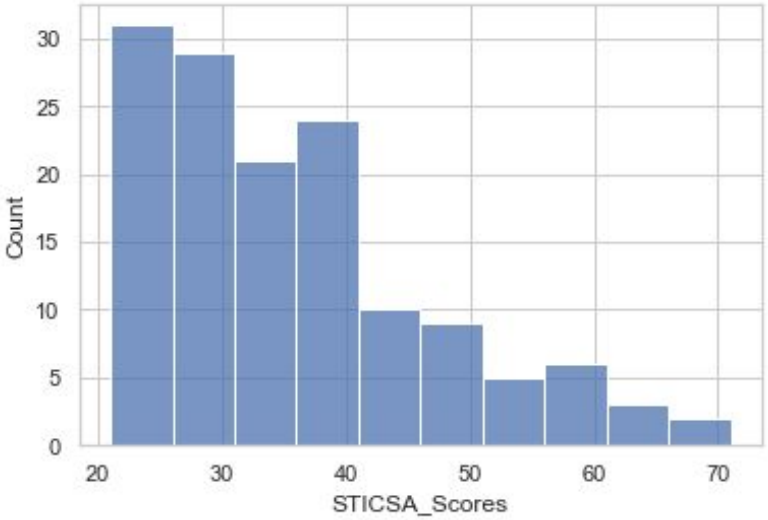
Grupe, D.W., & Nitschke, J.B. (2013). Uncertainty and anticipation in anxiety: An integrated neurobiological and psychological perspective. Nature Reviews Neuroscience, 14(7). 488-501. DOI: 10.1038/nrn3524

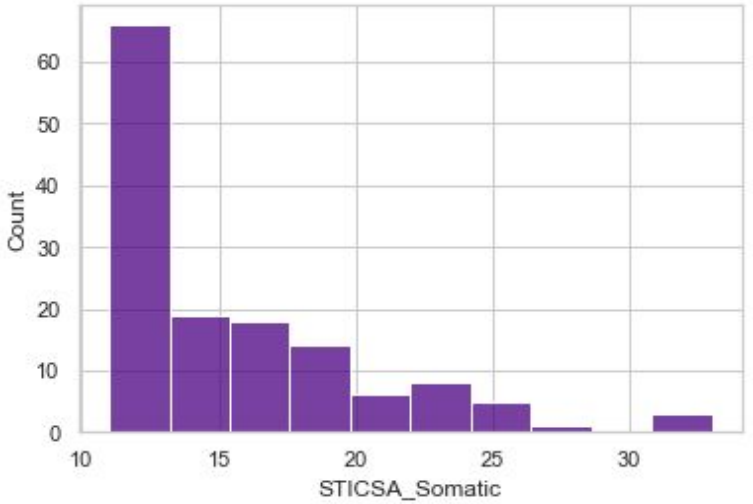
Pine, A., Sadeh, N., Ben-Yakov, A., Dudai, Y. & Mendelsohn A. (2018). Knowledge acquisition is governed by striatal prediction errors. Nature Communications, 9(1), 1673. DOI: 10.1038/s41467-018-03992-5

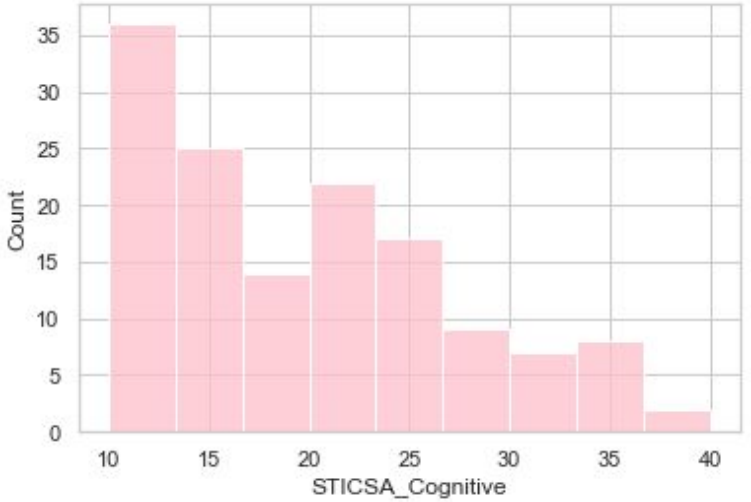
Rao, R.P., and Ballard, D.H. (1999). Predictive coding in the visual cortex: A functional interpretation of some extra-classical receptive-field effects. Nature Neuroscience, 2, 79-87. https://doi.org/10.1038/4580

Stoeber, Joachim (1998) The Frost Multidimensional Perfectionism Scale revisited: More perfect with four (instead of six) dimensions. Personality and Individual Differences, 24(4), 481-491. DOI:10.1016/S0191-8869(97)00207-9.

STICSA Score Distributions







Linear Mixed-Effects Model Calls

```
model_lmer_c2 <- glmer(accuracy_test ~ PE_c * challenge_task * STICSA_Cognitive_c + (1 + PE_c| Respondent.ID), data = CoL_errors,
family=binomial, control=glmerControl(optimizer="bobyqa", optCtrl=list(maxfun=10e4)))
Anova(model_lmer_c2, type = 3) #look at overall results
```

```
model_lmer_c3 <- glmer(accuracy_test ~ PE_c * challenge_task * Perfectionism_c + (1 + PE_c| Respondent.ID), data = CoL_errors,
family=binomial, control=glmerControl(optimizer="bobyqa", optCtrl=list(maxfun=10e4)))
Anova(model_lmer_c3, type = 3) #look at overall results
```

```
plot_model(model_lmer_c2, type = "pred", terms = c("PE_c", "challenge_task"))+
  ylab("Memory Updating") +
  xlab("Prediction Error") +
  ggtitle("Memory Updating by Condition (+ Control)")
ggsave("all_cond.png", dpi = 300, units = "in", width = 7, height = 5)
```

```
plot_model(model_lmer_c3, type = "pred", terms = c("Perfectionism_c", "challenge_task"))+
  ylab("Memory Updating") +
  xlab("Perfectionism") +
  ggtitle("Memory Updating ~ Perfectionism x Condition")
ggsave("memupd_perf.png", dpi = 300, units = "in", width = 7, height = 5)
```

```
levels(CoL_errors$challenge_task)
emtrends(model_lmer_c2, pairwise ~ challenge_task, var="STICSA_Cognitive_c")
```