



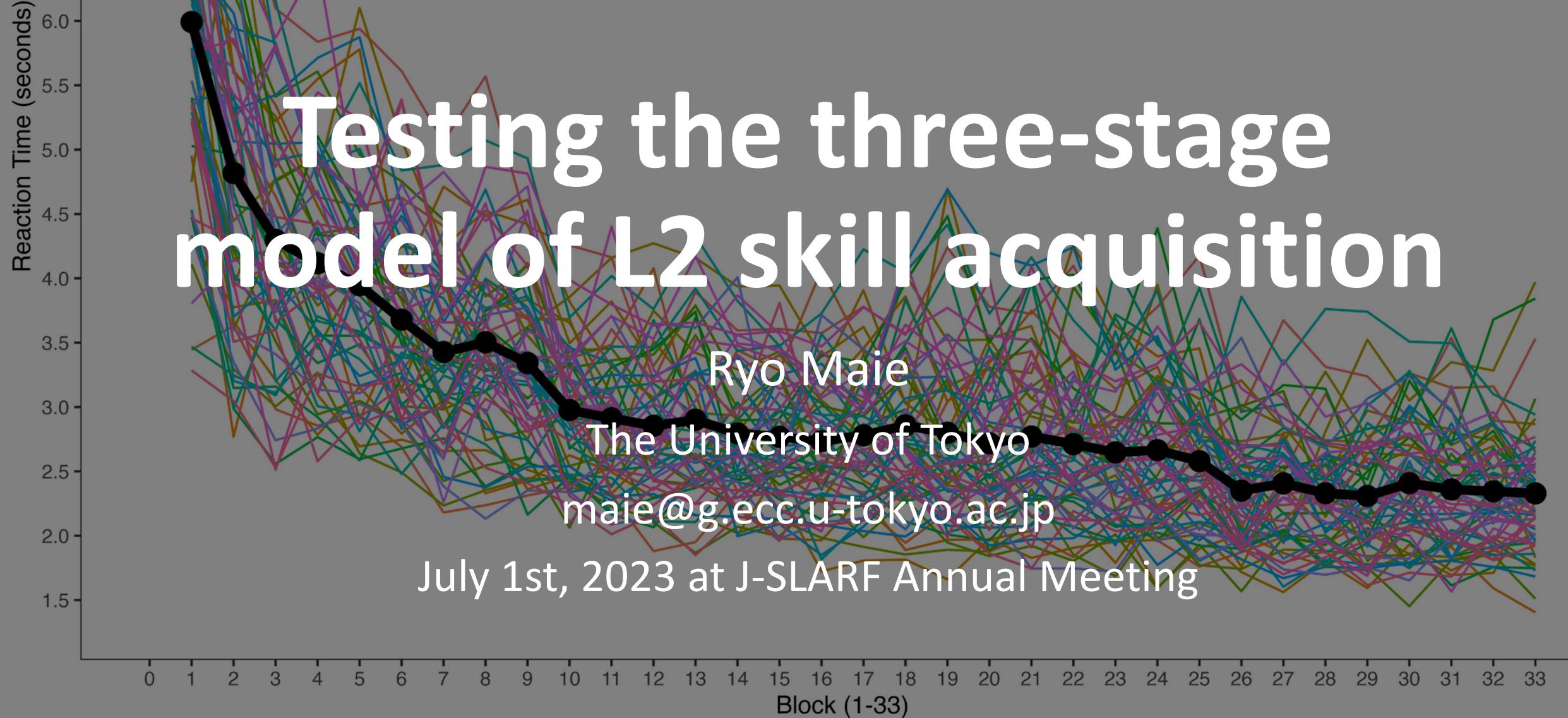
# Testing the three-stage model of L2 skill acquisition

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July 1st, 2023 at J-SLARF Annual Meeting



# L2 learning as skill acquisition



Second  
Language

## Skill acquisition theory

Learning as acquisition of *skills*

Learning done by some simple sets of domain-general mechanisms

## L2 skill acquisition

Acquiring L2 skills = skill acquisition in other domains (e.g., typing, driving a car, solving math problems)

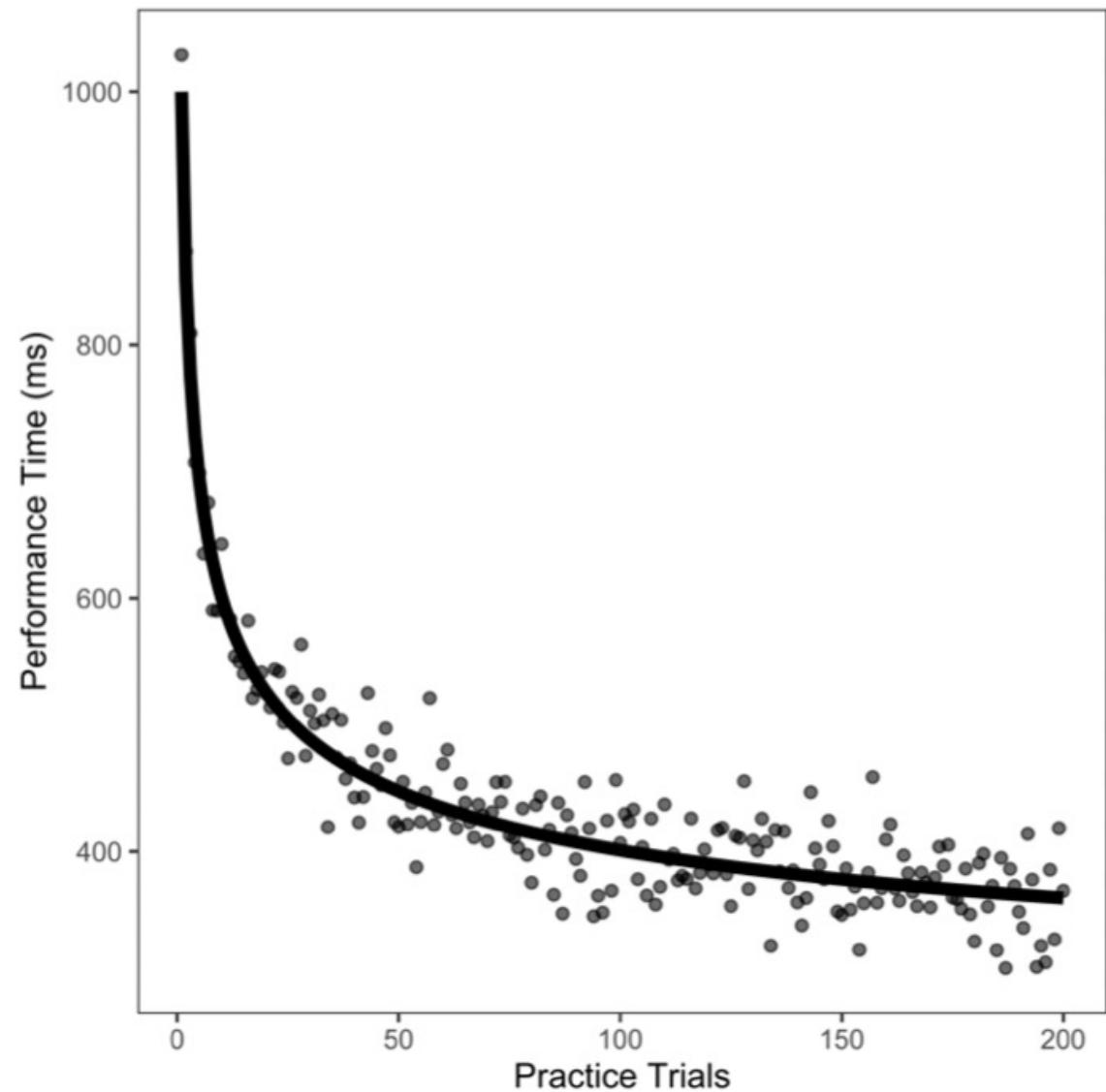
John Anderson (1983):

*“language is cut from the same cloth as the other cognitive processes”* (p.261)

# Evidence on **L2** skill acquisition

Skill acquisition ...

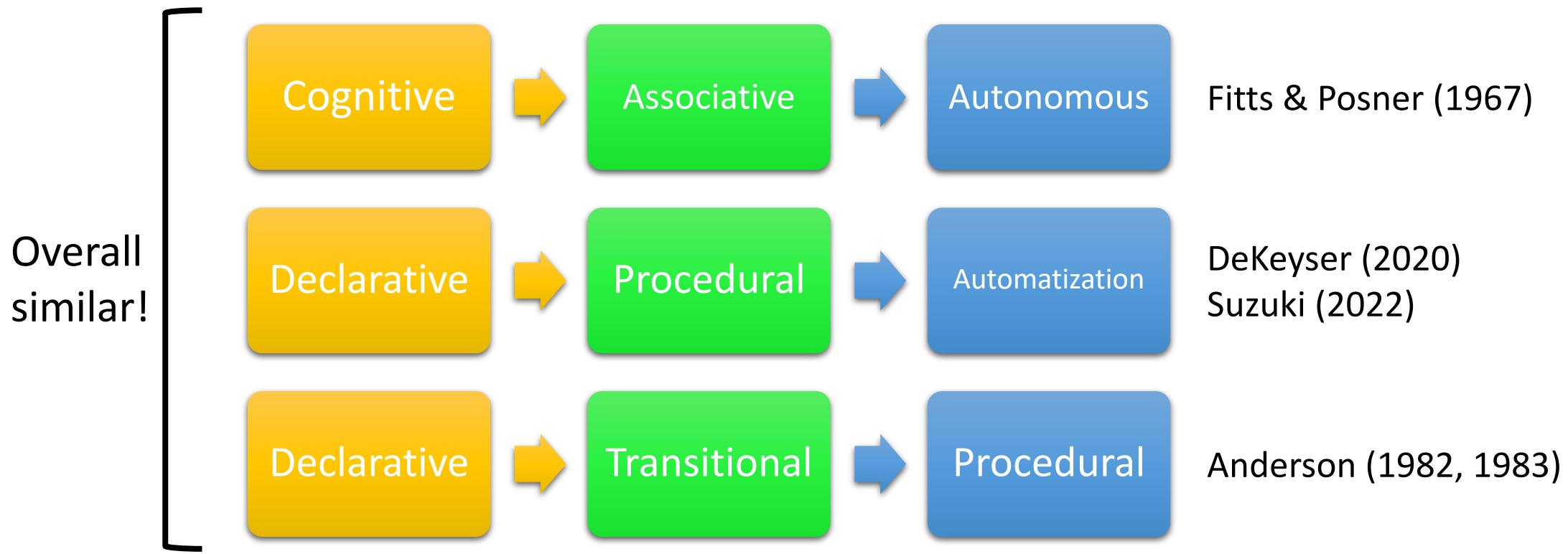
1. follows **the power-law of practice**
  - DeKeyser (1997), Ferman et al. (2009), Hui (2020), Maie (2020)
2. leads to **skill-specific** competence
  - comprehension vs. production
  - DeKeyser (1997), DeKeyser & Sokalski (1996), Li & DeKeyser (2017), Suzuki & Sunada (2019)



# Skill acquisition theory

The dominant view: **L2 skill acquisition is a three-stage process**

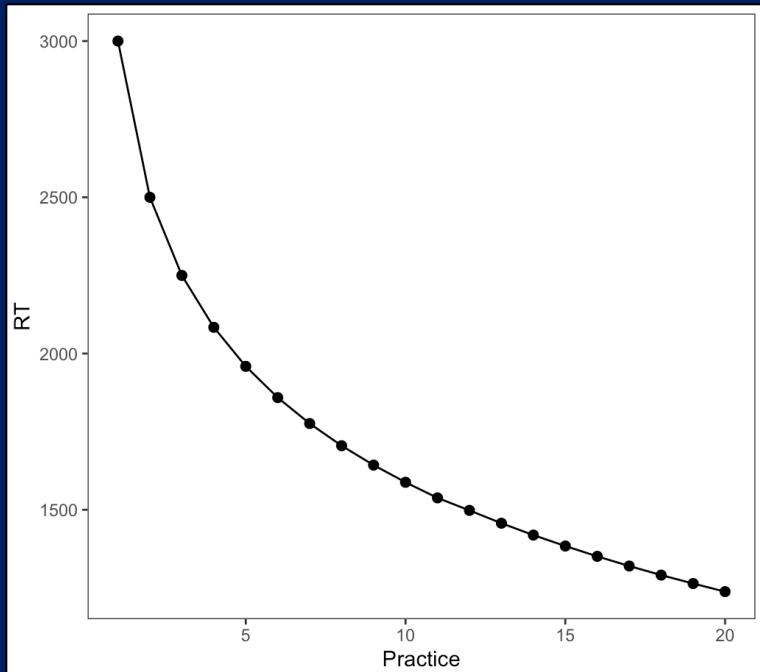
- skill “development from [1] initial representation of knowledge [2] through initial changes in behavior [3] to eventual fluent, spontaneous, largely effortless, and highly skilled behavior” (DeKeyser, 2020, p. 83)



# Race Model (Instance Theory)

Logan (1988)  
Logan (2002)

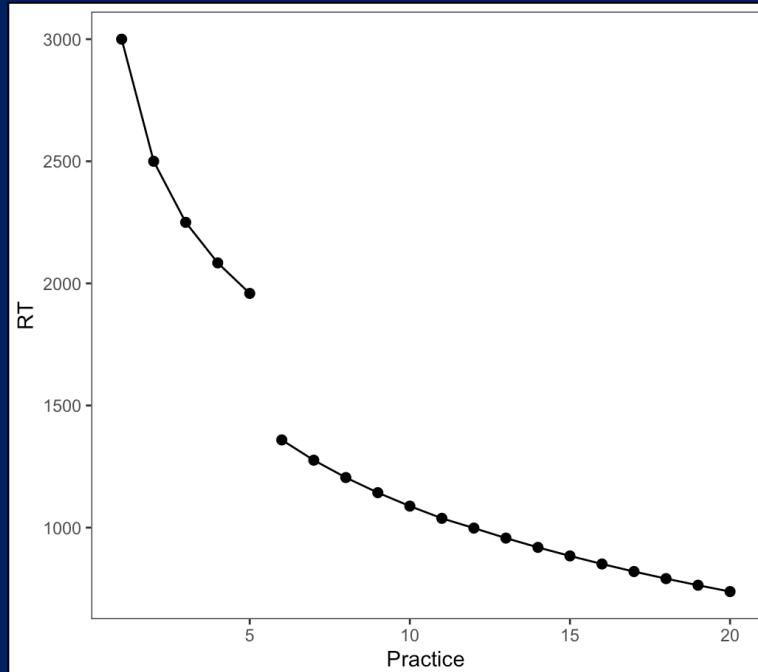
## Instance accumulation



# CMPL

Rickard (1997)  
Rickard (2004)

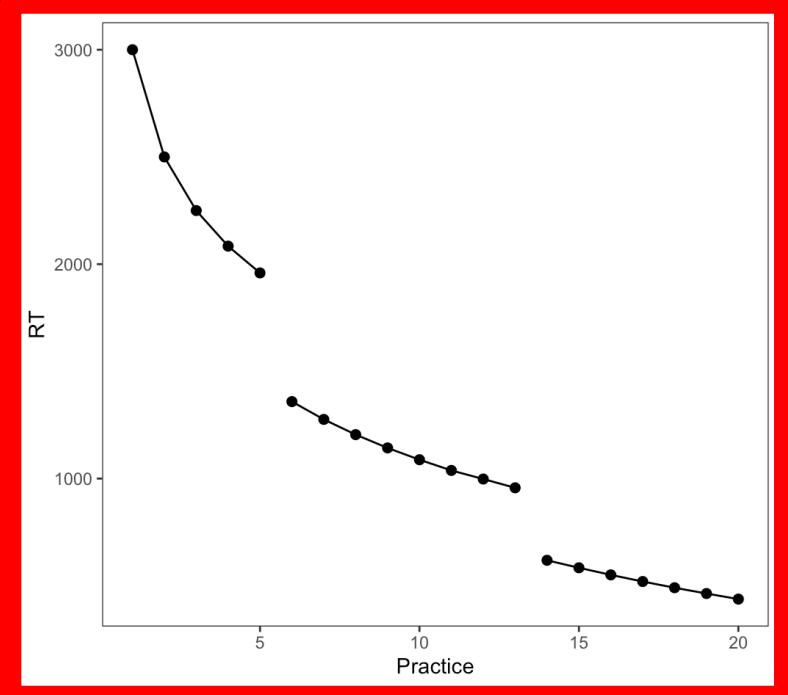
## Algorithm -> Item retrieval



# ACT-R

Anderson (1982)  
Anderson (2007)

## Declarative -> Transitional -> Procedural



One-stage  
model

Two-stage  
model

Three-stage  
model

# Individual differences in L2 skill acquisition

## The Declarative-Procedural Model (Ullman, 2004, 2014, 2020)

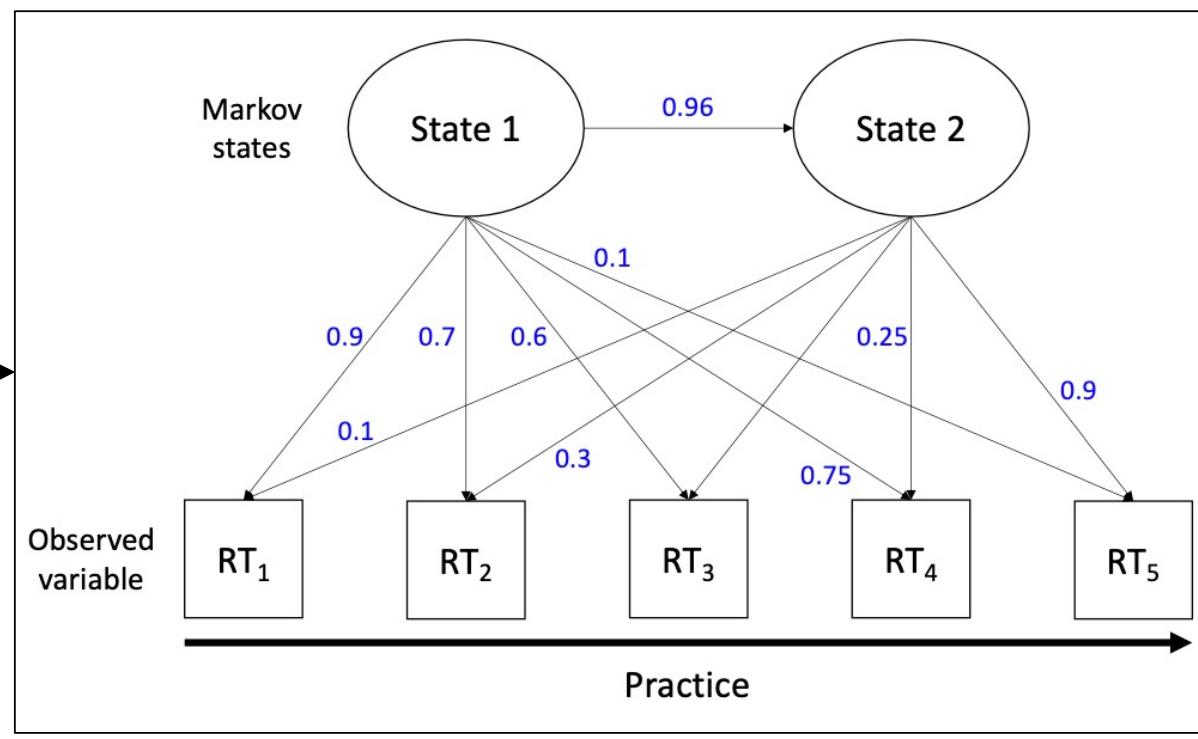
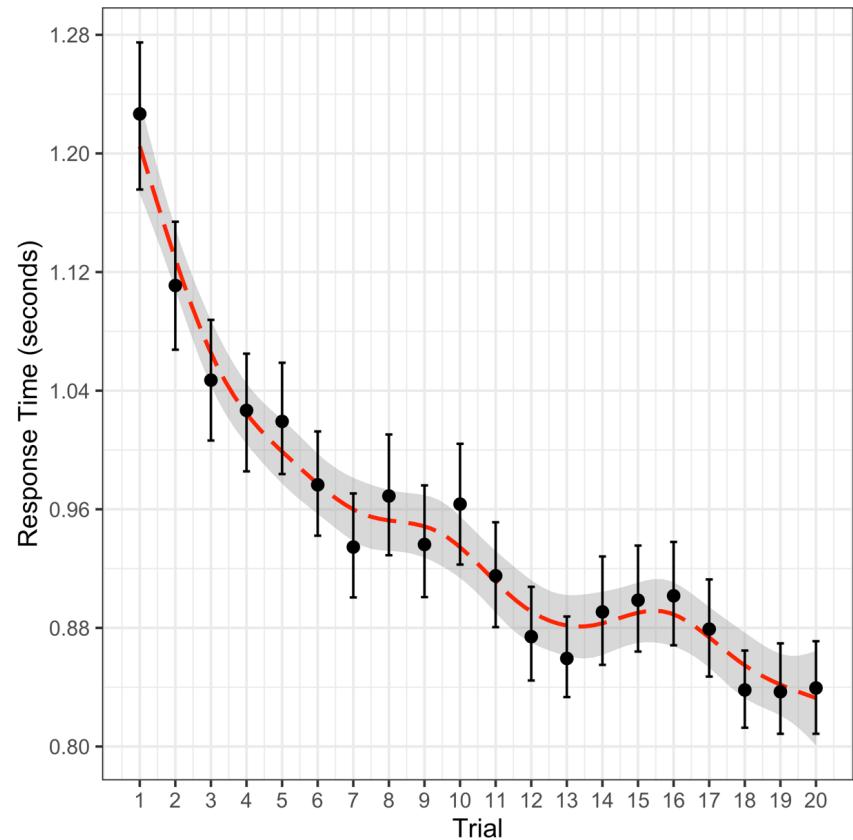
- Declarative memory: initial learning (for grammar)
- Procedural memory: gradually becomes dominant with proficiency
- Meta-analysis confirming the model (Hamrick et al., 2018)

## L2 automatization

- Procedural learning ability predicting the degree of automatization from practice (Pili-Moss et al., 2020; Suzuki, 2017)

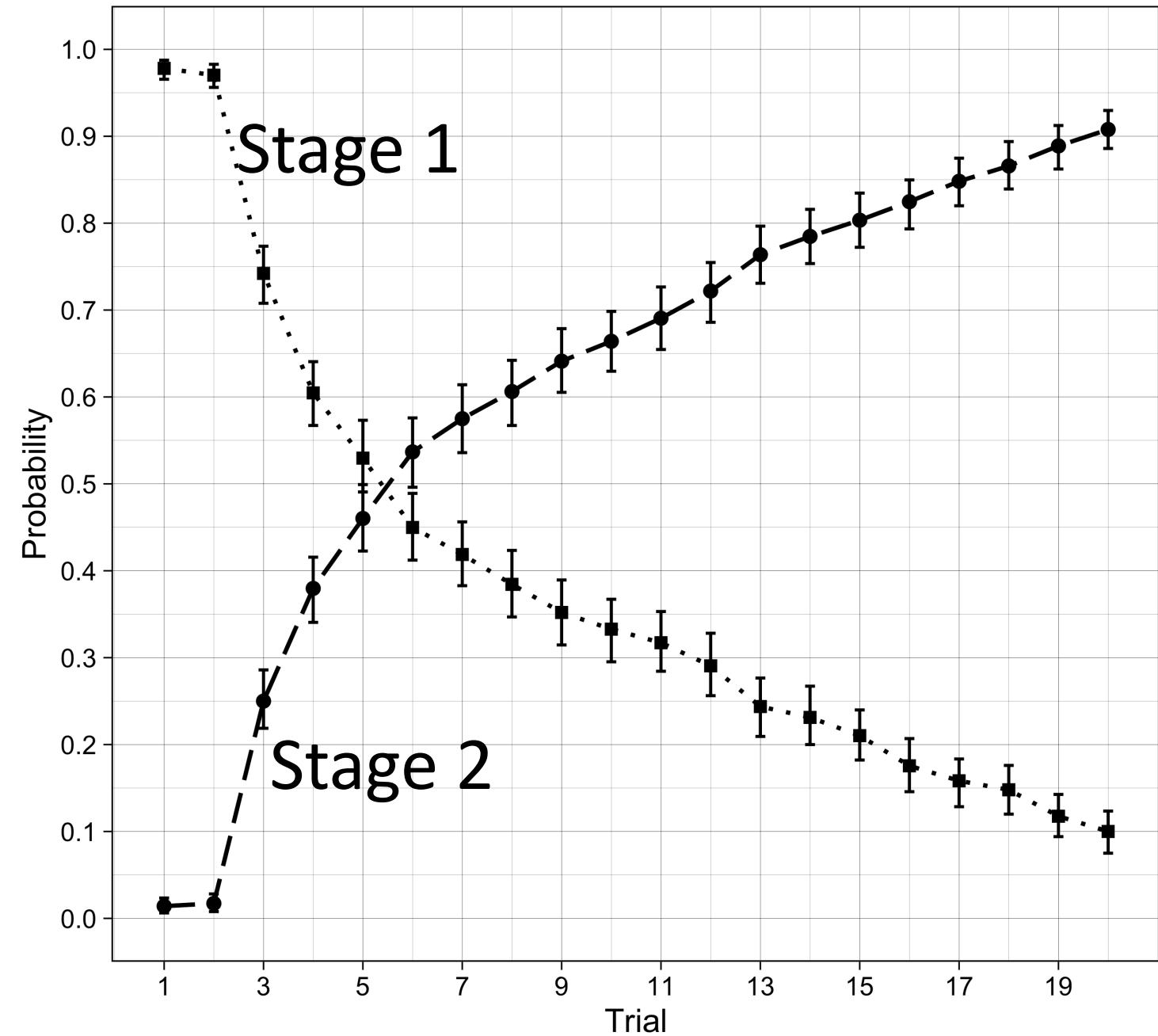
# Skill acquisition in L2 vocabulary (Maie, rejected)

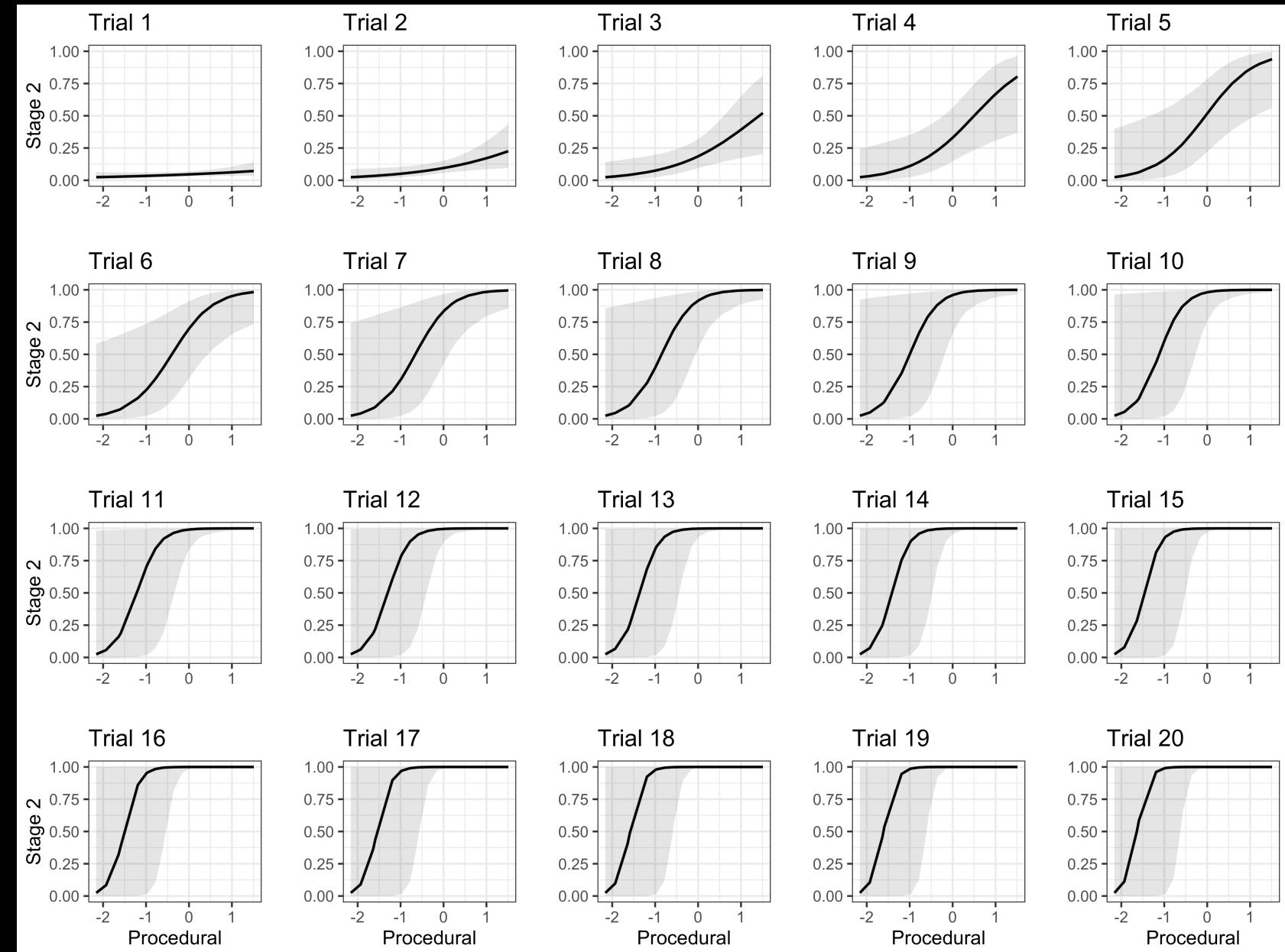
Applying cognitive modeling to reaction time data to test skill acquisition stages



Hidden Markov Modeling

# Skill acquisition in L2 vocabulary (Maie, rejected)





Higher  
procedural memory



Faster transition  
to Stage 2

# Maie & Godfroid (in progress)



When practicing a novel foreign language ...

1. How many stages of skill acquisition do L2 learners go through?
2. Which memory systems, declarative and/or procedural memory, are implicated in each learning stage?



6 days (6 hours in total)

# Language

---

- **Mini-Nihongo** (Mueller, 2006)
  - A miniature language based on Japanese
- Only S-O-V order
  - Canonical in Japanese

Grammar structure of Mini-Nihongo			
<p>The diagram illustrates the grammar structure of Mini-Nihongo. It shows a sequence of tokens: n, c, p, N, p, n, c, p, N, p, V. Brackets group these into three main parts: NP<sub>SUBJECT</sub> (n, c, p), NP<sub>OBJECT</sub> (n, c, p), and Verb (V). The NP<sub>SUBJECT</sub> and NP<sub>OBJECT</sub> groups each contain an N (noun) token, a p (postposition) token, and an n (number) token.</p>	NP <sub>SUBJECT</sub>	NP <sub>OBJECT</sub>	Verb
Vocabulary items and case-markers of Mini-Nihongo			
N [noun]	=	hato (pigeon), amo (duck), nezumi (mouse), neko (cat)	
V [verb]	=	tobikoeru (jump over), tsukamaeru (capture), oikakeru (chase away), otozureru (visit)	
n [number]	=	ichi (one), ni (two)	
c [classifier]	=	wa (bird class), hiki (small animal class)	
p [postposition]	=	ga (nominative), o (accusative), no (genitive)	

# Procedure

Day 1 (39 mins)	Min
1. Background questionnaire	1
2. Two-choice response task	3
3. Alternating serial reaction time task	15
4. Statistical learning task	20

Day 3 (70 mins)	Min
1. Vocabulary and grammar tests	5
2. Comprehension practice	20
3. Production practice	45

Day 4 (65 mins)	Min
1. Vocabulary and grammar tests	5
2. Production practice	40
3. Comprehension practice	45

Day 5 (60 mins)	Min
1. Vocabulary and grammar tests	5
2. Comprehension practice	20
3. Production practice	35

Day 6 (55 mins)	Min
1. Vocabulary and grammar tests	5
2. Production practice	30
3. Comprehension practice	20

# Language Training



## Explicit instruction of Mini-Nihongo (Day 2)

Explicit-deductive instruction in the form of a 19-minute video

Grammar explanation with examples and exercises

<https://osf.io/vh6ap>

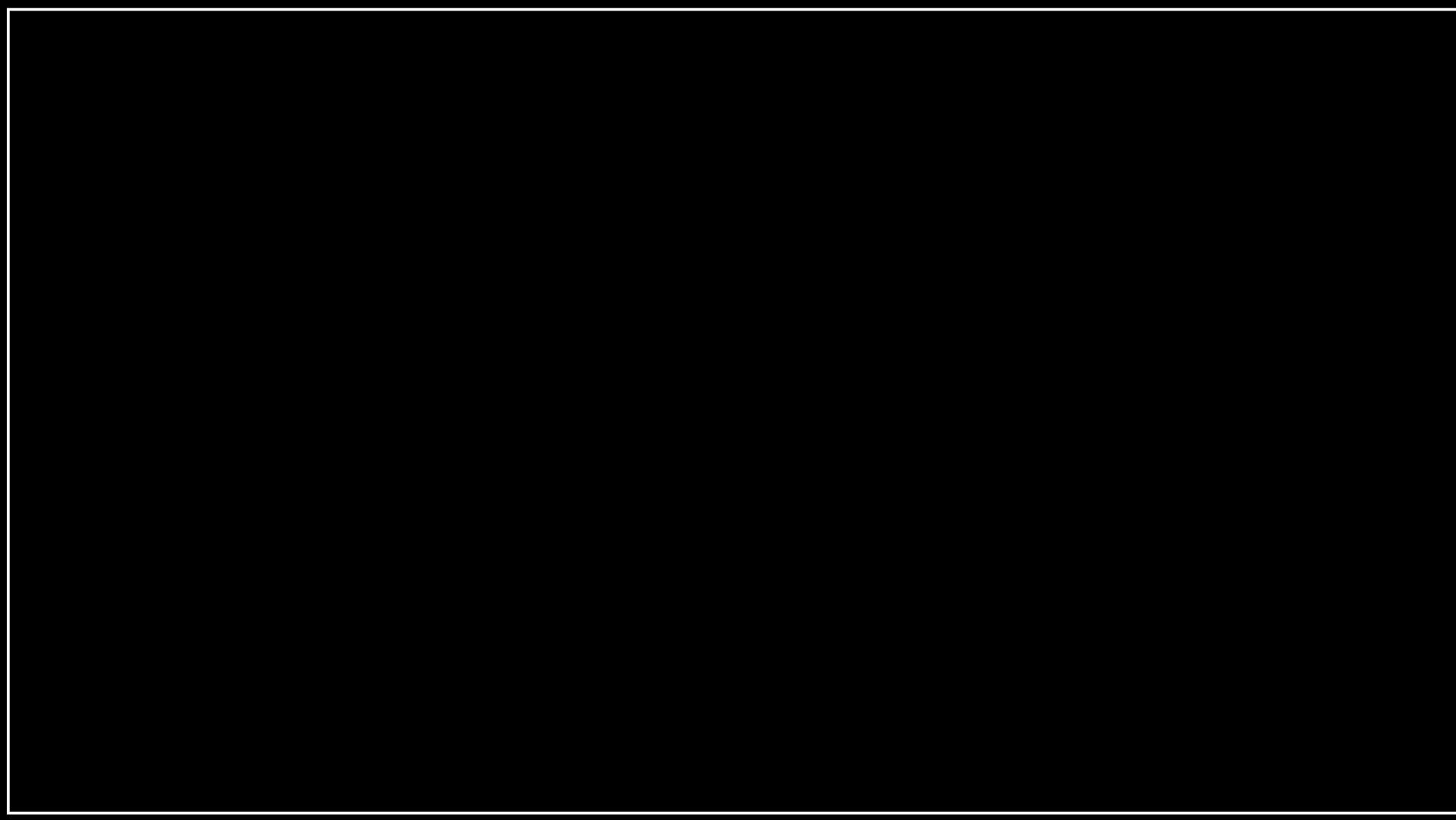


## Vocabulary and grammar knowledge test (Day 2, 3, 4, 5, 6)

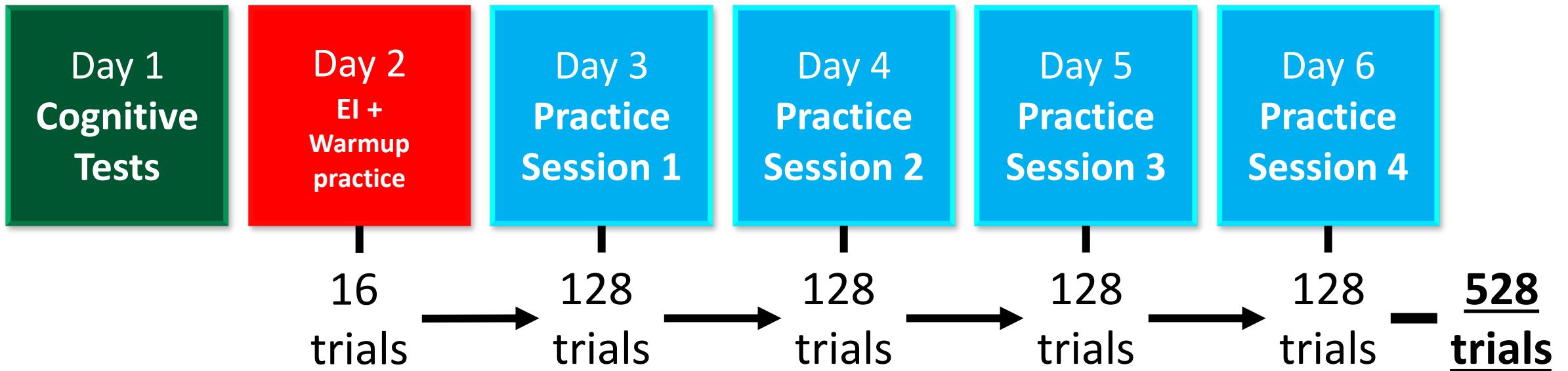
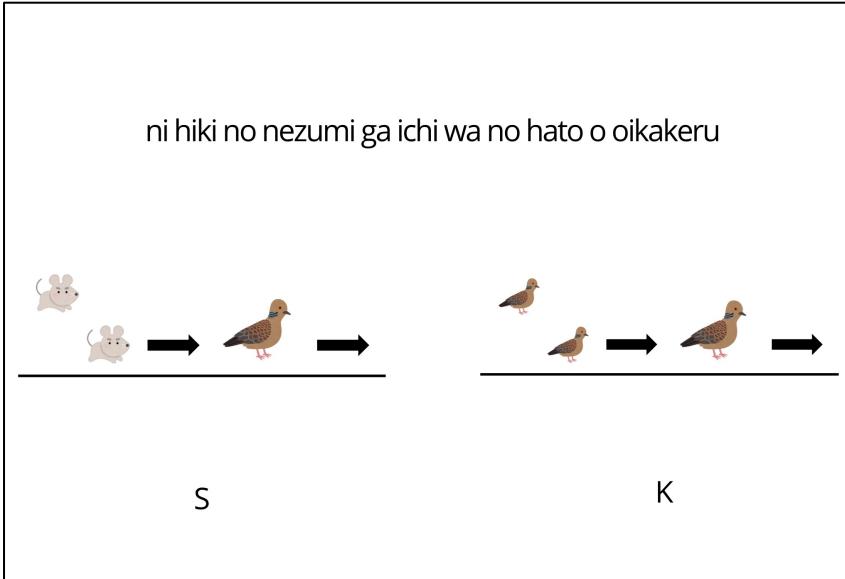
Vocabulary: A picture-word matching task for nouns and verbs ( $k = 24$ )

Grammar: A metalinguistic knowledge test with a fill-in-the-blank format ( $k = 9$ )

# Language Practice (Comprehension Practice)



# Language Practice (Comprehension Practice)



# Cognitive Tests

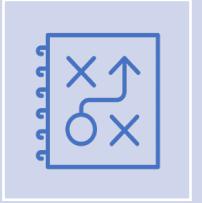


## Declarative Memory

### **Continuous Visual Memory**

**Task** (domain-general)

**LLAMA-B** (domain-specific)



## Procedural Memory

### **Alternating reaction time task**

(domain-general)

### **Statistical learning task**

(domain-specific)

# Measured Variables



**Accuracy** (0 or 1)



**Reaction Time**  
(seconds)



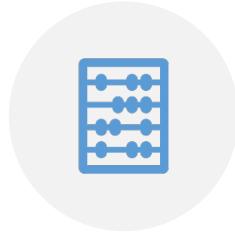
**CVMT** (d-prime)



**LLAMA-B** (0-100)



**ASRT** (milliseconds)



**SL** (0-24)

# ► Analysis

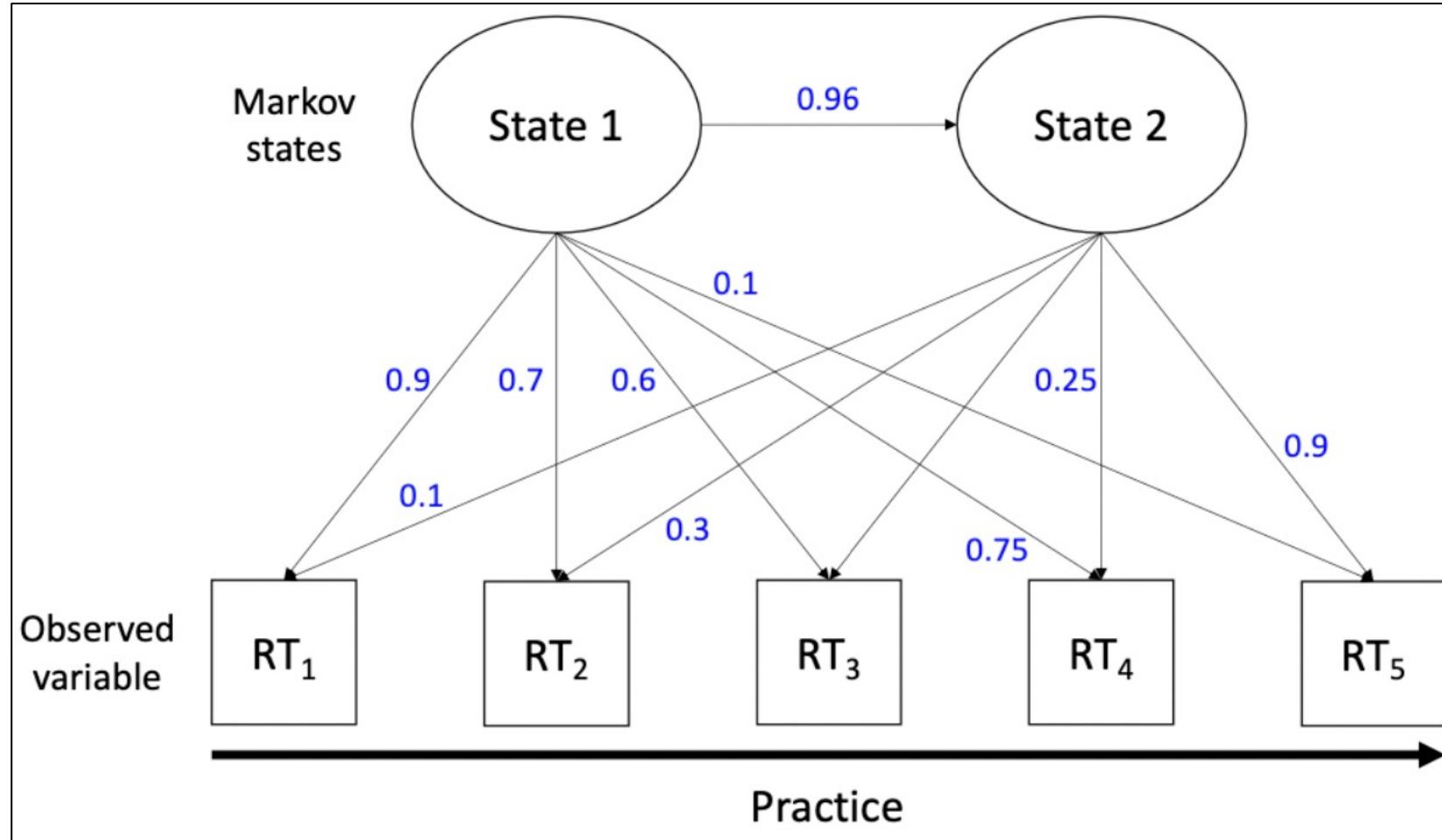
## 1. Hidden Markov modeling

- takes RT as the dependent variable
- estimates the probability of each participant residing in each learning stage on each practice trial
- identifies **the number** of skill acquisition stages by comparing one, two, and three-states models

## 2. Regression modeling

- identifies **the nature** of skill acquisition stages by investigating which cognitive abilities predict learning in each learning stage

# Hidden Markov modeling



Three HMM models

- One-state model
- Two-state model
- Three-state model

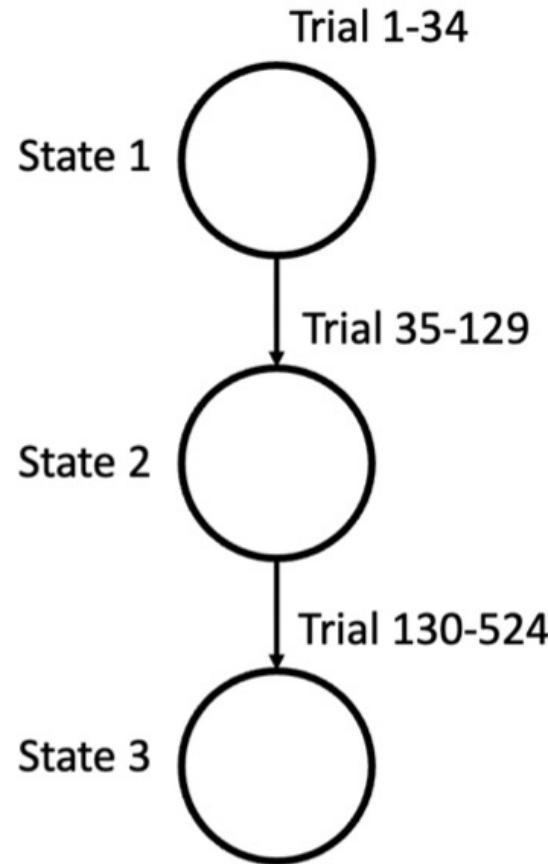


Model comparison

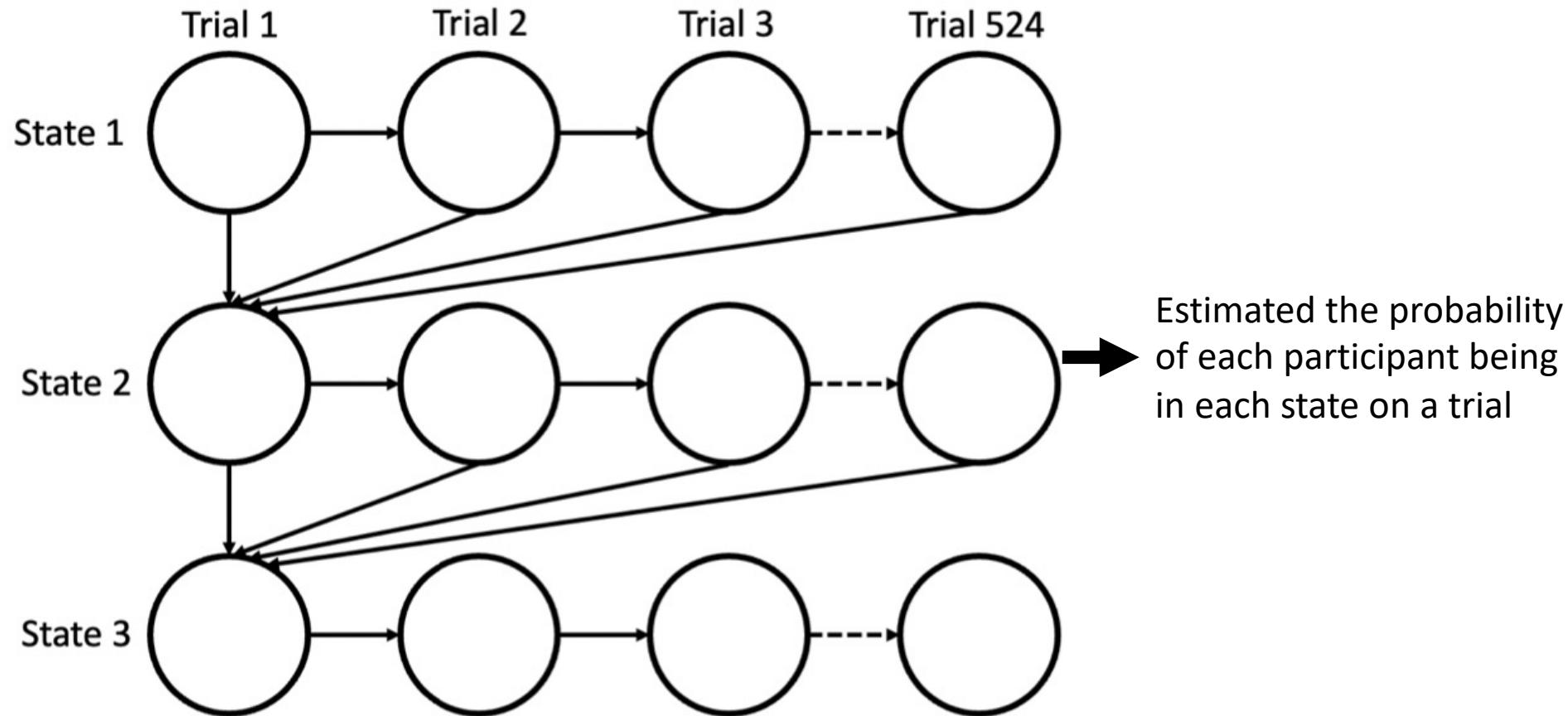
- Log-likelihood
- AICc
- BIC

# Hidden Markov modeling

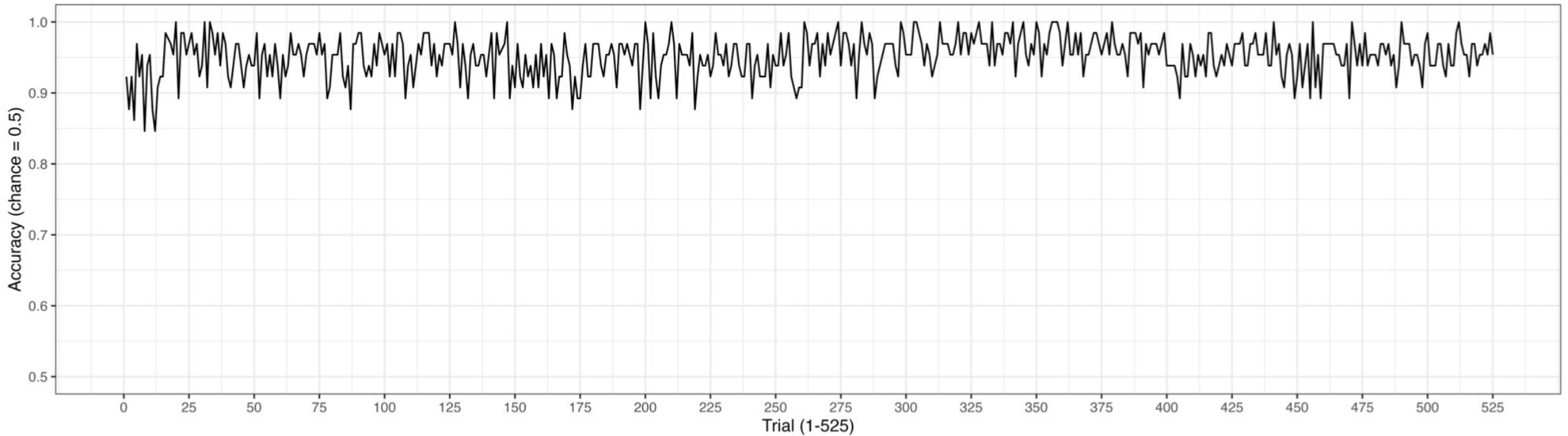
(a)



(b)



# Results: Accuracy



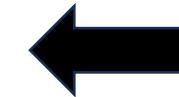
# Results: Reaction Time



# Hidden Markov Modeling

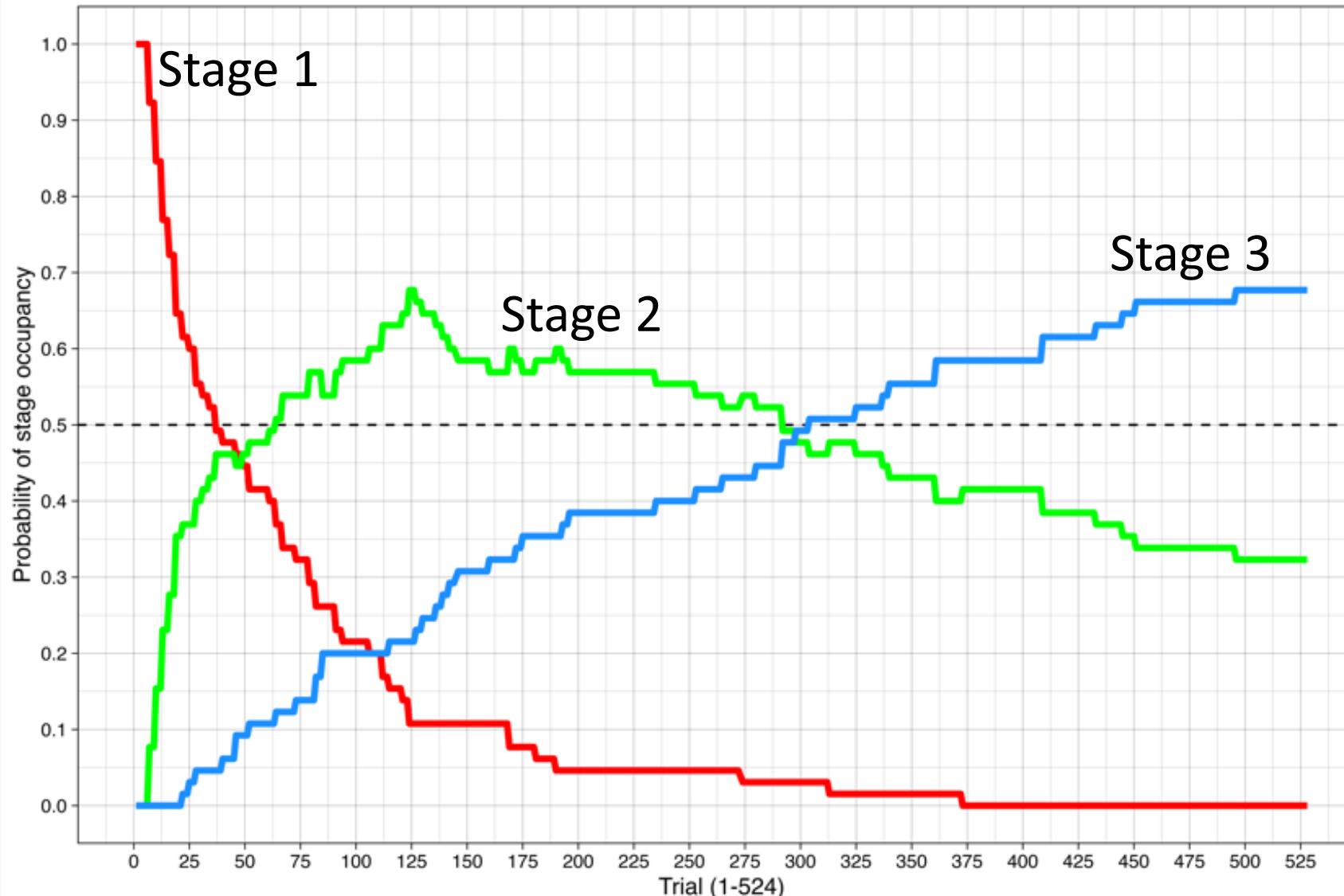
	BIC	Diff	Pr(M)
One-stage	39902	3239	.000
Two-stage	36700	37	.000
Three-stage	36663	0	$\approx 1.000$

The best fitting model  
&  
Way(!) more probable  
than the other models



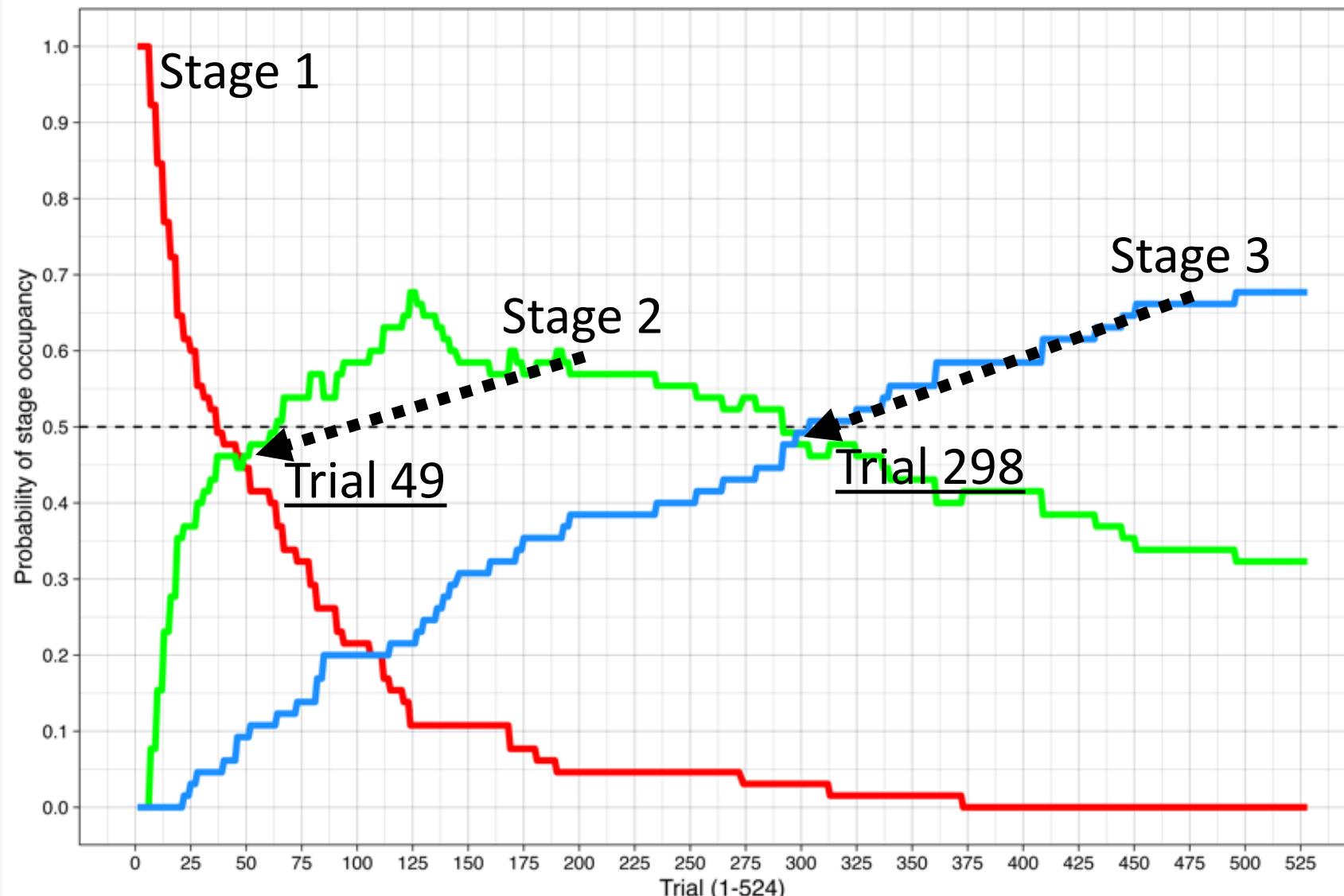
	Intercept	$\beta_{\text{Stage1}}$	$\beta_{\text{Stage2}}$	$\beta_{\text{Stage3}}$	$\alpha$
One-stage	0.07	7.17	-	-	-0.23
Two-stage	0.50	6.70	4.25	-	-0.20
Three-stage	0.00	6.65	4.85	3.60	-0.12

# Hidden Markov Modeling



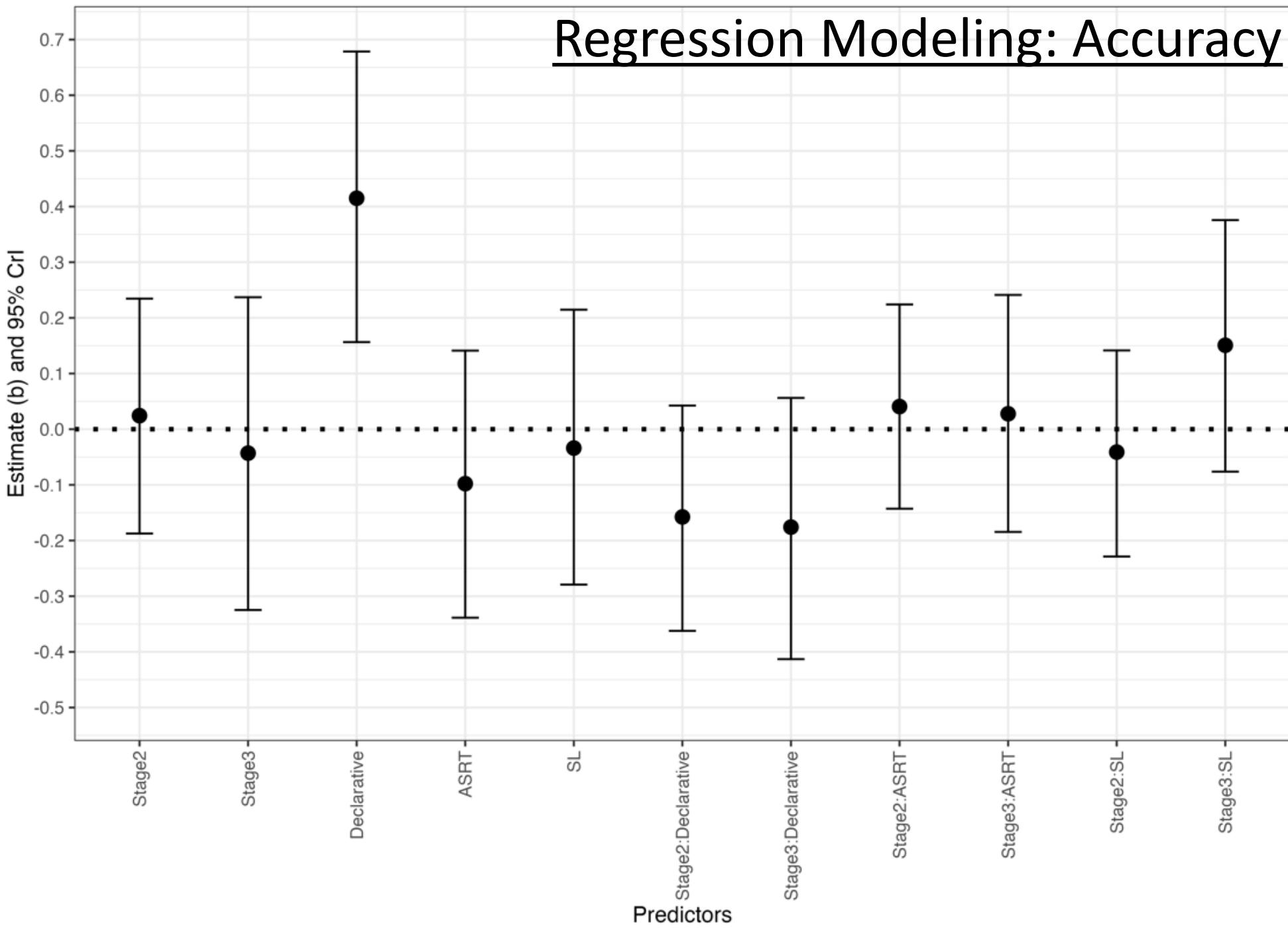
Note: DeKeyser (1997) – proceduralization can take place after 8-16 trials

# Hidden Markov Modeling

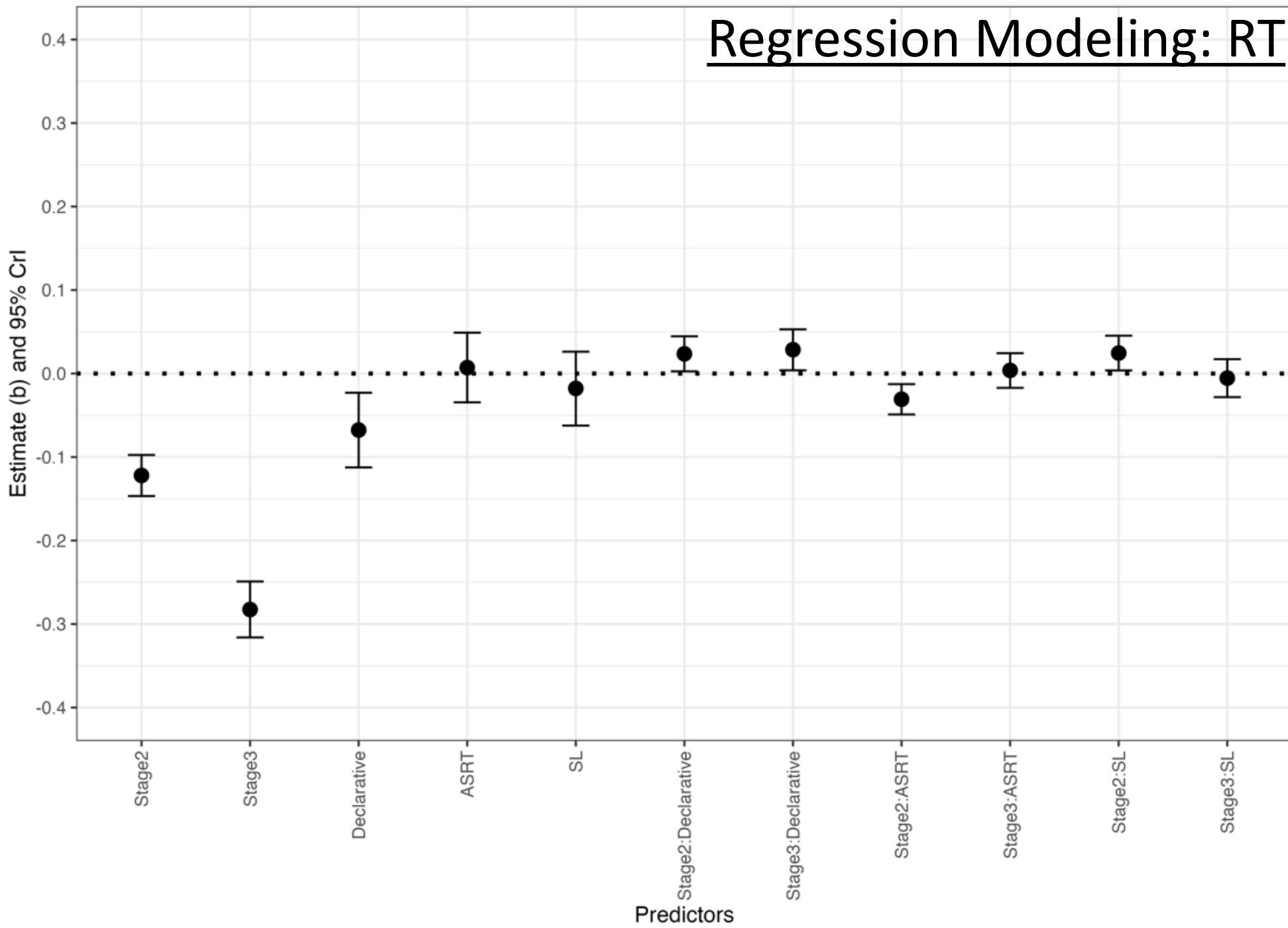


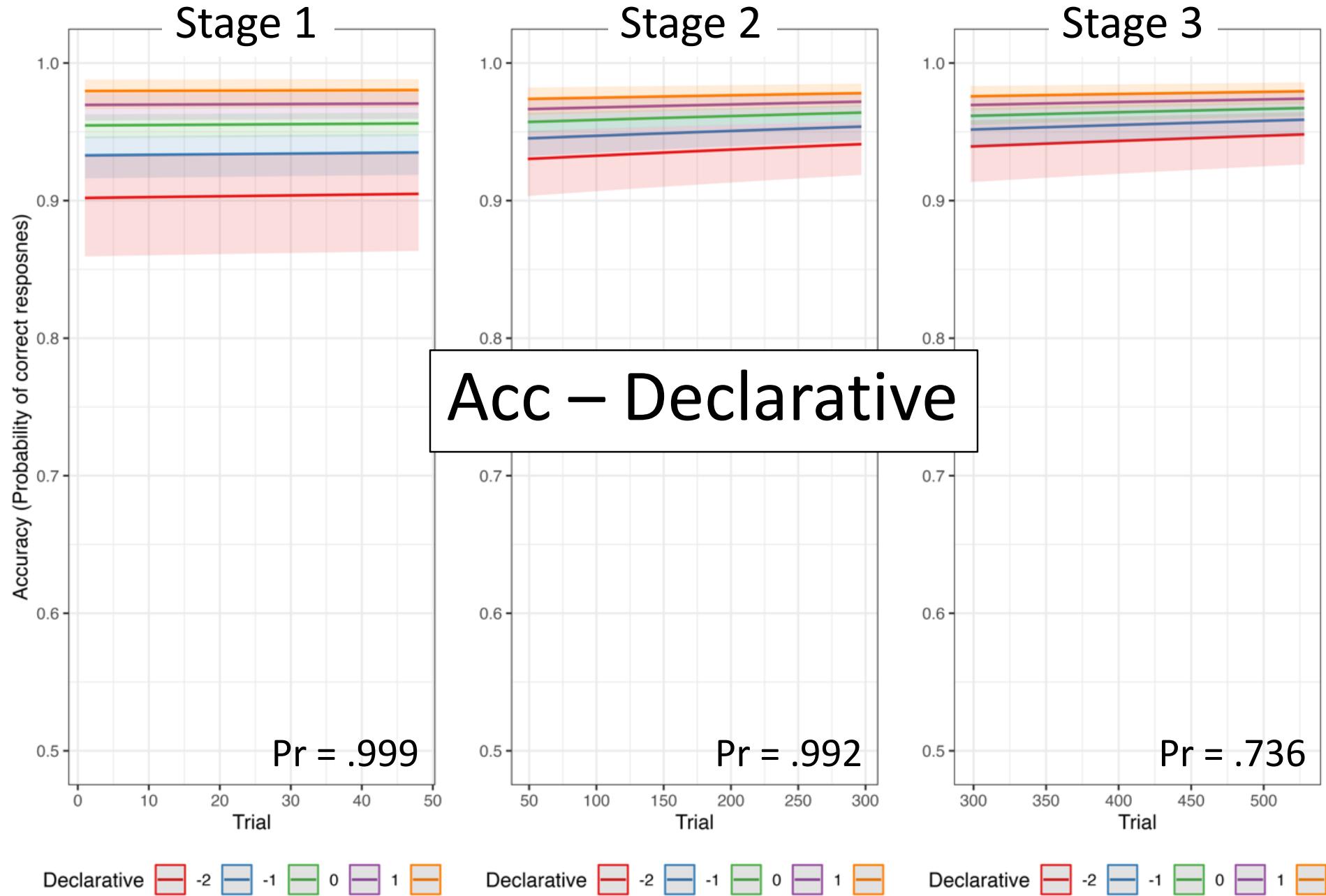
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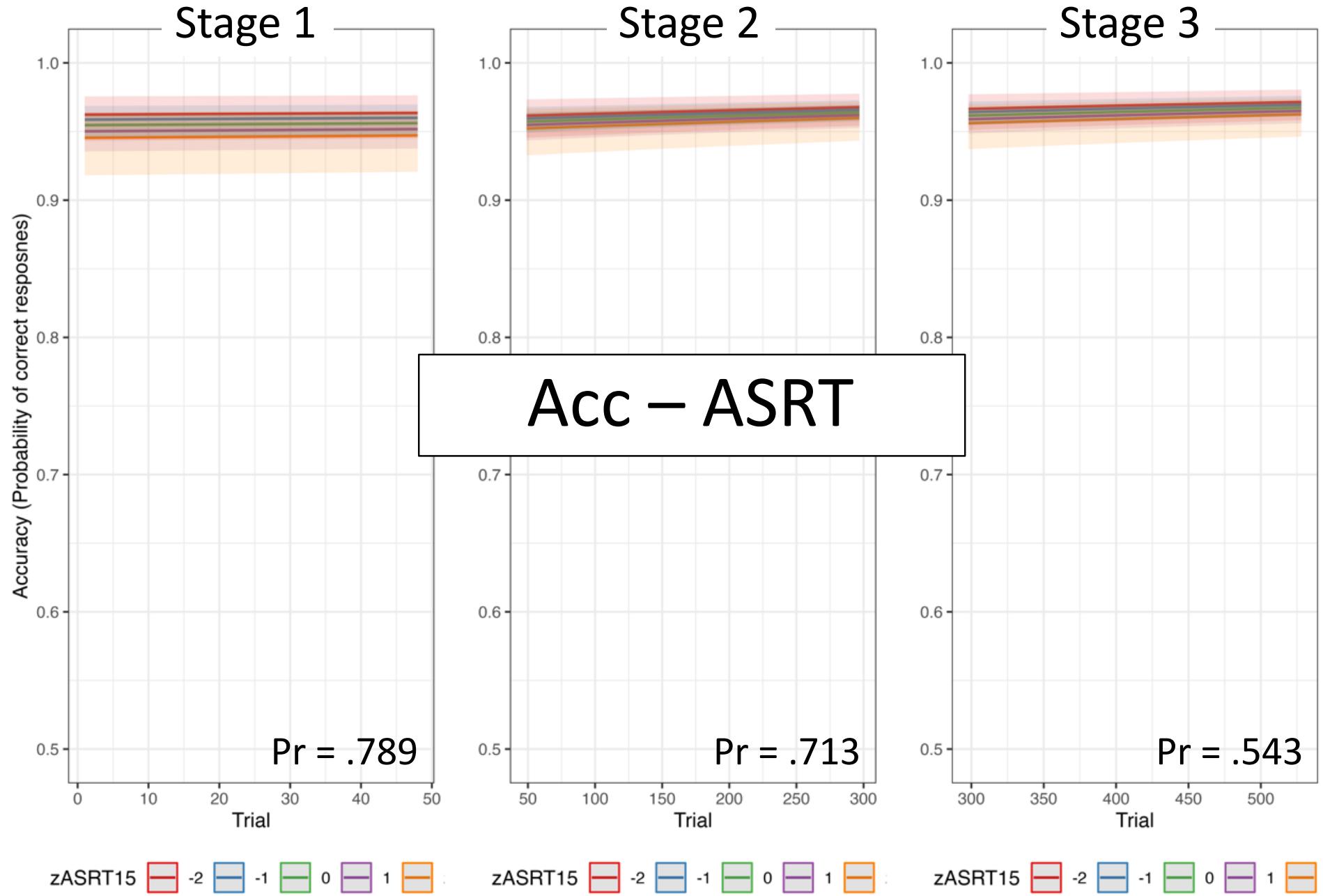
# Regression Modeling: Accuracy

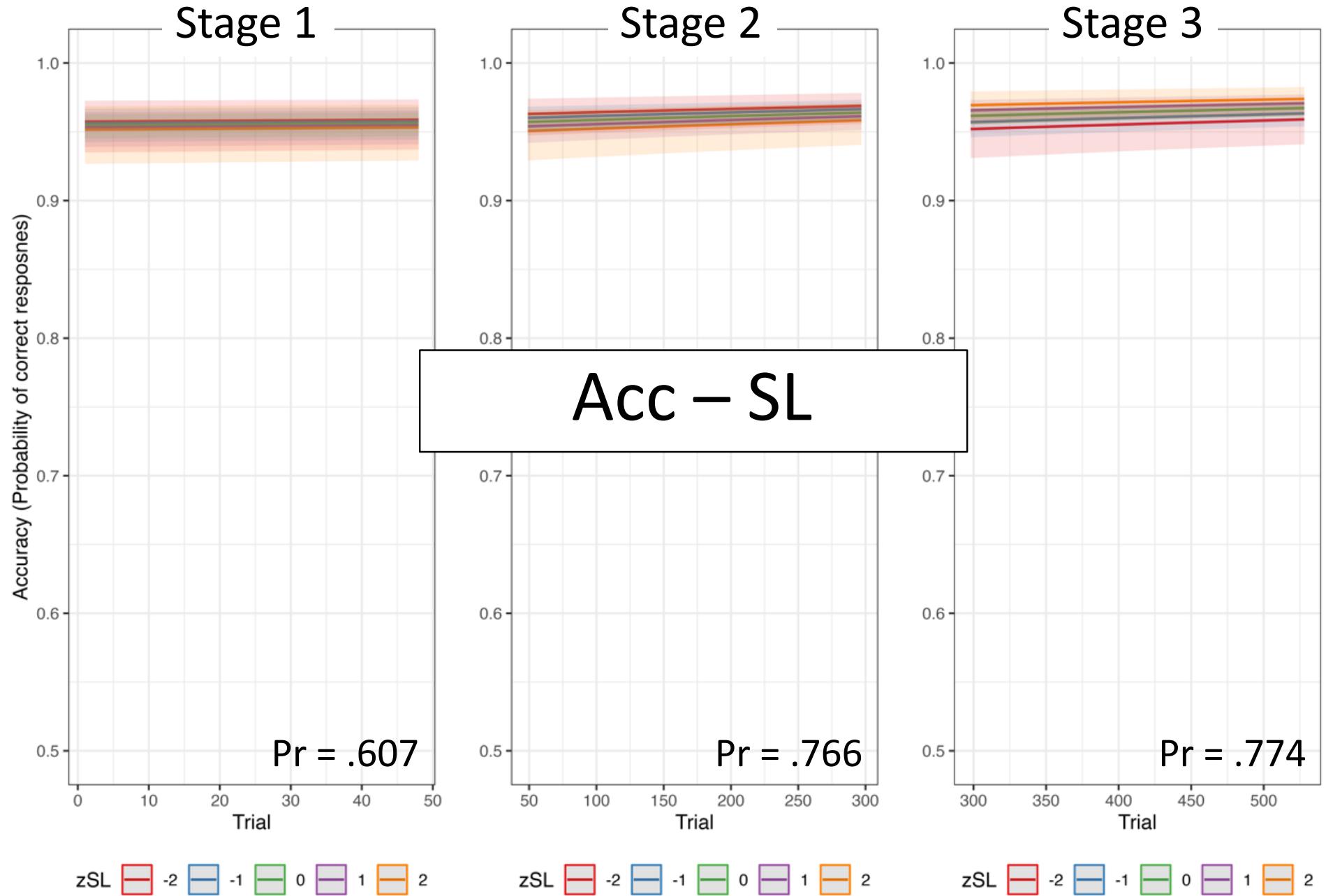


# Regression Modeling: RT

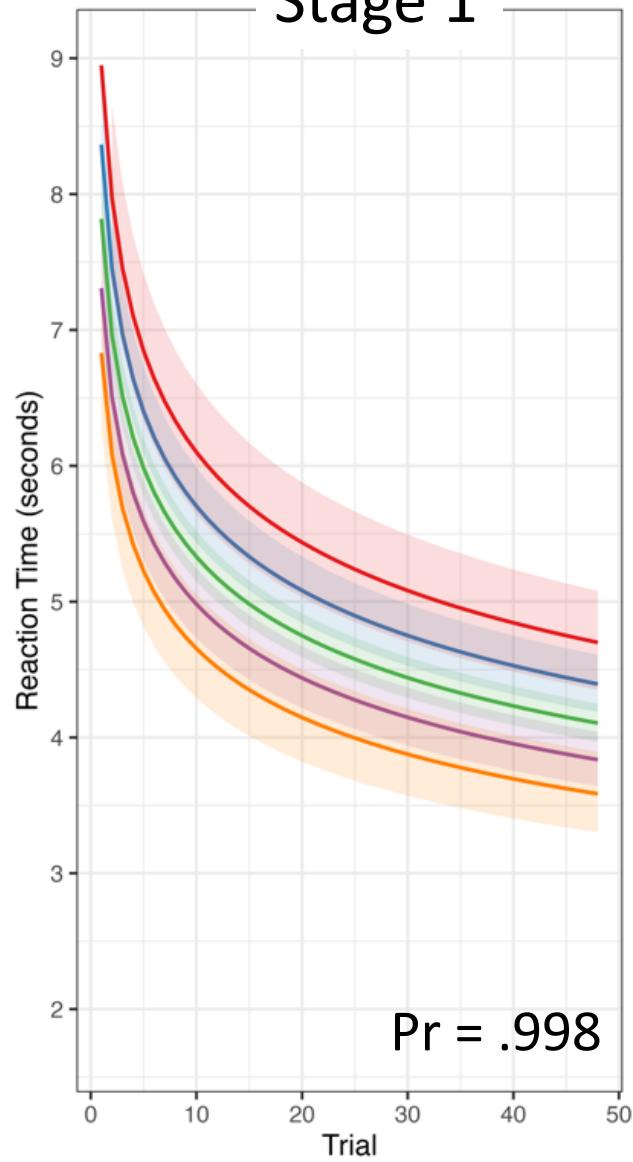




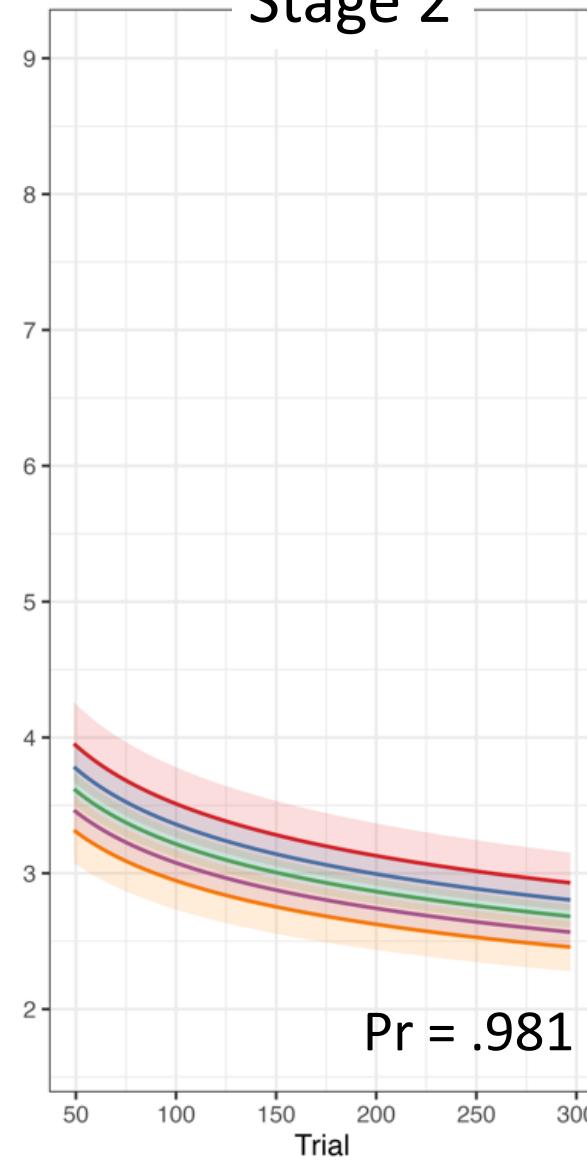




Stage 1

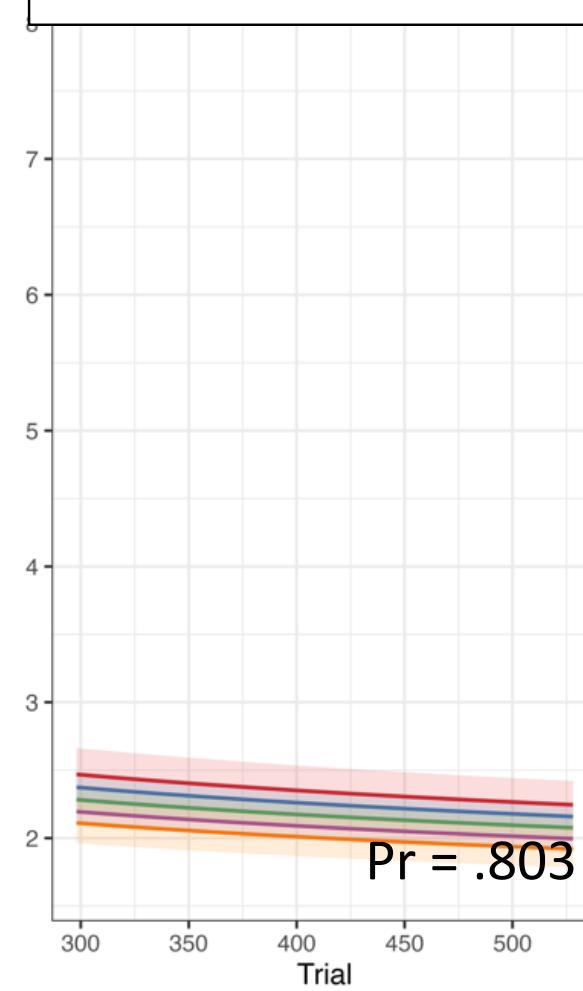


Stage 2

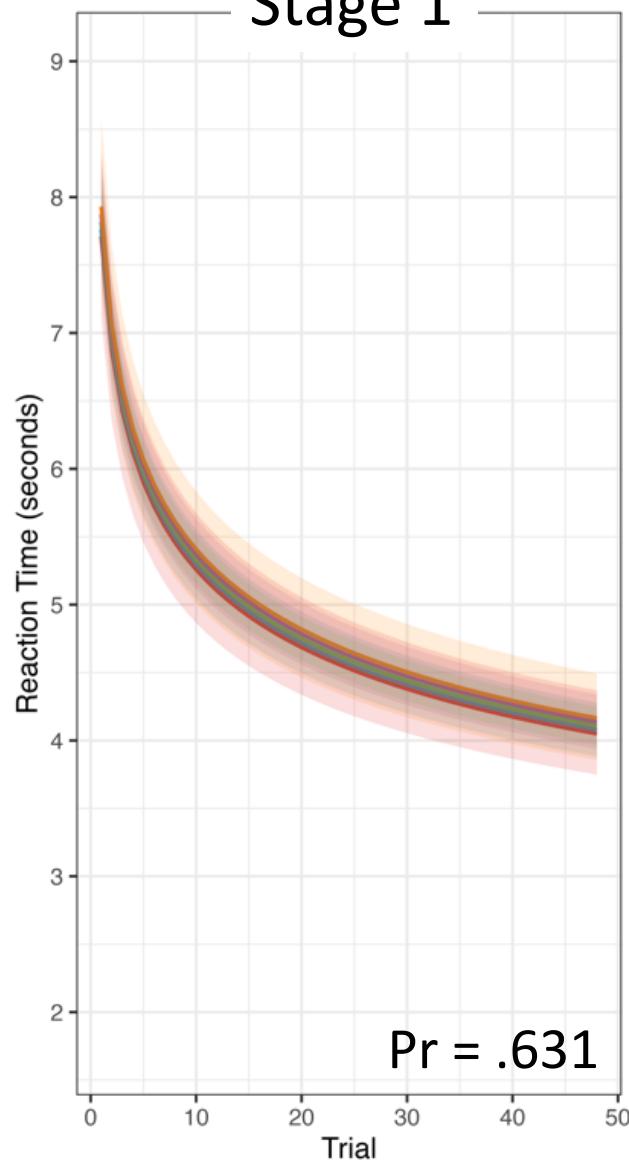


Stage 3

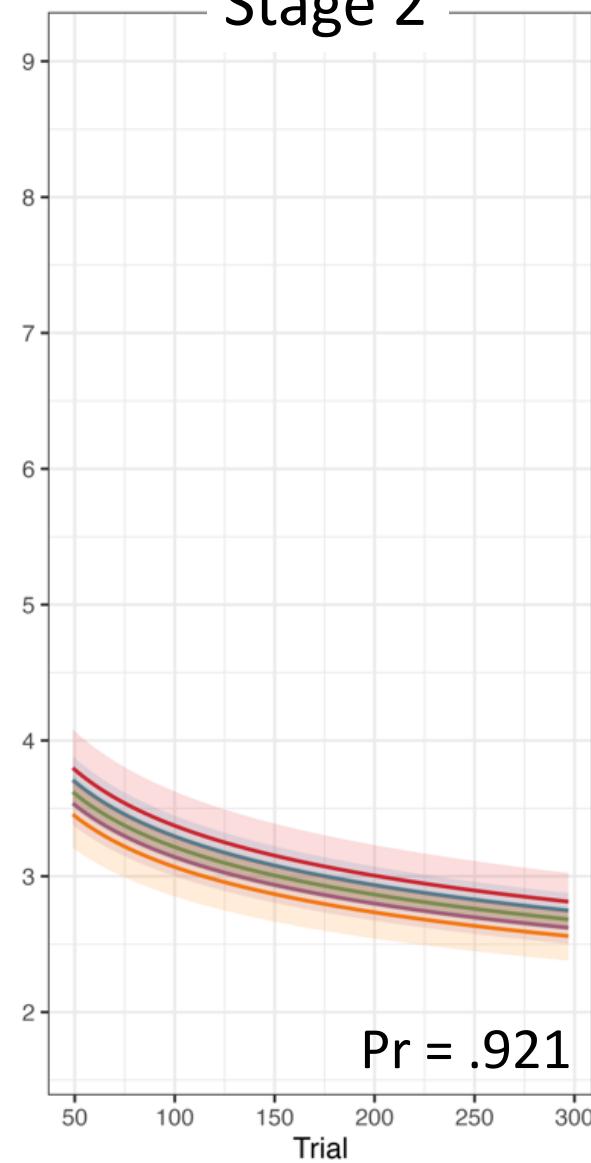
RT – Declarative



Stage 1

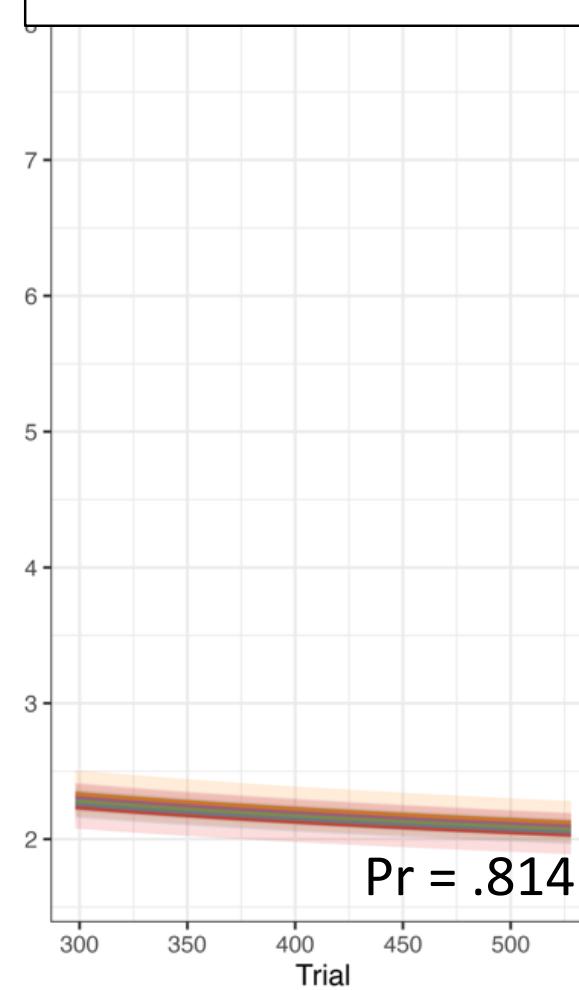


Stage 2



Stage 3

RT – ASRT

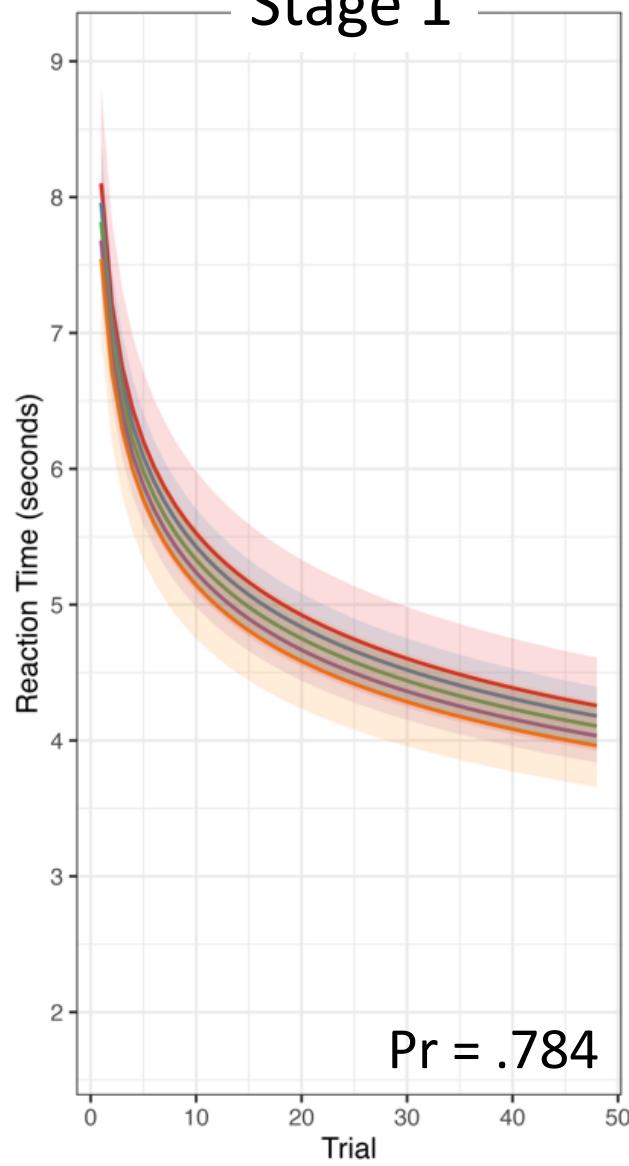


zASRT15 -2 -1 0 1 2

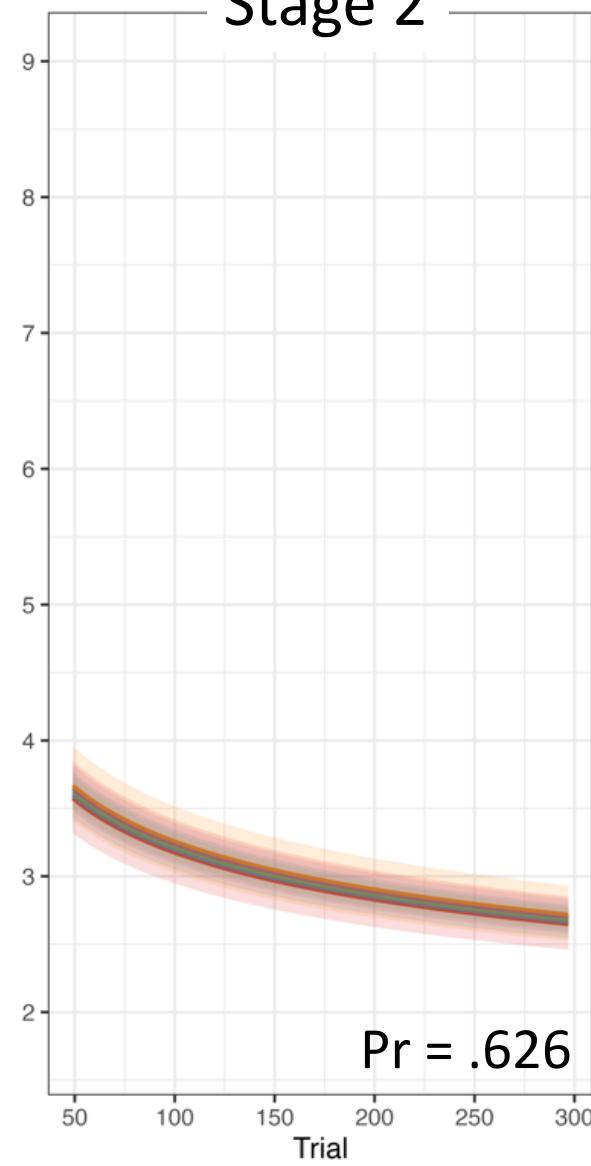
zASRT15 -2 -1 0 1 2

zASRT15 -2 -1 0 1 2

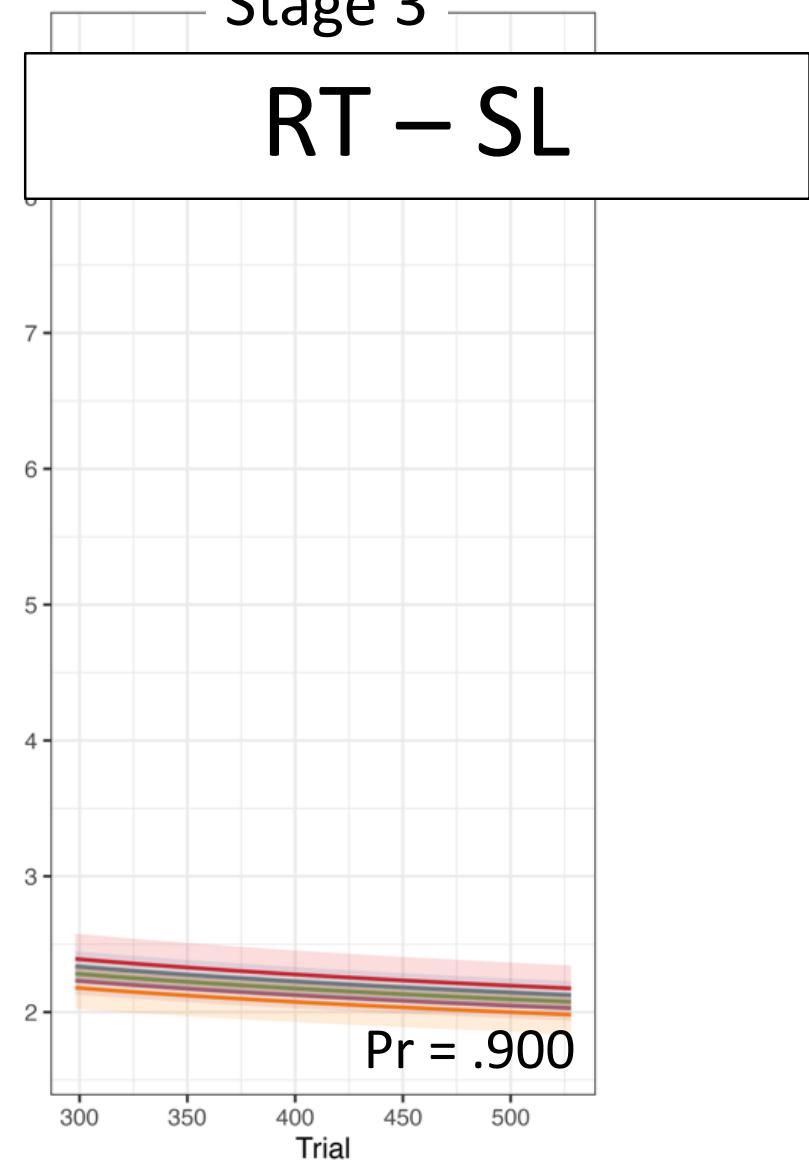
### Stage 1



### Stage 2

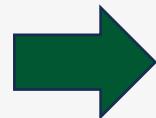
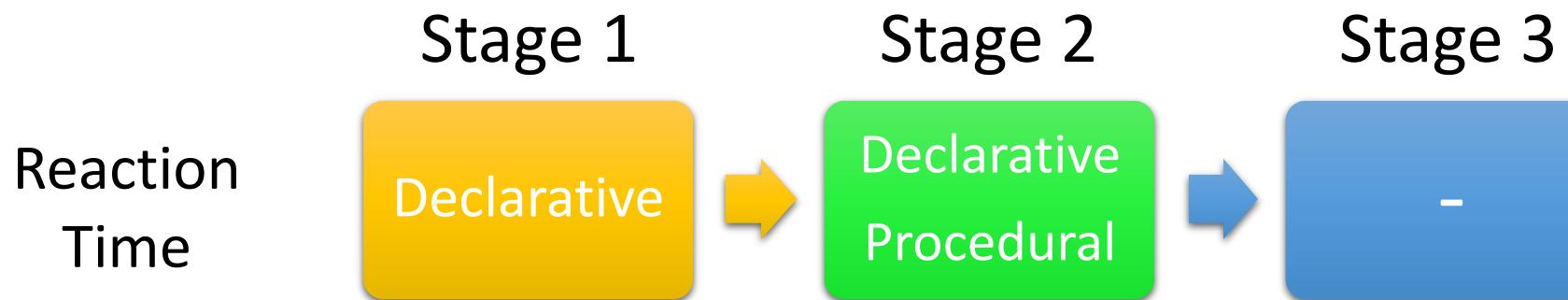
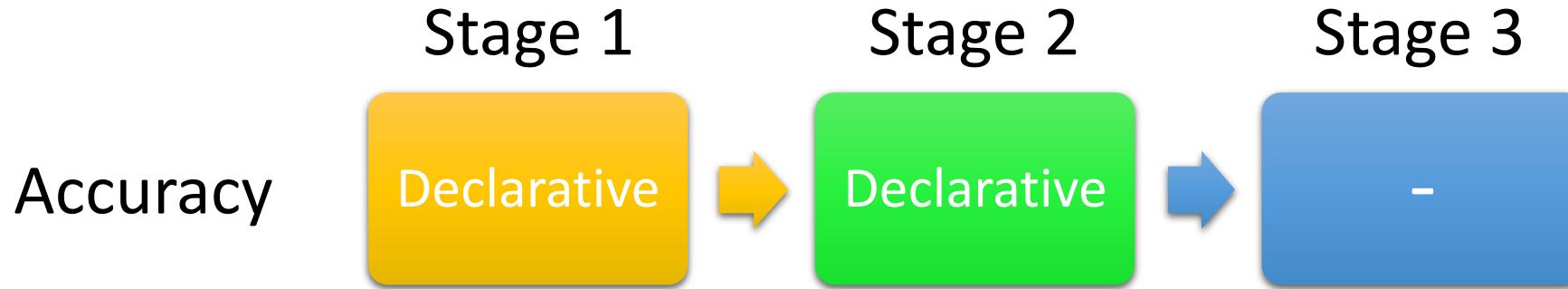


### Stage 3



RT – SL

# Summary



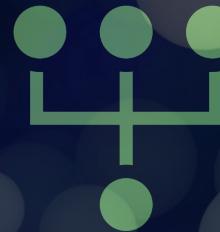
**Evidence for skill acquisition theory (the three-stage model & ACT-R)**

# Future Direction: Empirical



## Cross-validation of mechanisms

fMRI data for more direct evidence on learning mechanisms



## Skill acquisition at processing levels

Skill acquisition investigated not only at the level of learning mechanisms but **at the level of cognitive processing**

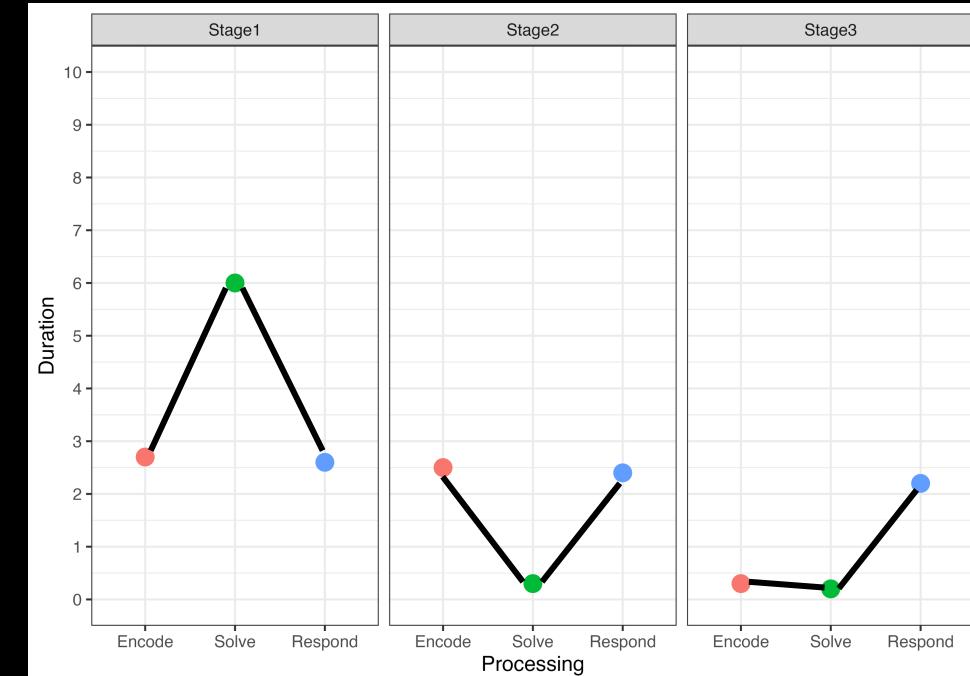
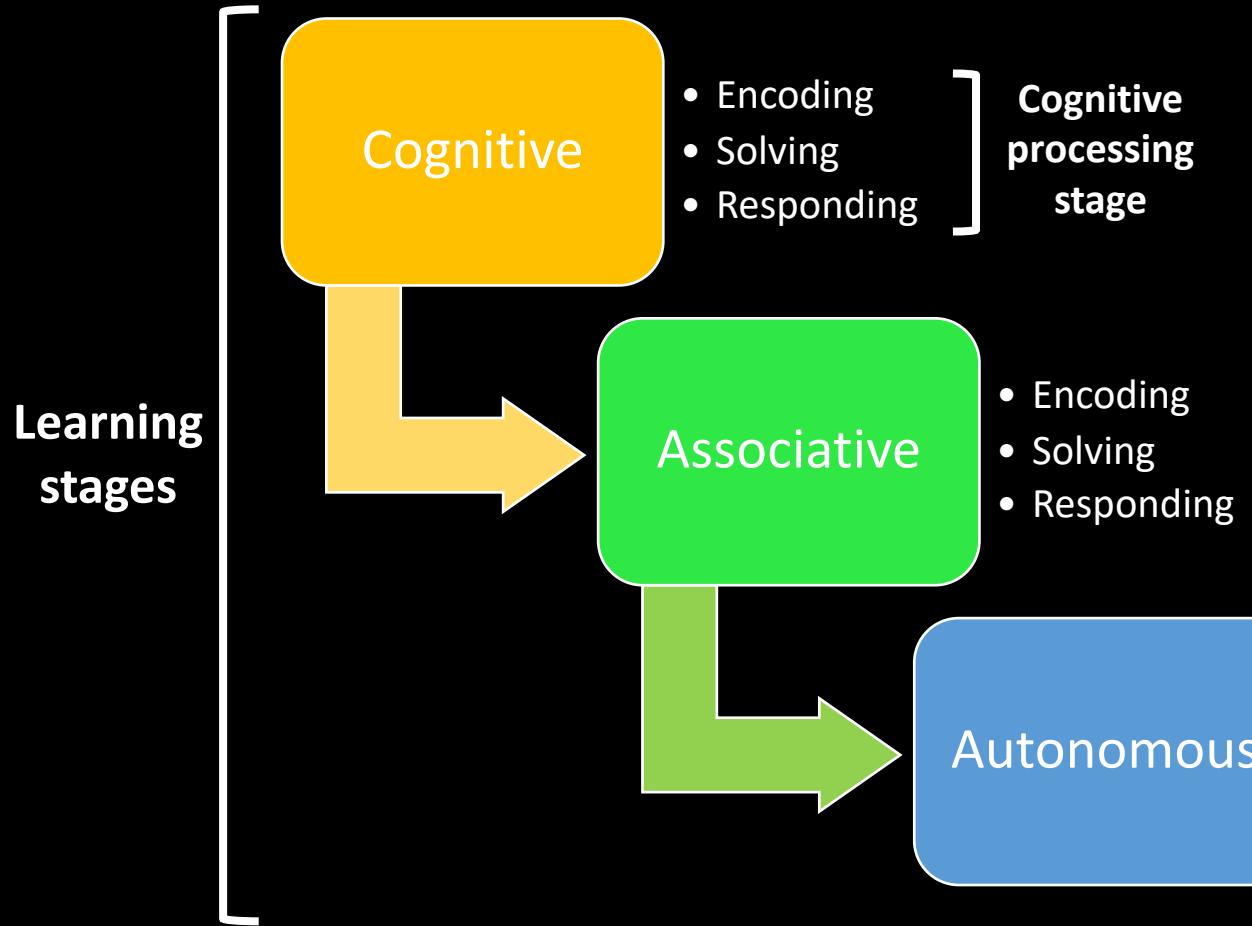
SLA is citing skill acquisition theory of **40 years ago!**

# Tenison et al. (2016)

$$5\$3 \rightarrow 5 + 4 + 3 = 12$$

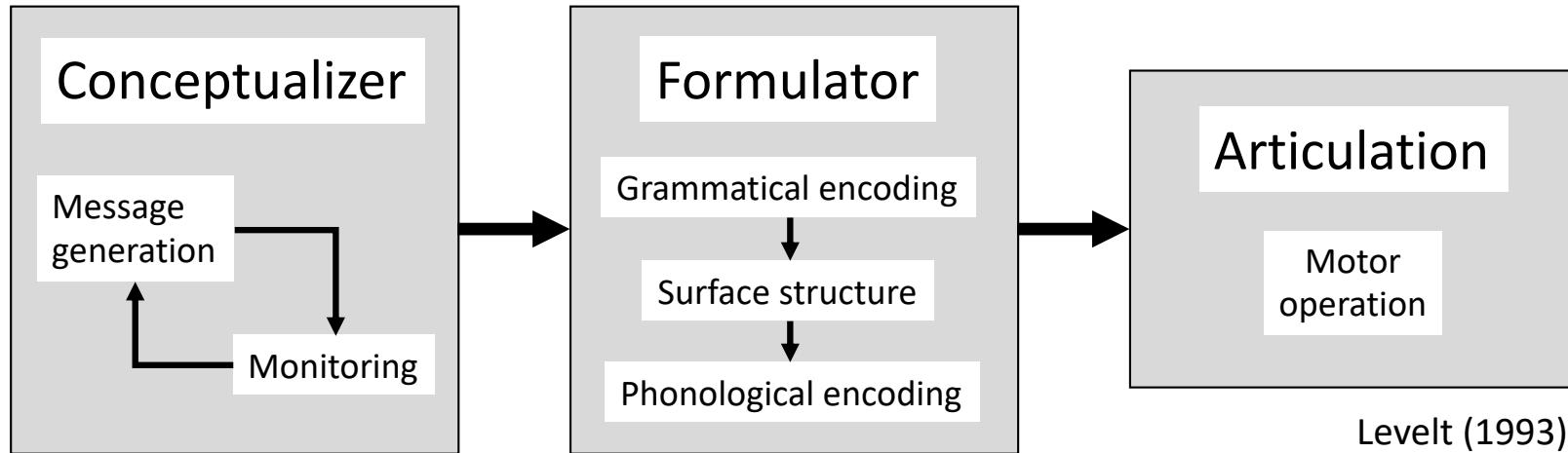


Skill acquisition in an arithmetic task (Pyramid problem)



# Future Direction: Theoretical

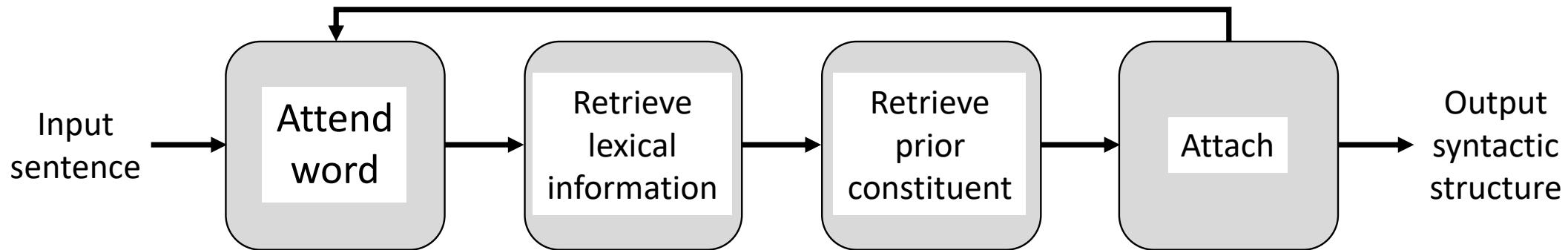
## Production



How do each process is affected by automatization?

Proceduralization  
(restructuring)

## Comprehension



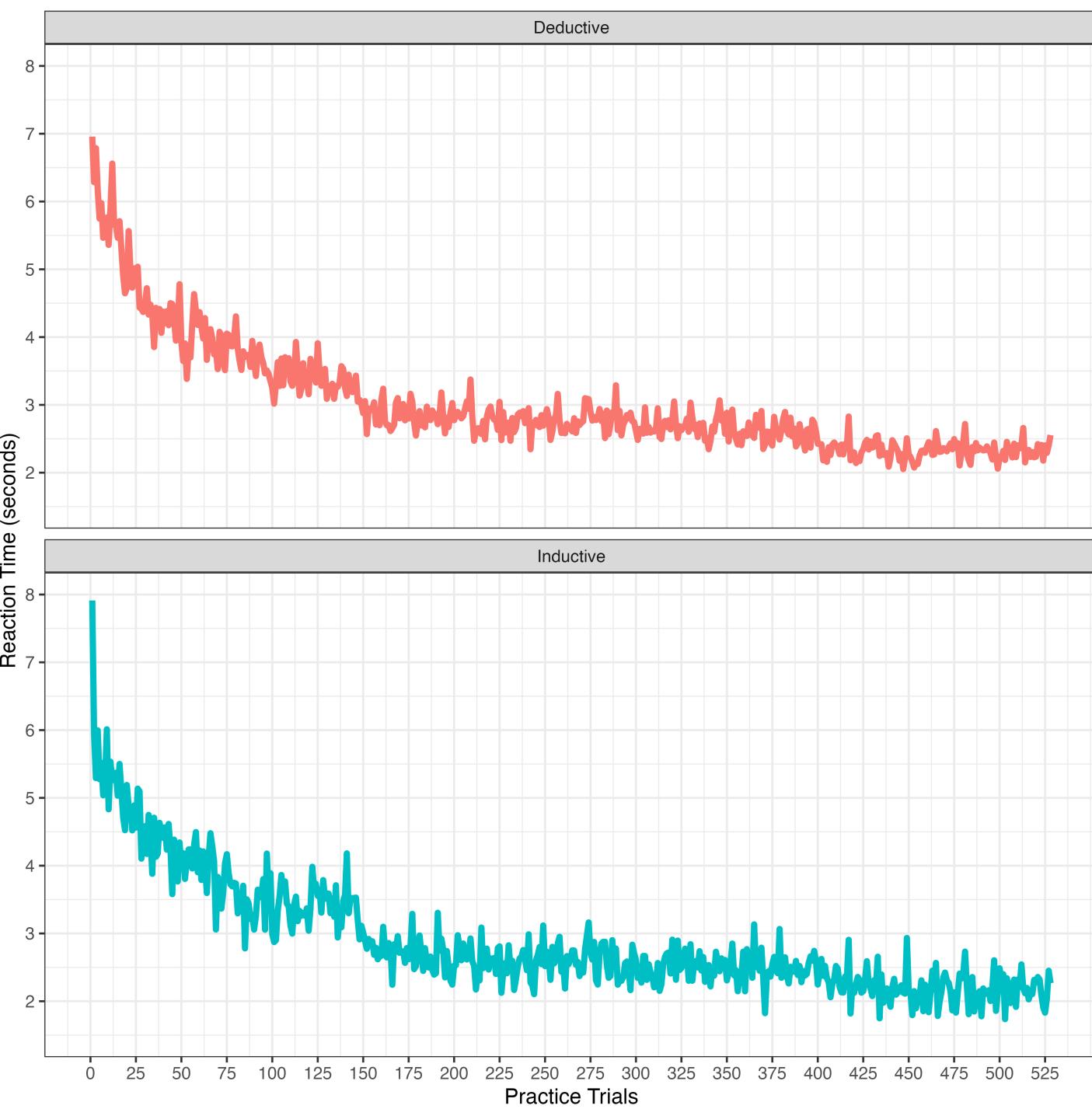
Lewis & Vasishth (2005)  
Vogelzang et al. (2017)



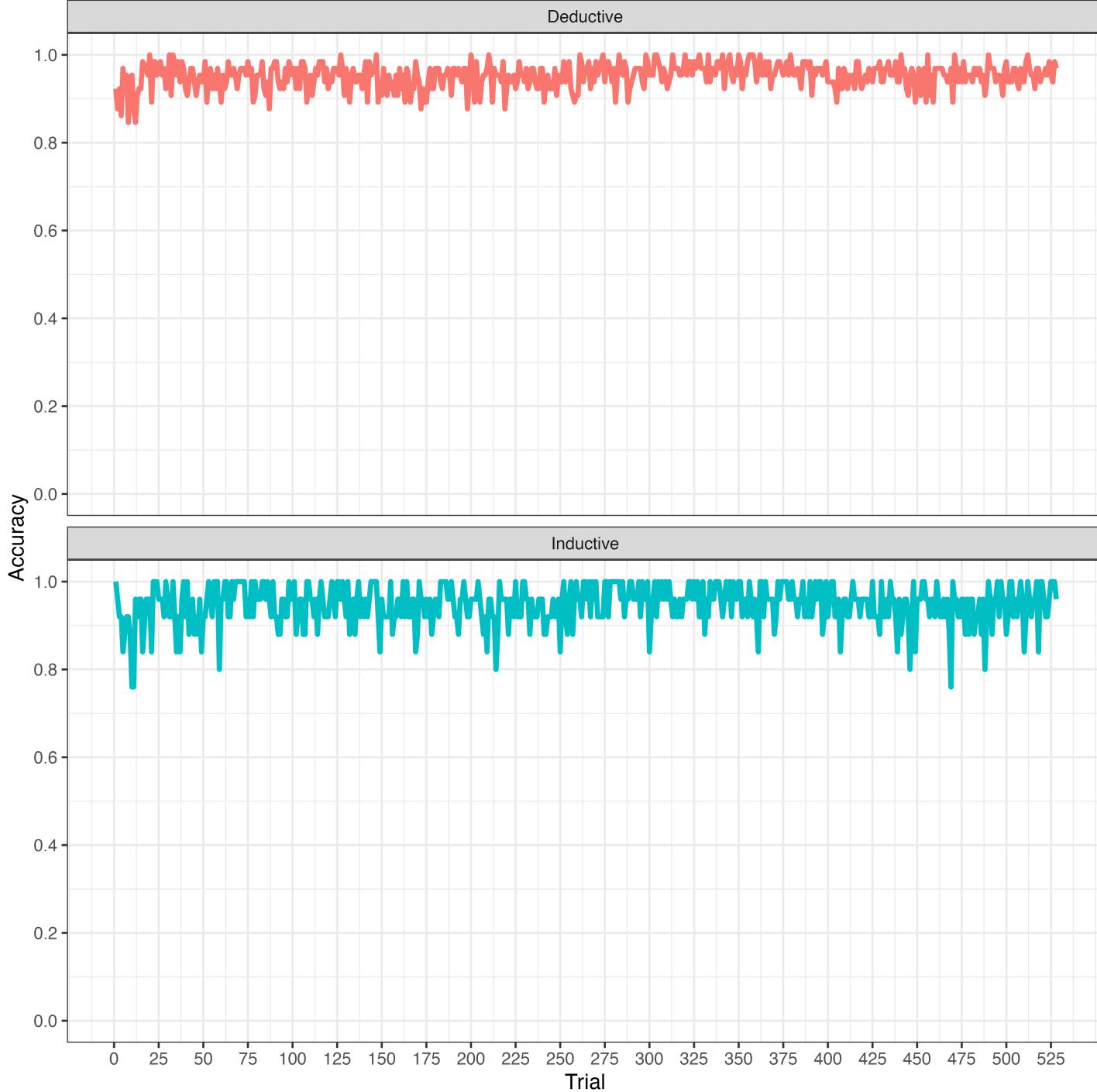
Explicit (Deductive)  
Implicit (Inductive)?



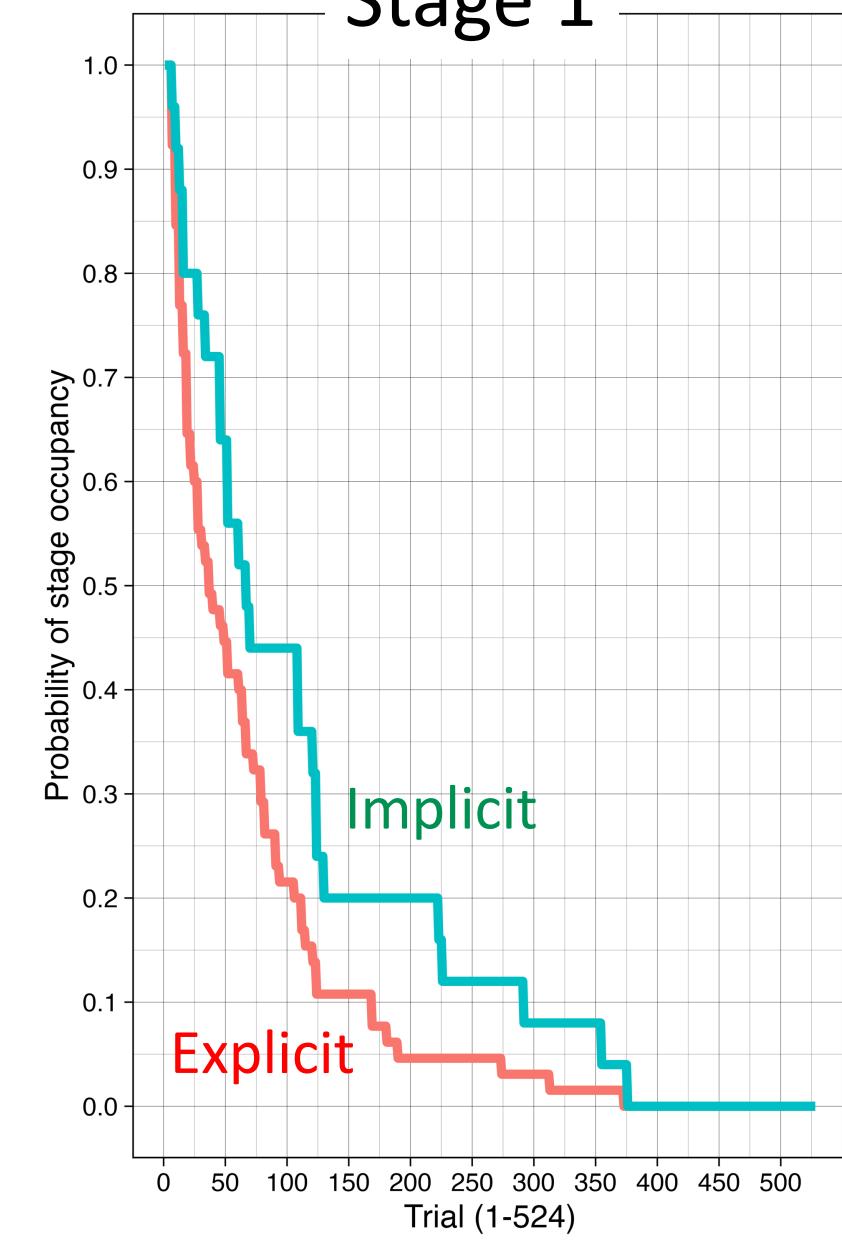
Implicit  
Inductive  
( $n = 25$ )



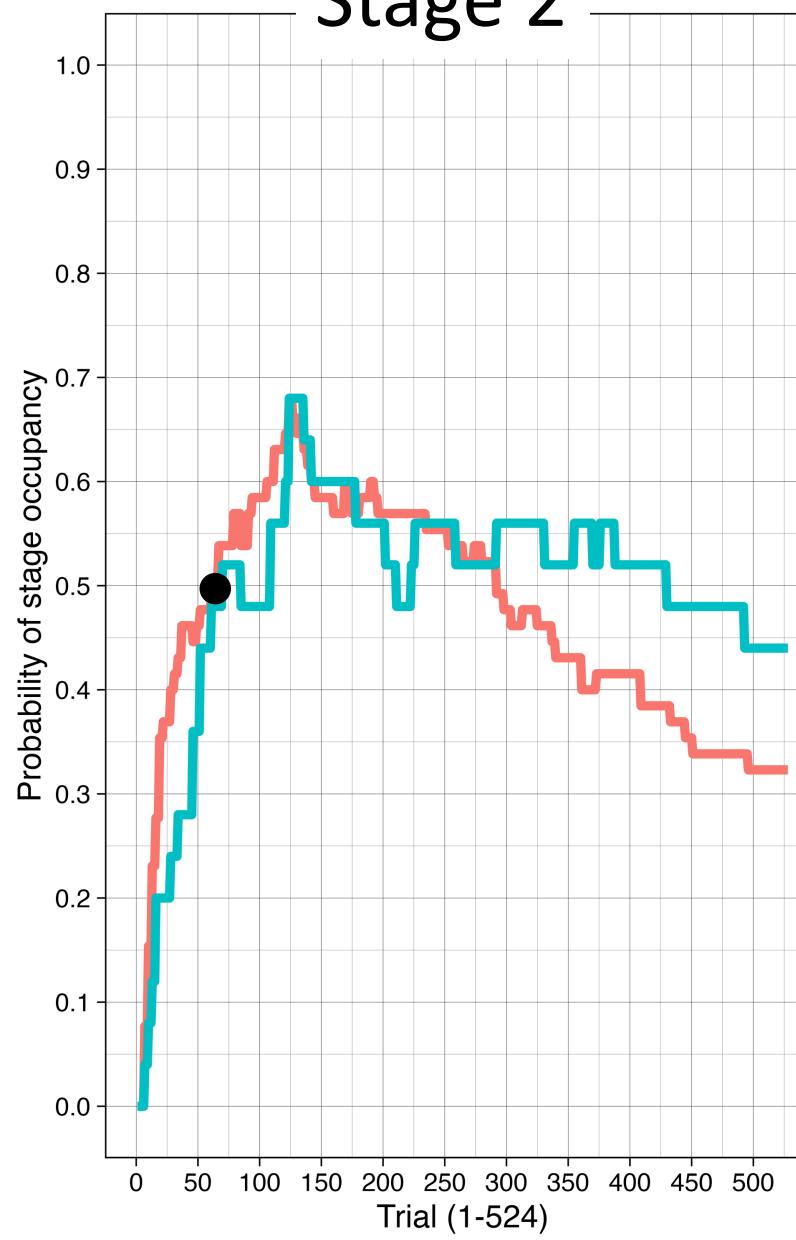
Implicit  
Inductive  
( $n = 25$ )



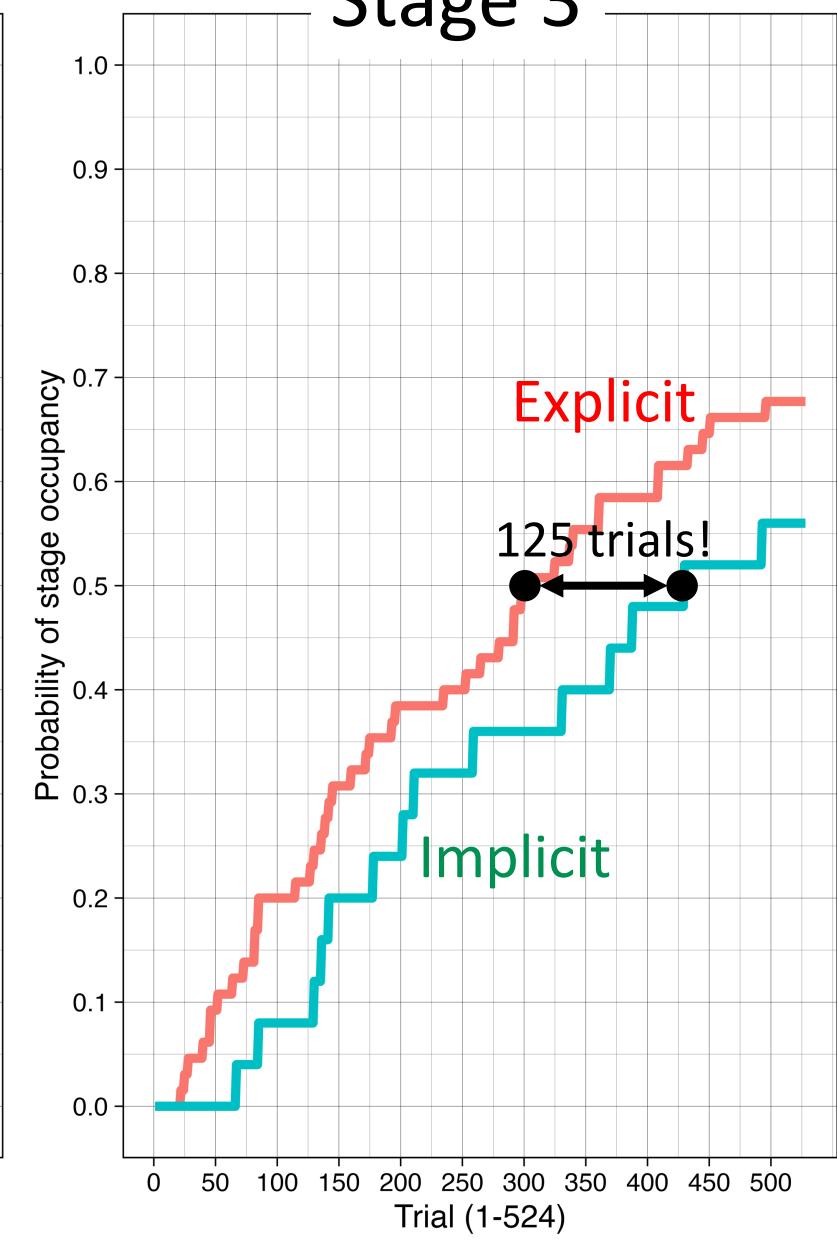
# Stage 1



# Stage 2



# Stage 3





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