Memory as a Belief Technology

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Motivation: Experiences Shape Beliefs

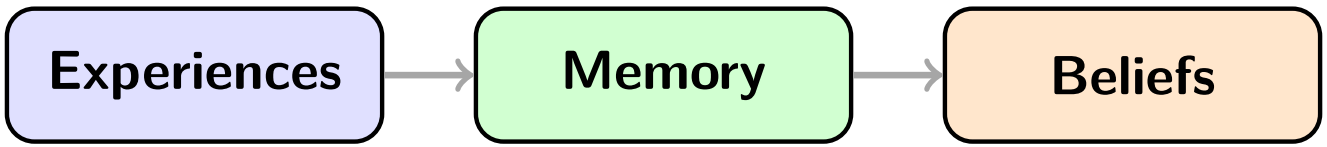
Intuition: Past experiences are a building block for what we think will happen in the future: If the last week was sunny every day, I might expect tomorrow will also be sunny also.

"Experience effects" papers:

- **Malmendier & Nagel (2011)**: Individuals who grew up during the Great Depression are more pessimistic about future returns and invest less in stocks for the rest of their lives $\rightarrow$ formative macroeconomic experiences have large, persistent effects on financial decisions.
- **Malmendier & Shen (2024)**: Households that lived through recessions persistently think a future recession is more likely and under consume relative to their fundamentals, even decades after recovery.

Motivation: Experiences Operate *Through* Memory

Intuition: if you cannot remember last week's sunny days, those experiences are unlikely to shape your belief about tomorrow's weather.



Memory determines how well experiences are accessed:

- **Tulving (2002)**: Episodic memory underlies "mental time travel." Amnesiac patients cannot simulate future events or form stable forward-looking beliefs.
- **Klein, Loftus & Kihlstrom (2002)**: Patients with amnesia cannot construct or update self-relevant beliefs about the future; their beliefs are highly unstable even across short intervals.

Memory-Based Models of Belief Formation

- Motivates a class of "Memory-Based Models" of Belief Formation (Bordalo et al., 2023; Wachter & Kahana, 2024).
- **Model Setup**
  - Individuals have a database of experiences $E = \{e_1, e_2, \ldots\}$
  - Each experience has contextual features $F = \{f_1, \ldots, f_k\}$
  - Similarity $S(e, H)$ between features governs recall probability $r(e)$
- **Belief Decomposition**

$$\underbrace{\widehat{\pi(H)}}_{\text{P(event)}} = \sum_{e \in E} \underbrace{r(e)}_{\substack{\text{recall} \\ \text{prob}}} \cdot \sigma(e) \qquad \text{where} \quad r(e) = \frac{S(e, H)}{\sum_{u \in E} S(u, H)}$$

- Probability judgments emerge from *similarity-based retrieval* of past experiences.
- "Irrelevant" information can influence beliefs if it shares contextual features with the event H (Bordalo et al., 2024)

Empirical Tests of Memory-Based Models

- **Bordalo, Gennaioli & Shleifer (2024, Restud) — "Imagining the Future"**: People assess novel risks by simulating them from similar past experiences rather than from base rates, causing personal history to systematically bias beliefs.
- **Enke, Schwerter & Zimmermann (2024, JFE) — "Associative Memory"**: When people receive new information, they selectively recall past news that shares the same contextual features.
- **Jiang, Liu, Peng & Yan (2025, *QJE*) — "Investor Memory and Biased Beliefs"**: Investors' recalled (not actual) past experiences drive return expectations — rising markets trigger selectively positive memories, leading to excess optimism.
- **Andre, Pizzinelli, Roth & Wohlfart (2022, Restud) — "Subjective Models of the Macroeconomy"**: Irrelevant cues can shift mental models for how macro shocks will propogate.

This Paper

The Gap: Existing work treats memory as a black box. Without measuring individual memory strength, we cannot know *by how much* memory moderates the role of experiences (if at all).

This paper:

1. **Directly measure memory strength** (Recall Fluency, RF) using validated cognitive tests.
2. **Test whether RF amplifies experience effects on beliefs**: We show that high-RF individuals have significantly larger "experience effects" compared to low-RF.
3. **Memory as a stable trait**: like risk aversion or IQ, RF is largely stable within-person over time — a fundamental, persistent driver of belief formation.

Setting: Stock market beliefs (chance stocks $\uparrow$ next year), using each individual's lifetime S&P 500 return history as experiences.

A Model of Belief Formation With Memory Strength

(1) Setup

- **Database** $\mathbf{f} = \{f_e\}_{e \in E}$: lifetime experiences stored as frequency counts over categories $e = (s, v, c)$ — signal, valence, context.
- **Cue** $q_X = (s_X, v, X)$: current signal, mood, and domain. Can think of q_X as the belief question itself.

(2) Retrieval — the probability of recalling experience category e given cue q:

$$r_e(q, \mathbf{f}) = \frac{S(e, q) \cdot f_e}{\sum_{e'} S(e', q) \cdot f_{e'}}$$

- *Frequency*: more commonly lived experiences are easier to recall
- *Similarity*: experiences closer in features (s, v, c) to the cue are easier to recall
- *Interference*: Irrelevant experiences crowd out relevant ones

Recall Fluency: From Retrieval to Beliefs

(3) Attention a_i governs similarity gradient: $S(e, q) = S[\alpha_i \cdot d(e, q)]$

- Higher $a_i \Rightarrow$ steeper gradient $\Rightarrow$ cue-congruent experiences upweighted, irrelevant experiences suppressed.

(4) Belief Decomposition:

$$\mathbb{E}(s_X|q, \mathbf{f}) = \sum_{e:\, \sigma_X(e) \in T_X} \underbrace{r_e(q, \mathbf{f})}_{\text{recall prob}} \cdot \underbrace{\sigma_X(e)}_{\text{simulation}}$$

Linearizing around $a_i = 0$ yields the belief decomposition:

$$\mathbb{E}(s_X|q, \mathbf{f}) \approx \underbrace{\sum_e \frac{f_e}{|\mathbf{f}|} \sigma_X(e)}_{\text{frequency anchor}} + \underbrace{a_i \sum_e \frac{f_e}{|\mathbf{f}|} \big[d(q) - d(e, q)\big] \sigma_X(e)}_{\text{RF amplification of similar experiences}}$$

Reduced Form Regression

Empirical Analogue:

$$p_{X,it} \approx \eta_0 + \underbrace{\eta_1 \cdot \bar{s}_{it}}_{\text{frequency anchor}} + \underbrace{\eta_2 \cdot a_i \cdot \bar{s}_{it}}_{\text{RF}\times\text{avg. experience}} - \underbrace{\eta_3 \cdot a_i \cdot \widehat{\text{cov}}_i}_{\text{RF}\times\text{similarity to today}}$$

- $\bar{s}_{it}$: average past DS experience in domain X — the frequency anchor on beliefs.
- $\eta_2 > 0$: high RF amplifies sensitivity to the average past experience database.
- $\widehat{\text{cov}}_i \equiv \text{cov}[s, (s - s_{it})^2]$: how closely past experiences s resemble today's signal s_{it}.
- $\eta_3 > 0$: high RF further amplifies recall of experiences *similar to today* — the same news hits differently depending on whether it matches your personal history.

Testable Predictions

Prediction 1 — Agnosticity: Low-RF individuals give more *agnostic* answers: they are more likely to report "Don't Know" or an uncertain 50/50 when asked about future returns.

- High-RF individuals are more able to commit to a directional belief.

Prediction 2 — Database (DS) Amplification:

- $\hat{\eta}_2 > 0$: High-RF individual who has experienced good market returns is more bullish than a low-RF individual with the same experiences.
- $\hat{\eta}_3 < 0$: High-RF individuals disproportionately recall past experiences similar (low $cov[s, (s - s_{it})^2]$) to today's signal — the same news hits differently depending on whether it rhymes with your personal history.

Prediction 3 — Non-Database (NDS) Experiences: RF also amplifies the role of experiences *outside* the financial database.

- Early-life episodes stored in memory that shape the context for later recall (childhood health, childhood SES)

Data and Setting

Health and Retirement Study (HRS): nationally representative panel of Americans aged 50+, surveyed biennially 2002–2020 (≈20,000 individuals)

Belief variables (outcomes):

- Chance stocks ↑ [0-100]
- Chance house prices ↑ [0-100]
- Chance survive 10+ years [0-100]

Experience variables:

- $\bar{s}_{it}$: mean lifetime S&P 500 return
- $\widehat{\text{cov}}_{it}$: $\text{cov}[s, (s - s_{it})^2]$
- Childhood health index (NDS)
- Childhood SES index (NDS)

Cognition measures:

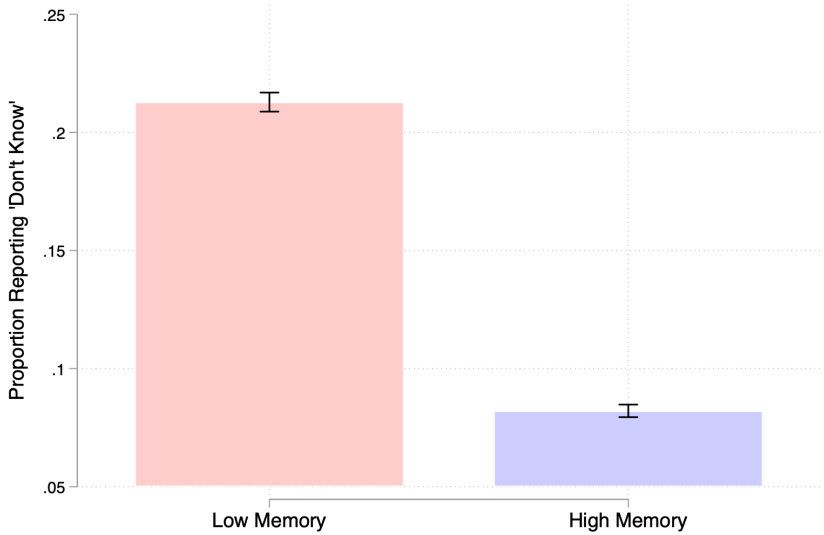
- **RF**: standardized index of immediate recall, delayed recall, verbal fluency (memory strength)
- **IQ**: math index (numeracy, counting backwards, series)

Controls:

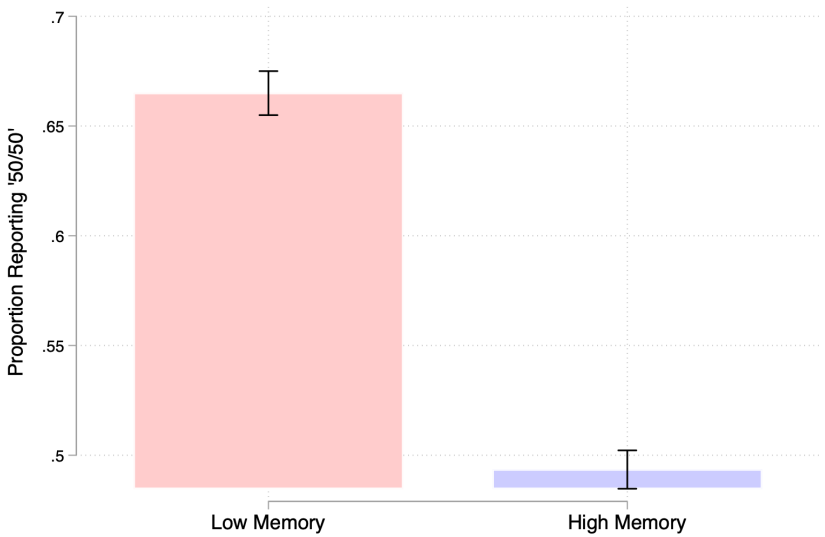
- Age, gender, marital status, retirement, income, education

Prediction 1: Low RF ⇒ More Agnostic Answers

Prop. "Don't Know", Stocks



Prop. "50/50 + Unsure", Stocks



- **Takeaway:** Low-RF individuals are significantly more likely to say "Don't Know" (left) and, among those who answer 50/50, more likely to report genuine uncertainty (right).

Prediction 2: RF Amplifies Experience Effects

	Chance Stocks ↑	
	(1)	(2)
Cognition		
RF	.	0.002
		[0.005]
DS Experience		
$\bar{s}_{it}$ $(\hat{\eta}_1)$	0.001	0.002
	[0.002]	[0.003]
RF Interactions		
RF $\times$ $\bar{s}_{it}$ $(\hat{\eta}_2)$	0.006***	0.006***
	[0.000]	[0.002]
RF $\times$ $\widehat{\text{cov}}_i$ $(\hat{\eta}_3)$	-0.004***	-0.004***
	[0.000]	[0.000]
N	139345	139345
DV Mean	0.47	0.47

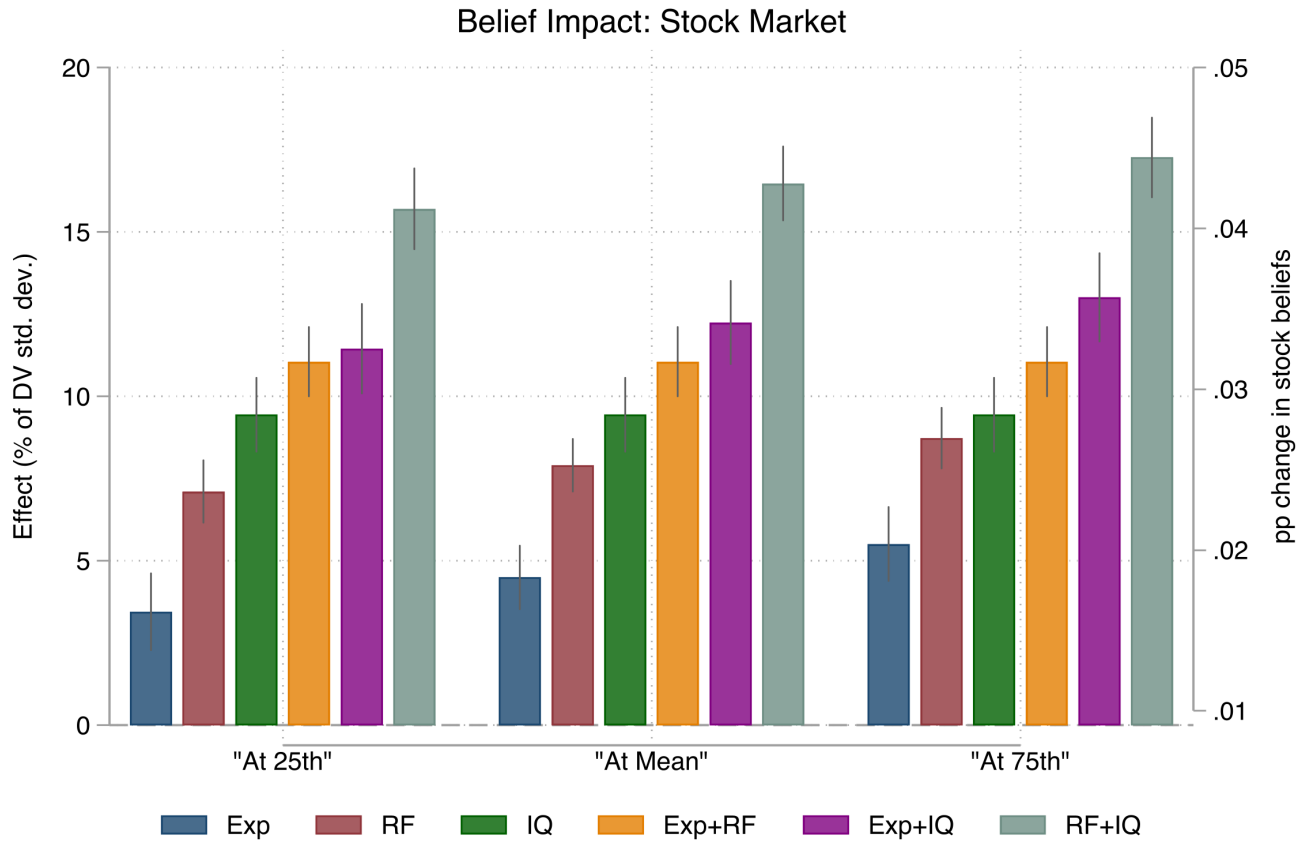
Takeaways:

$\hat{\eta}_1 > 0^{**}$: Lifetime experiences anchor beliefs — more positive past returns $\Rightarrow$ more optimistic.

$\hat{\eta}_2 > 0$: RF amplifies this — high-RF individuals are more sensitive to their personal history.

$\hat{\eta}_3 < 0$: RF further amplifies recall of experiences *similar to today* — same news hits differently depending on personal history.

Prediction 2: The Role of Memory — Graphical



- **Takeaway** RF alone explains a meaningful share of belief volatility. 1 std change in RF worth twice as much as 1 std change in experiences.

Prediction 3: Memory Amplifies Early-Life Experiences

	Chance Stocks ↑	
	(1) Child. Health	(2) Child. SES
DS Experience		
$\bar{s}_{it}$ $(\hat{\eta}_1)$	0.001	0.001
	[0.002]	[0.002]
RF Interactions		
RF $\times$ $\bar{s}_{it}$ $(\hat{\eta}_2)$	0.006***	0.006***
	[0.000]	[0.000]
RF $\times$ $\widehat{\text{cov}}_i$ $(\hat{\eta}_3)$	-0.003***	-0.004***
	[0.000]	[0.000]
NDS Experience		
NDS	-0.001	-0.003
	[0.001]	[0.002]
RF $\times$ NDS	0.005***	0.005***
	[0.001]	[0.001]
N	134136	139342
DV Mean	0.47	0.47

Takeaways:

- High-RF individuals carry childhood health and SES into adult beliefs via memory's amplification.
- Happens through "valence-based" channel of the experience e = (s,v,c)
- NDS only matter *through* RF — consistent with a memory channel, not omitted variables.
- **Memory makes even normatively irrelevant experiences matter**

Taking Stock

	Prediction	**Result**
P1	*Agnosticity*: Low RF ⇒ more agnostic answers (DK or uncertain 50/50)	✓ Low-RF more likely to report "Don't Know" or uncertain 50/50
P2	*DS amplification*: RF amplifies lifetime market experience effects	✓ $\hat{\eta}_2 > 0$: RF×$\bar{s}_{it}$ significant; $\hat{\eta}_2 < 0$: RF×$cov[s, (s - s_{it})^2]$
P3	*NDS amplification*: RF amplifies early-life experience effects	✓ RF×Child Health and RF×Child SES impact beliefs *through memory*

All three predictions of the memory-based model are supported in the data. Memory actively mediates the relationship between experience and belief — and explains more belief variance than lifetime experiences alone.

Conclusion

- **Memory as a belief technology**: we propose and test a memory-based model of belief formation; the data are strongly consistent across three distinct predictions.
- **Memory is a stable individual trait [not discussed today]** — like risk aversion or IQ — that varies substantially across people, creating a persistent wedge between the experiences people have and the beliefs they form.
- **Memory amplifies experience effects** — for both lifetime market returns (database) and early-life conditions (non-database). Individuals with identical experience histories form different beliefs based on cognitive endowment.
- **Memory explains more belief variance** than lifetime experiences alone (in the stock market), underscoring its first-order importance for understanding cross-sectional heterogeneity in beliefs and financial decisions.

Robustness: Housing Market and Health Beliefs

	Chance House ↑		Chance Live 10+	
	(1)	(2)	(3)	(4)
Cognition				
RF	.	-0.013	.	0.006**
	.	[0.010]	.	[0.003]
IQ	0.016***	0.017***	-0.018***	-0.019***
	[0.003]	[0.003]	[0.002]	[0.002]
DS Experience				
$\bar{s}_{it}$ $(\hat{\eta}_1)$	0.038***	0.029***	0.001***	0.001***
	[0.003]	[0.008]	[0.000]	[0.000]
RF Interactions				
RF $\times$ $\bar{s}_{it}$ $(\hat{\eta}_2)$	0.006***	0.011***	0.000***	0.000***
	[0.001]	[0.004]	[0.000]	[0.000]
RF $\times$ $\widehat{\mathrm{cov}}_i$ $(\hat{\eta}_3)$	-0.035***	-0.035***	-0.000***	-0.000***
	[0.001]	[0.001]	[0.000]	[0.000]
N	49972	49972	129518	129518
Adj. R^2	0.053	0.053	0.102	0.102
DV Mean	0.53	0.53	0.47	0.47

Notes: Same specification as Slide 10. Cols (1)–(2): housing market beliefs; cols (3)–(4): health beliefs (chance live 10+ years). Memory amplification of experience effects is robust across all three belief domains.