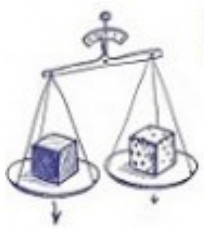


Usher Lab
Decisions
Cognition
Neural Computation

TEL AVIV UNIVERSITY
אוניברסיטת תל אביב

The cognition/metacognition tradeoff

David Rosenbaum, Moshe Glickman, Stephen M. Fleming & Marius Usher

ASIC 2023

Choice & Confidence & Confidence-resolution (*metacognitive*

- **Task: predict who will win in elections**
- **Rate your confidence on a 1-6 scale**

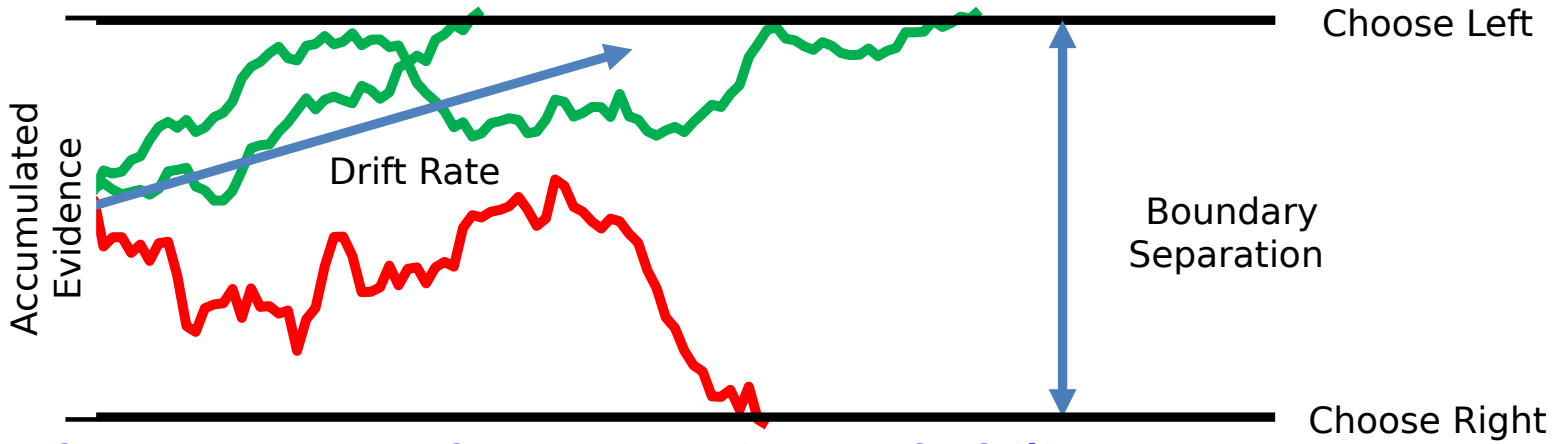
Likelihood to be correct

Confidence resolution:
confidence (correct) – Confidence (incorrect) >0
(Other measures: Gamma-correlation; Type-2 AUROC

Integration to boundary

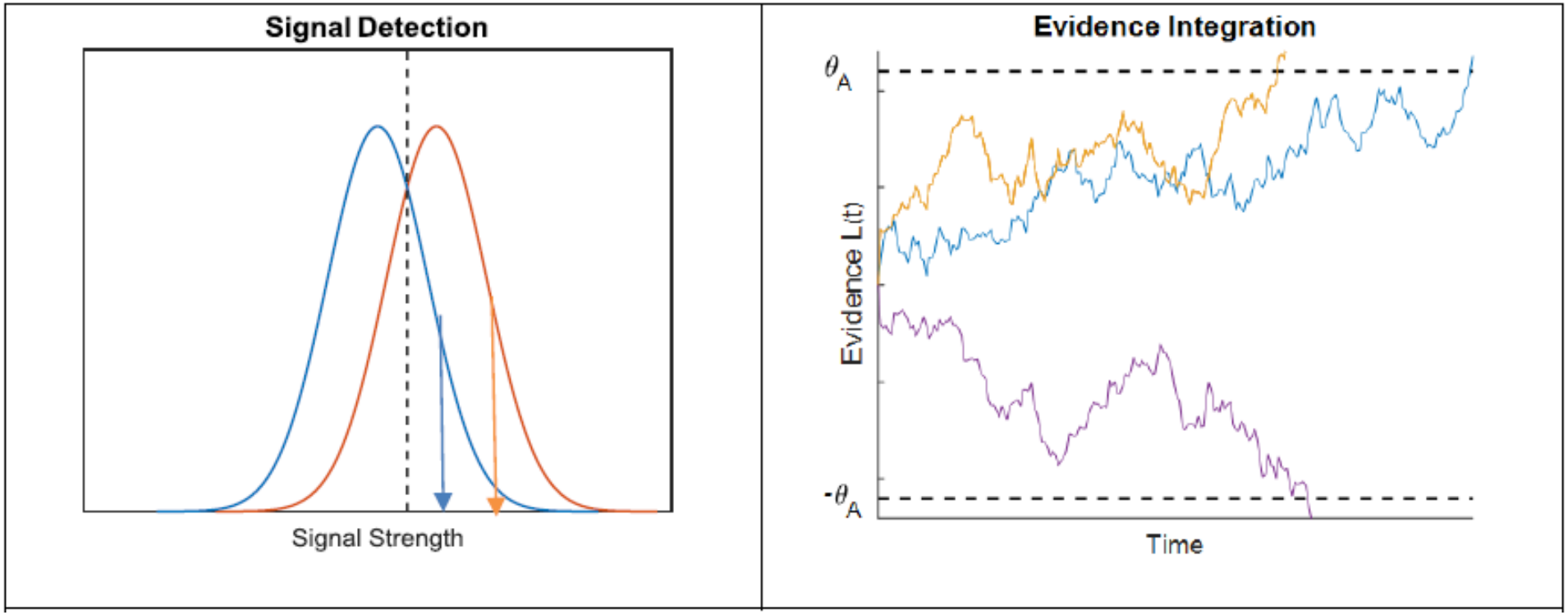
- ***Normative mechanism for self-terminated decisions with stochastic evidence***

Normative Model – SPRT: Fastest response-time for a given accuracy rate (Wald, 1947)



- Boundary corresponds to posterior probability
- Confidence ~ subjective likelihood of being correct ~ constant
- By integrating to boundary we reduce variability in evidence that can signal accuracy and thus reduces ***confidence-resolution***

Confidence resolution in SD model VS. integration to boundary



Signal detection with ***exogenous determined stimuli*** (***interrogation***)

- **Distance from boundary signals confidence**
- **Confidence resolution>0**
  - *Use RT as confidence indicator (Conf. negatively correlated with RT):*
  - *Use post-decision information (or WM)*

Integrated evidence for ***endogenous determined stimuli*** (***free choice/sampling***)

- **Decisions triggered by the same amount of evidence; Confidence resolution=0**

Confidence resolution: i) Free response (Last sample), ii) Interrogation (SD)

Values sampled from : *X~N(52, 15) and Y~N(48, 15)*

Integration to boundary: Accuracy 72%; Mean-RT = 6.6

Fixed-time integration: Accuracy = 72%; Mean-RT =10

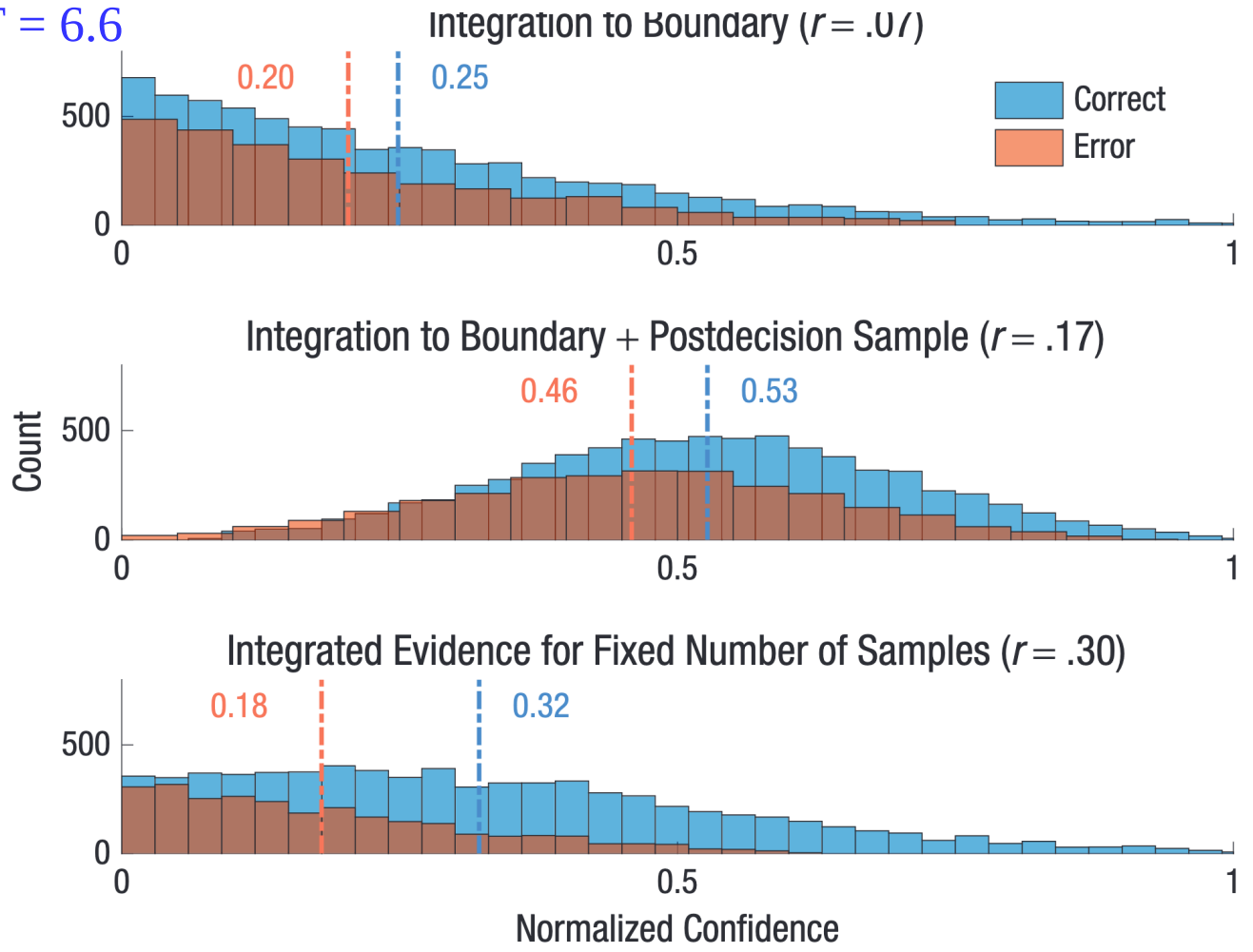


Fig. 3. Confidence distributions for three models of choice and confidence. For each model,

Does integration to boundary
have a cost in confidence resolution?

Study Goals

- Comparing confidence resolution between the interrogation and FR sessions with equal number of samples
- Comparing confidence predictors between the two sessions

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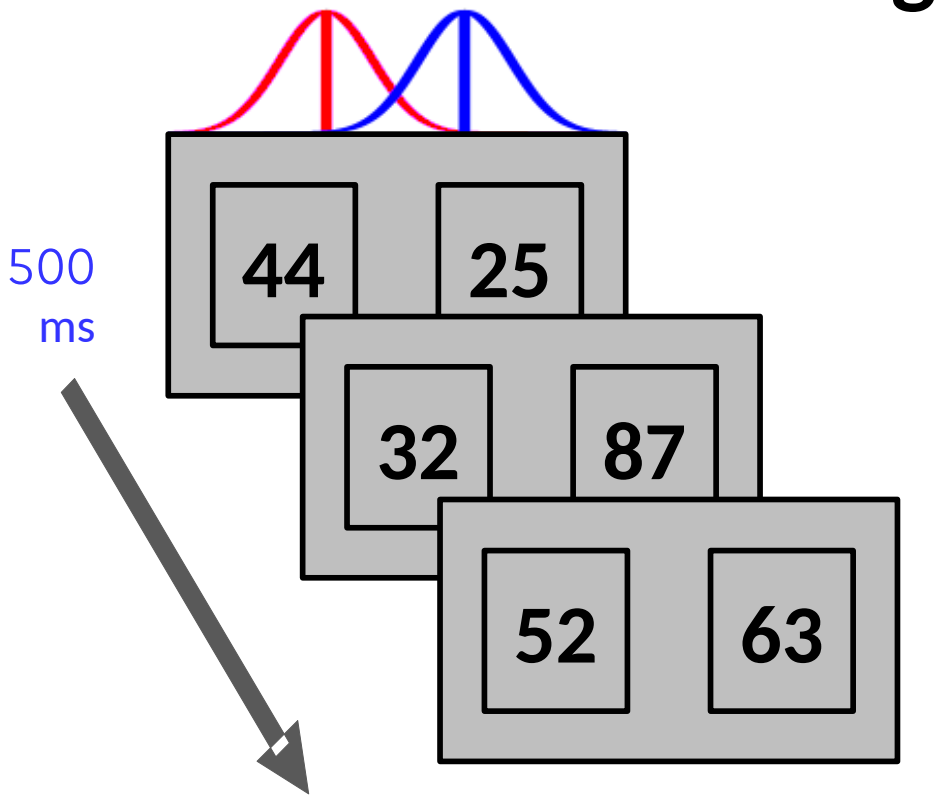
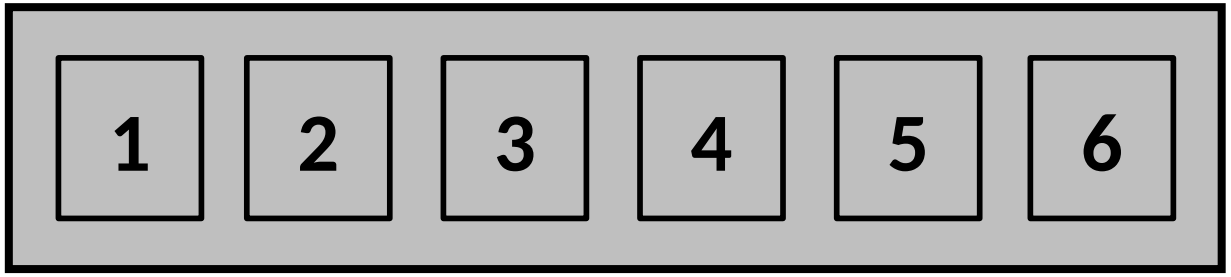
Value integration choice task



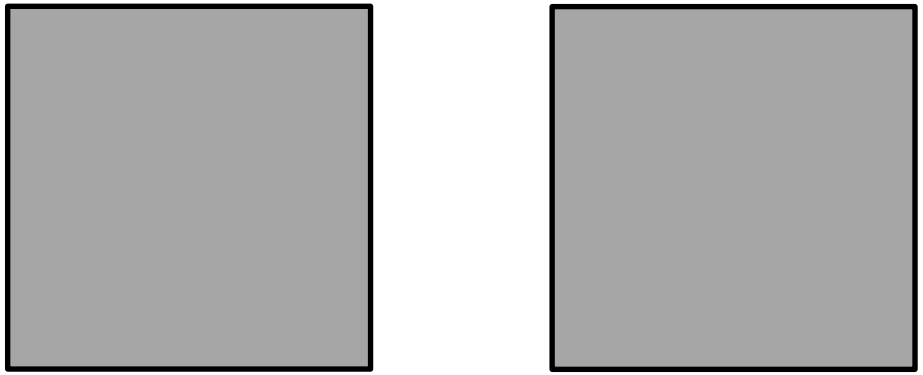
- Two sequences of numerical values
- Samples were drawn from 2 Gaussians
- Task: choose the sequence with the higher mean
- Rate your confidence on a 1-6 scale
- Session 1 = Free response paradigm
- Session 2 = Interrogation paradigm



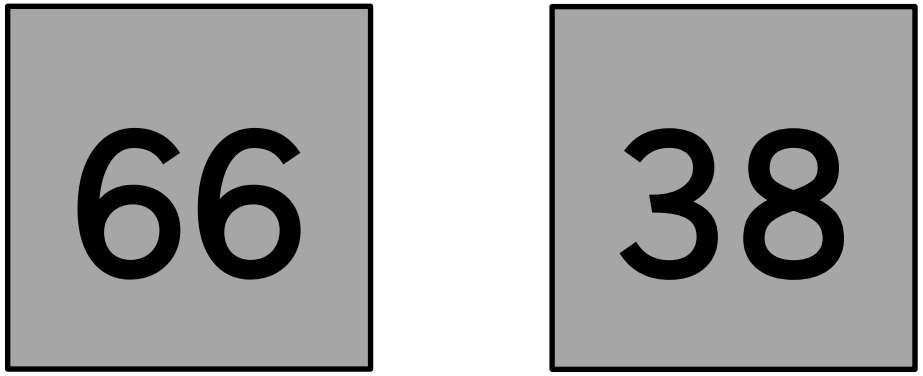
- For each S, session-2 presents trials with the same number of frames & sampled from the same payoff distributions as in session-1

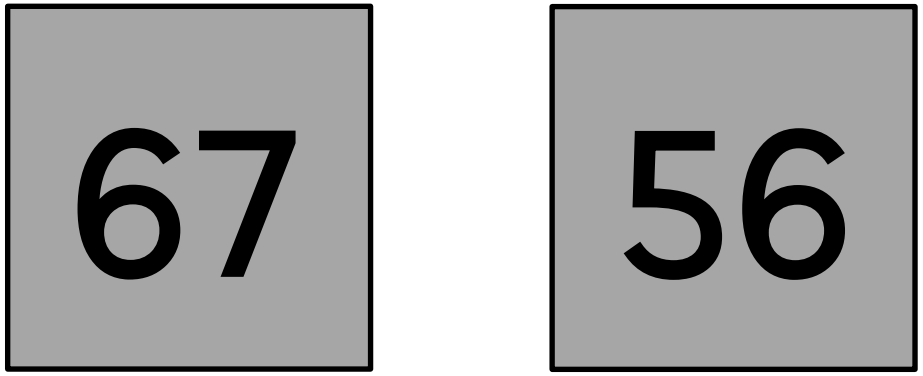
Value integration choice task

(Glickman & Usher, 2019; Glickman et al., 2018; Tsetsos et al., 2012)



Which sequence was drawn from a ? distribution with a higher mean


66
38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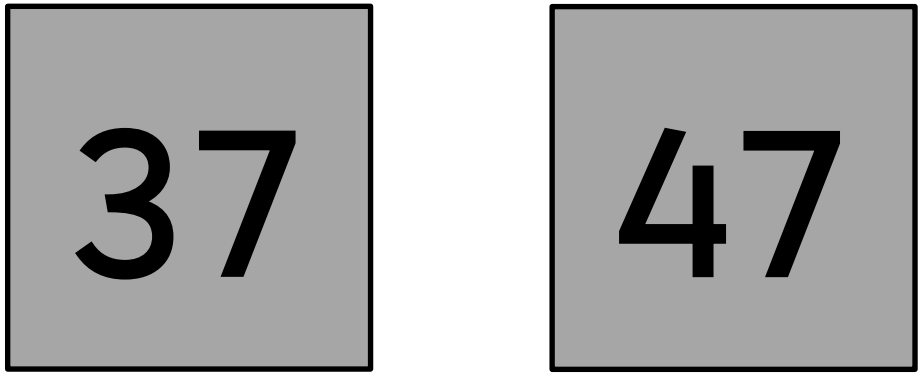
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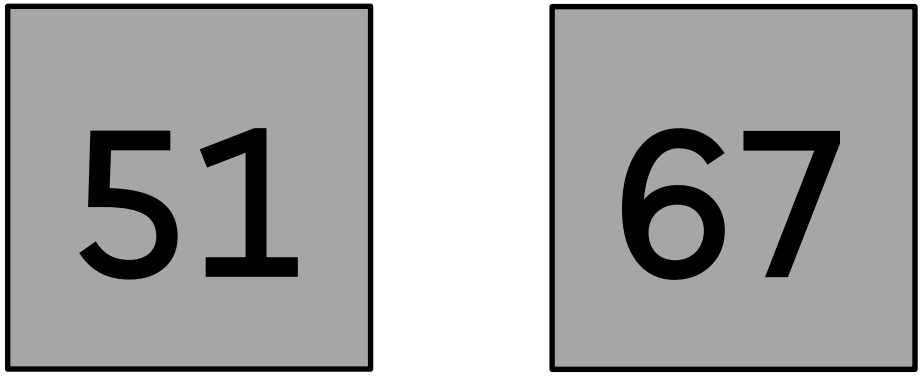
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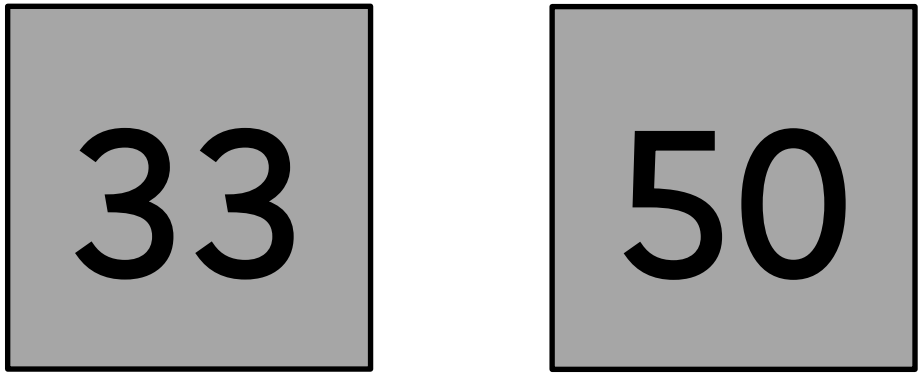
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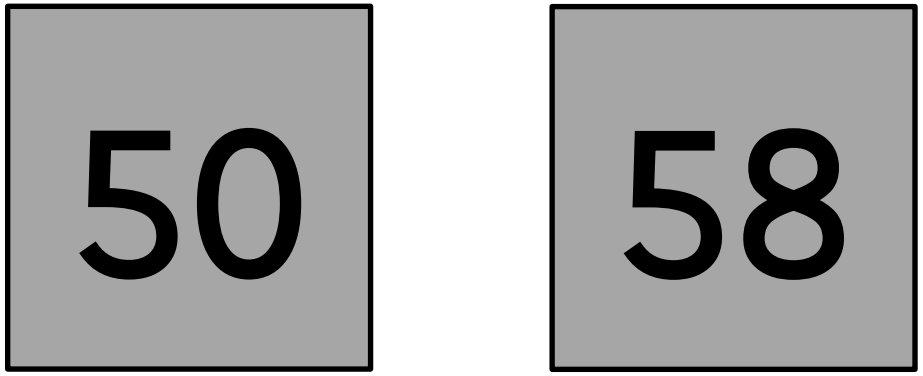
50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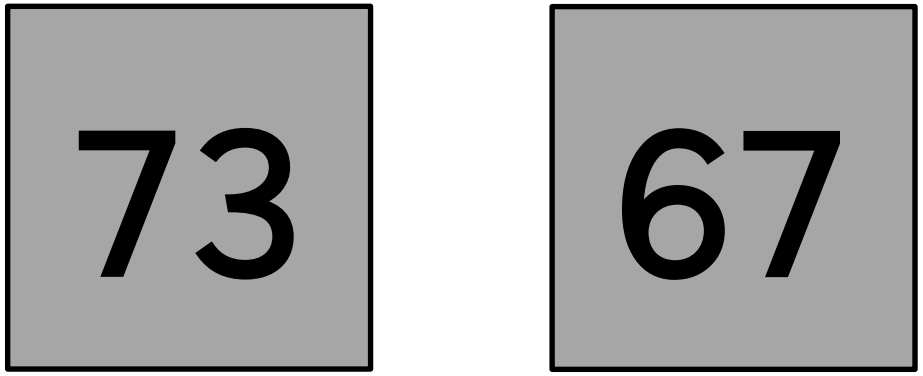
58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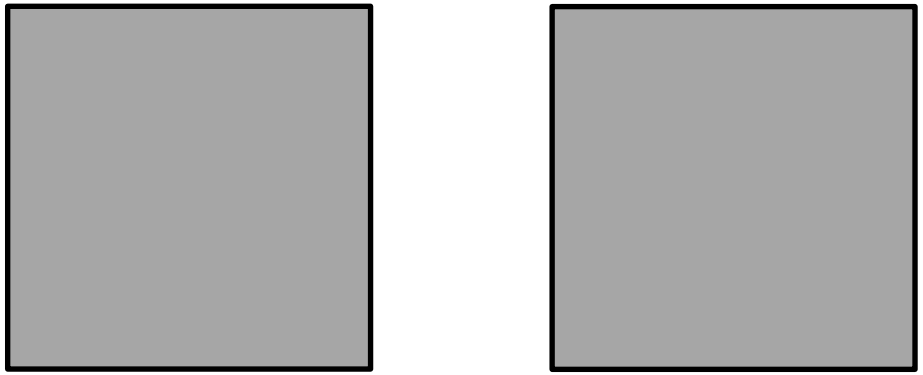
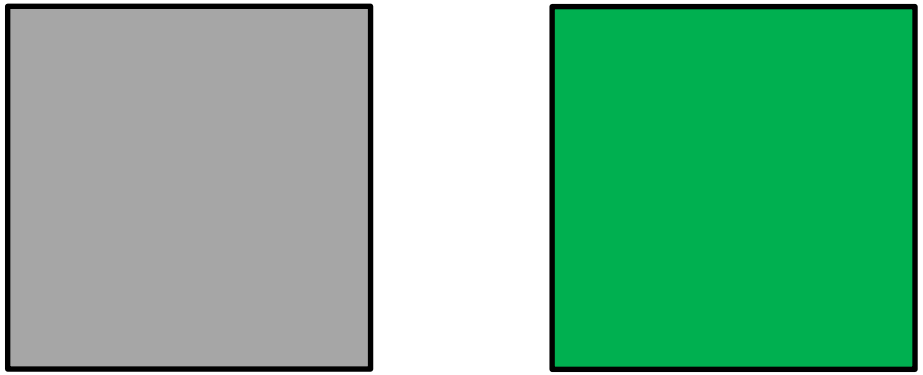
67



Decision: Right or left

Confidence rate: On a 1-6 scale



Decision: Right (Correct)

Free response: Decision terminates the trial

Interrogation: Fixed number of samples (matched trial by trial)

2 within-S experiments

- Exp. 1 (N=17)
- Exp. 2 (Preregistered replication; N=35)

Is there a cost in confidence resolution from self-terminated (free choice) compared to exp. terminated (interrogation)?

Results: accuracy and conf-resolution

Experiment 1

	Accuracy	Conf-resolution	Gamma correlation	Type 2 AUROC
Free-response	81.	87.	51.	67.
Interrogation	81.	1.01	58.	70.
t-test	*t*(16)=0.44, p = .66	*t*(16)=2.33, **p = .03**	*t*(16)=1.83, *p* = .08	*t*(16)=2.11, ***p* = .05**

Experiment 2

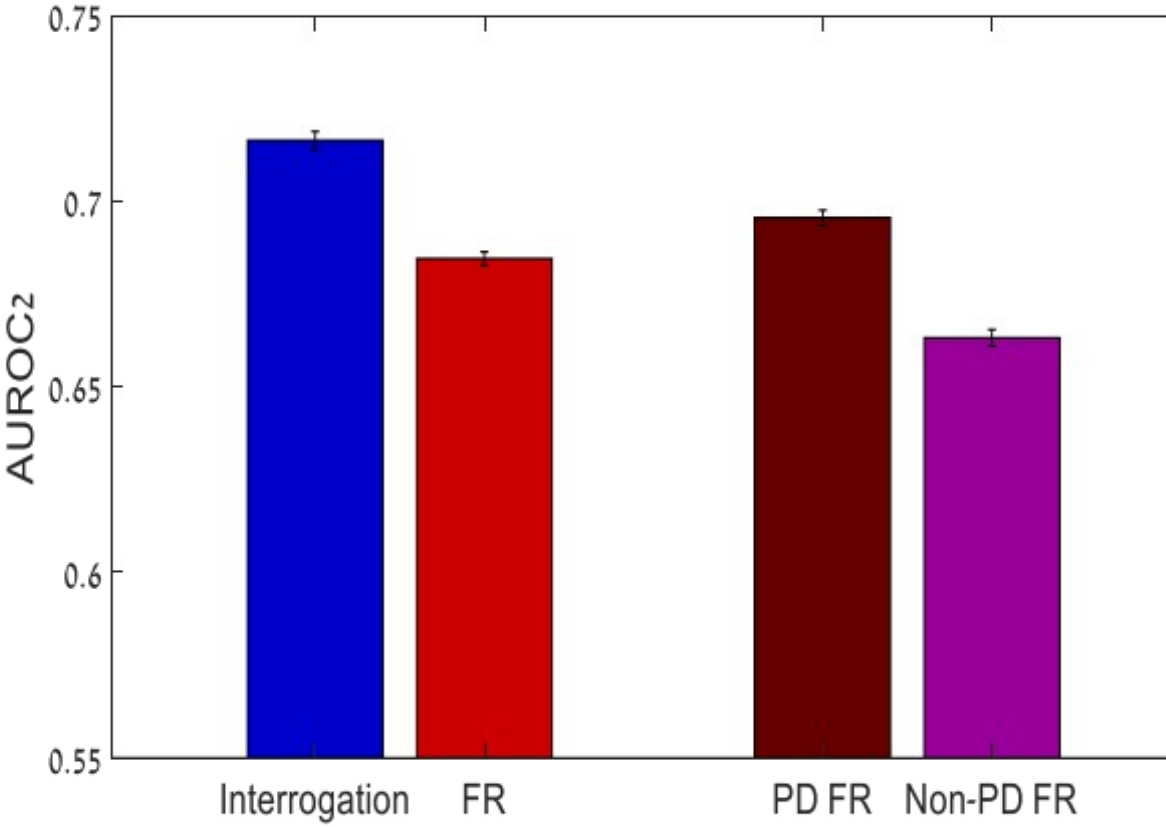
	Accuracy	Conf-resolution	Gamma correlation	Type 2 AUROC
Free response	79.	84.	49.	67.
Interrogation	83.	1.1	59.	0.72
	t(34)=5.7, p<.001	*F*(1,1)=2.7, p =.1	*F*(1,1)=4.9, ***p* =.03**	*F*(1,1)=5, ***p* = .03**

***t*-test**

Ancova

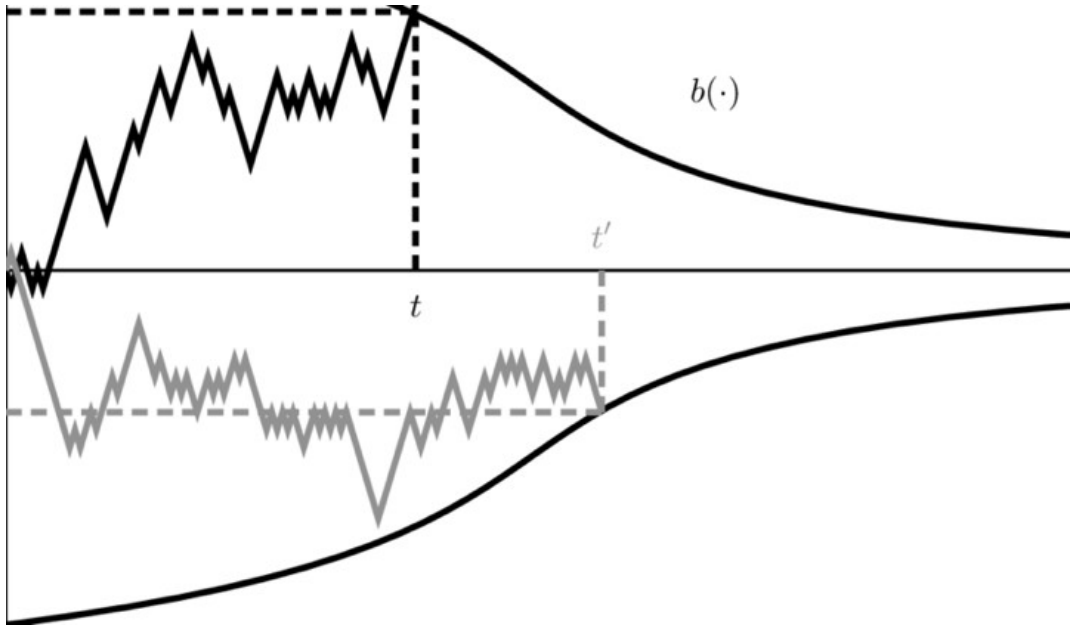
? What contributes to confidence-resolution in free response

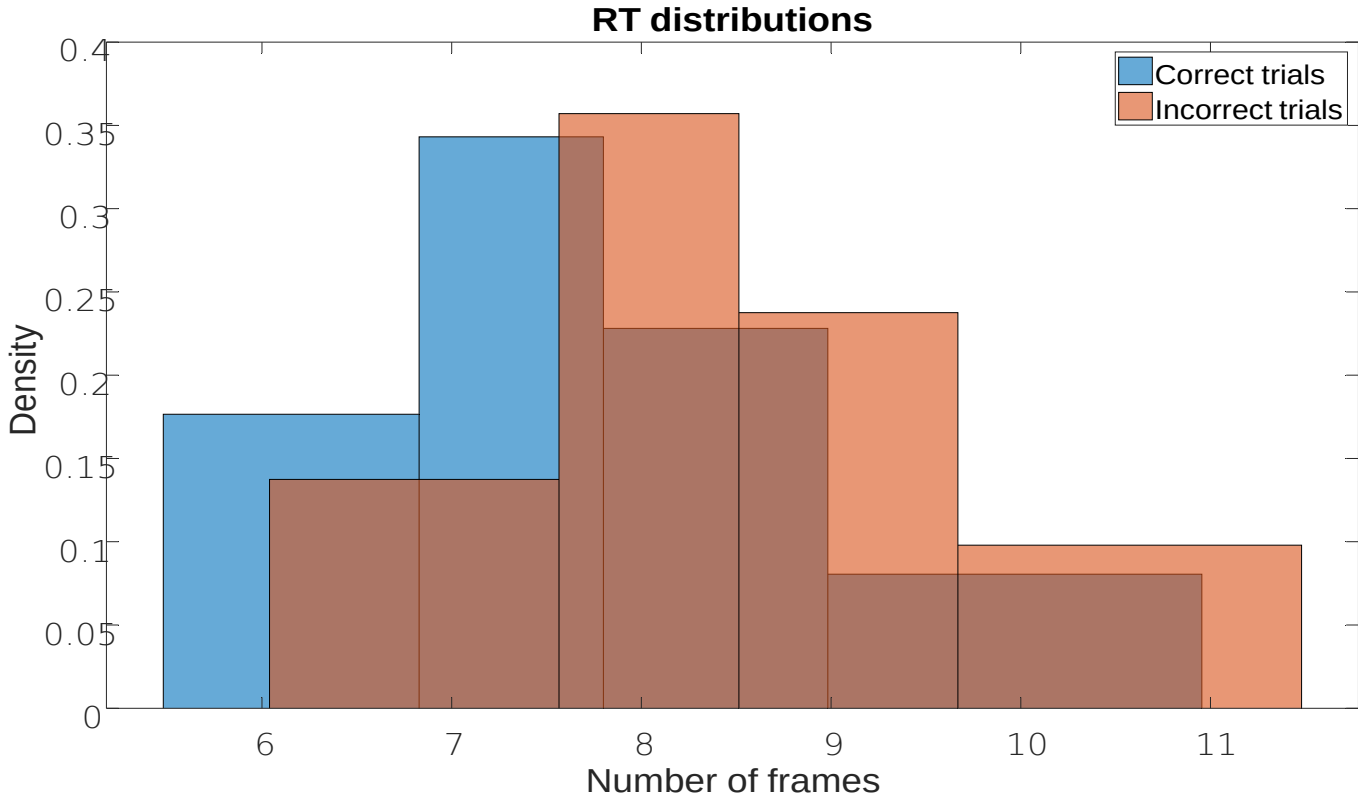
- **1) Post-decision mechanism** (Pleskac & Busemeyer, 2010): fast RT (<250 ms from last frame) correspond to stimuli in which choice was determined before last frame:
- Separate free response trials into fast/slow ones (relative to last event)



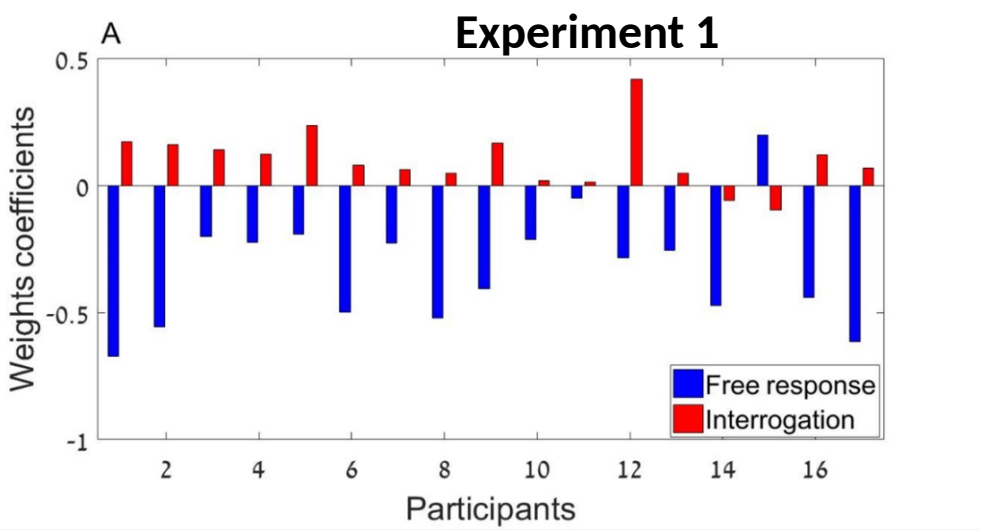
CONF-resolution in free-choice: 2) RT

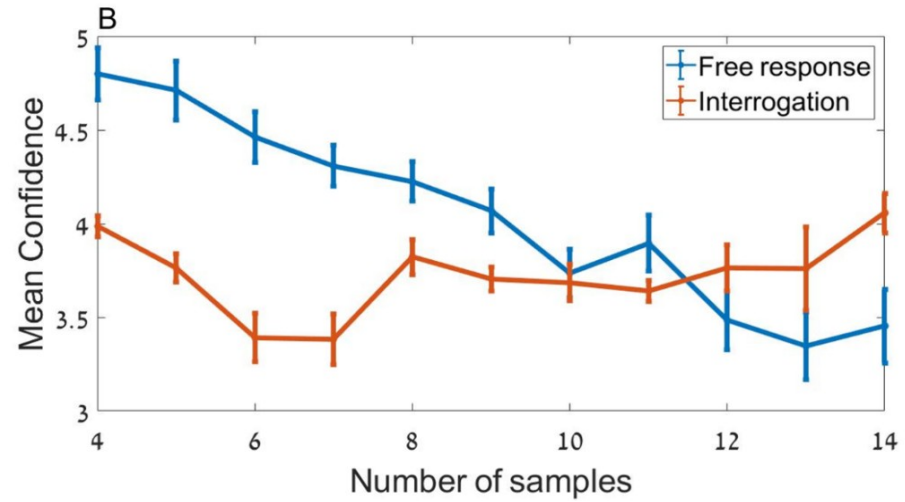
RT for integration to collapsing boundary: if correct choices are faster than incorrect choices

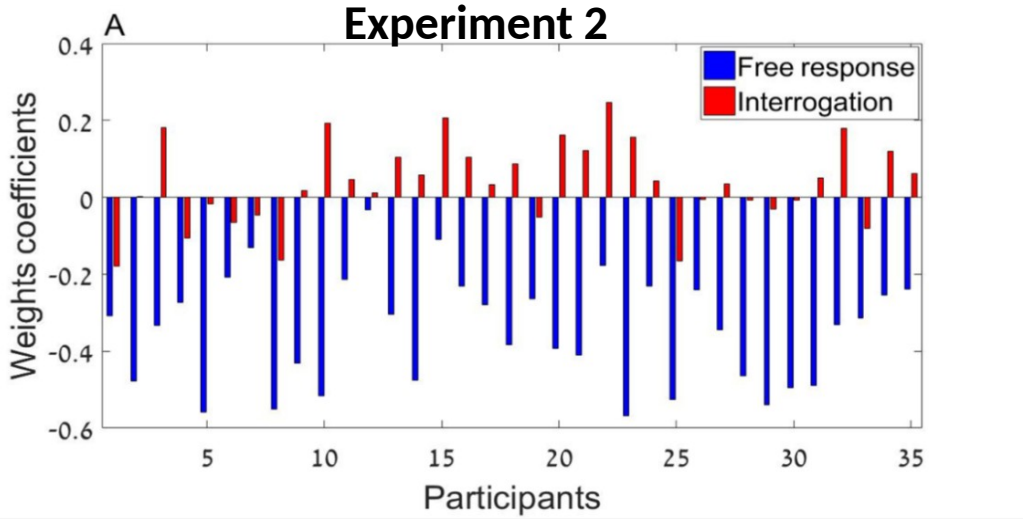


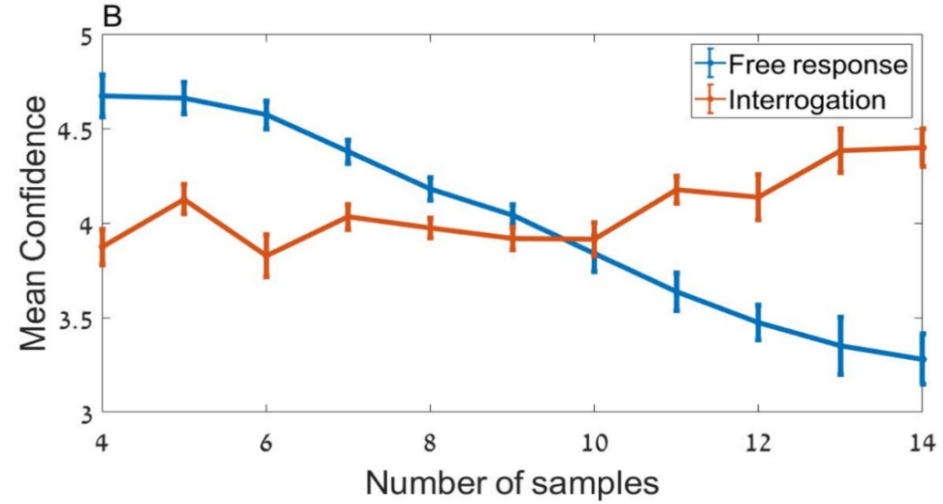


Confidence-RT correlations (free choice vs interrogation)





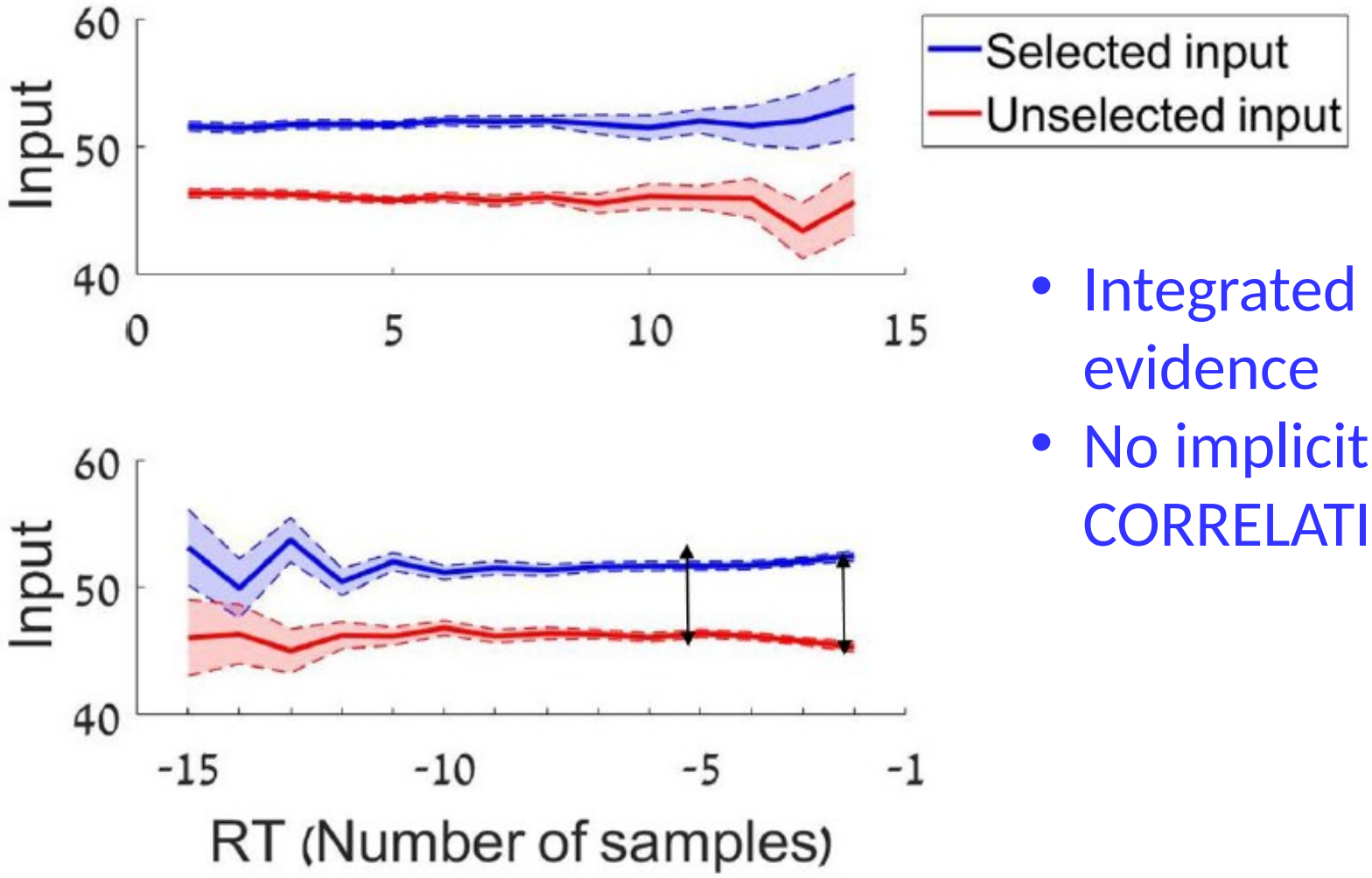




Computational models for FR choice (model selection)

Vickers' Accumulator model	Diffusion model Collapsed	Diffusion model Fixed	
1 (967)	34 (801)	0(1000)	Winners Frequency (Group BIC)

Computational models for interrogation choice



- Integrated evidence/Leaky integrated evidence
- No implicit boundary (REVERSE CORRELATION)

Computational models for confidence in FR

Several models to predict confidence:

- Accumulated evidence =
- Leaky accumulated evidence = λ^{n-i}
- RT (number of samples in each trial)
- Last item evidence =
- Last item evidence-1=
- Stop boundary point (correlated with RT)
- Split evidence=

Computational models for confidence

Free response session

Model	BIC	R	LL*(2−)
Last Item Evidence_Rest Evidence_RT	**346.50**	**0.57**	**326.88**
Last Item Evidence_RT	352.42	0.53	337.71
Split Last Item_RT	354.97	0.53	335.35
Last Item Evidence_Stopping Point Boundary	355.14	0.51	340.42
Accumulated Evidence_RT	355.30	0.51	340.59
Last Item Evidence_Stopping Point Boundary_RT	355.70	0.53	336.08
Leaky Integrated Evidence	356.86	0.51	342.00
Split Last Item_Stopping Point	357.64	0.52	338.02
Last Item Evidence_Rest Evidence	360.60	0.48	345.89
Last Item Evidence_Last Item Evidence-1_Rest	361.79	0.50	342.17
Accumulated Evidence	368.16	0.41	358.35
Selected Samples_Unselected Samples	374.37	0.50	340.04

Computational models for confidence

Interrogation session

Model	BIC	R	LL*(2−)
AccumulatedEvidence	**357.65**	0.48	347.84
LeakyIntegratedEvidence	358.3	**0.50**	343.59
LastItemEvidence_RestEvidence	359.32	0.49	344.6
AccumulatedEvidence_RT	359.86	0.49	345.14
LastItemEvidence_RestEvidence_RT	361.84	0.50	342.23
LastItemEvidence_LastItemEvidence-1_RestEvidence	362.42	0.50	342.81
LastItemEvidence_LastItemEvidence-1_RestEvidence_RT	361.13	0.50	340.61
LastItemEvidence_RT	389.41	0.25	374.70
SelectedSamples_UnselectedSamples	392.82	0.37	358.50
SplitLastItem_RT	393.08	0.25	373.47

Summary

- Integration to boundary is optimal for choice
- This comes with a coast in confidence-resolution: integrating to boundary reduces variability in relevant evidence that can signal posterior probability
- Some confidence resolution can be achieved by post-decision mechanism or by using collapsing boundaries (if corrects are faster than incorrects)
- The confidence mechanism differs in integration-to boundary (*RT & post-decision*) vs fix number of samples (*SD based on total evidence*)

Rosenbaum D, Glickman M, Fleming SM & Usher M (2022).
The Cognition/Metacognition Trade-Off. ***Psychological Science.***

David Rosenbaum Moshe Glickman Steve Fleming

Tel-Aviv University UCL, London

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