Testing the three-stage model of L2 skill acquisition

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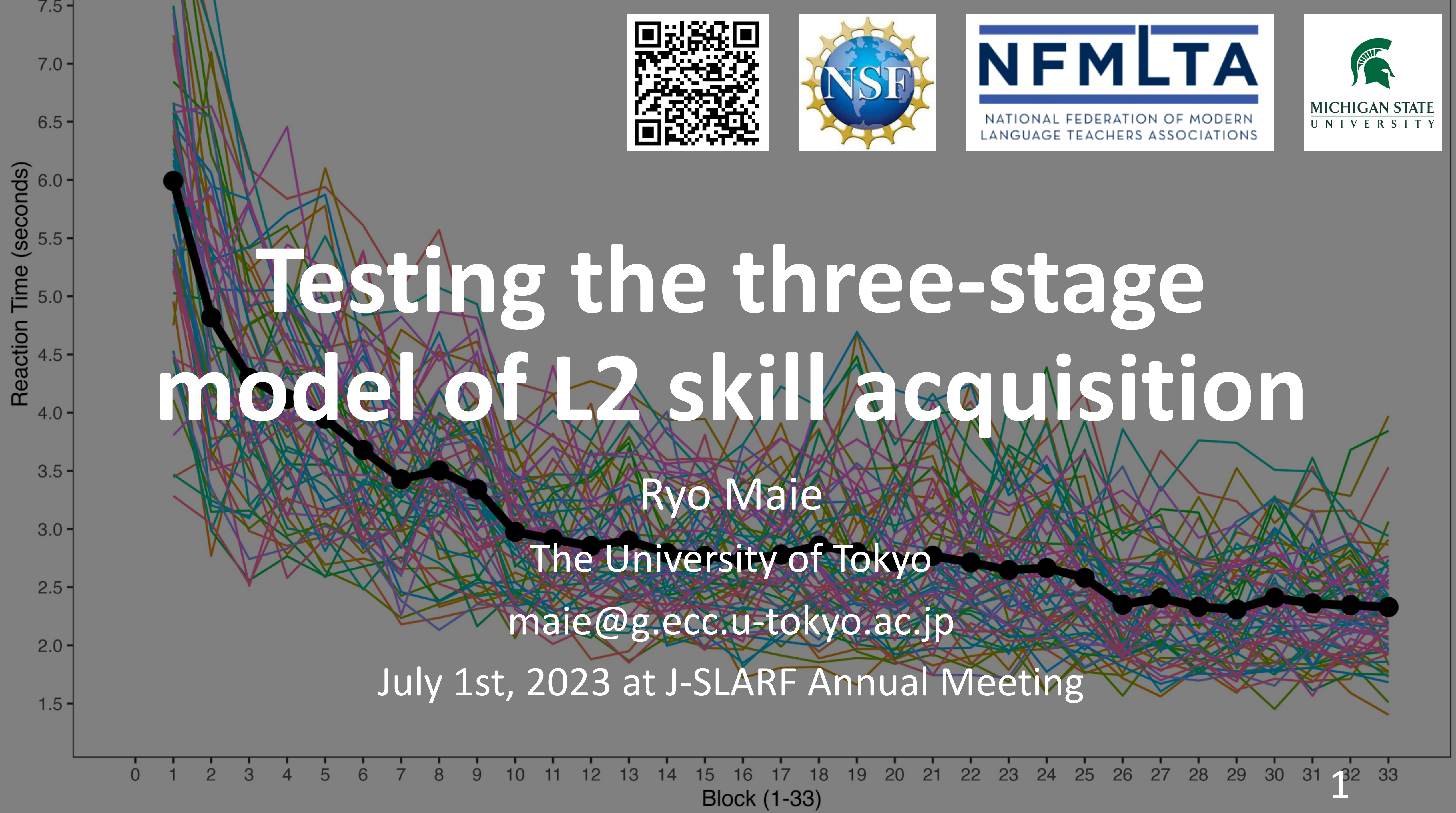


L2 learning as **skill acquisition**

Skill acquisition theory

<u>Learning</u> as acquisition of *skills*

<u>Learning</u> 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)

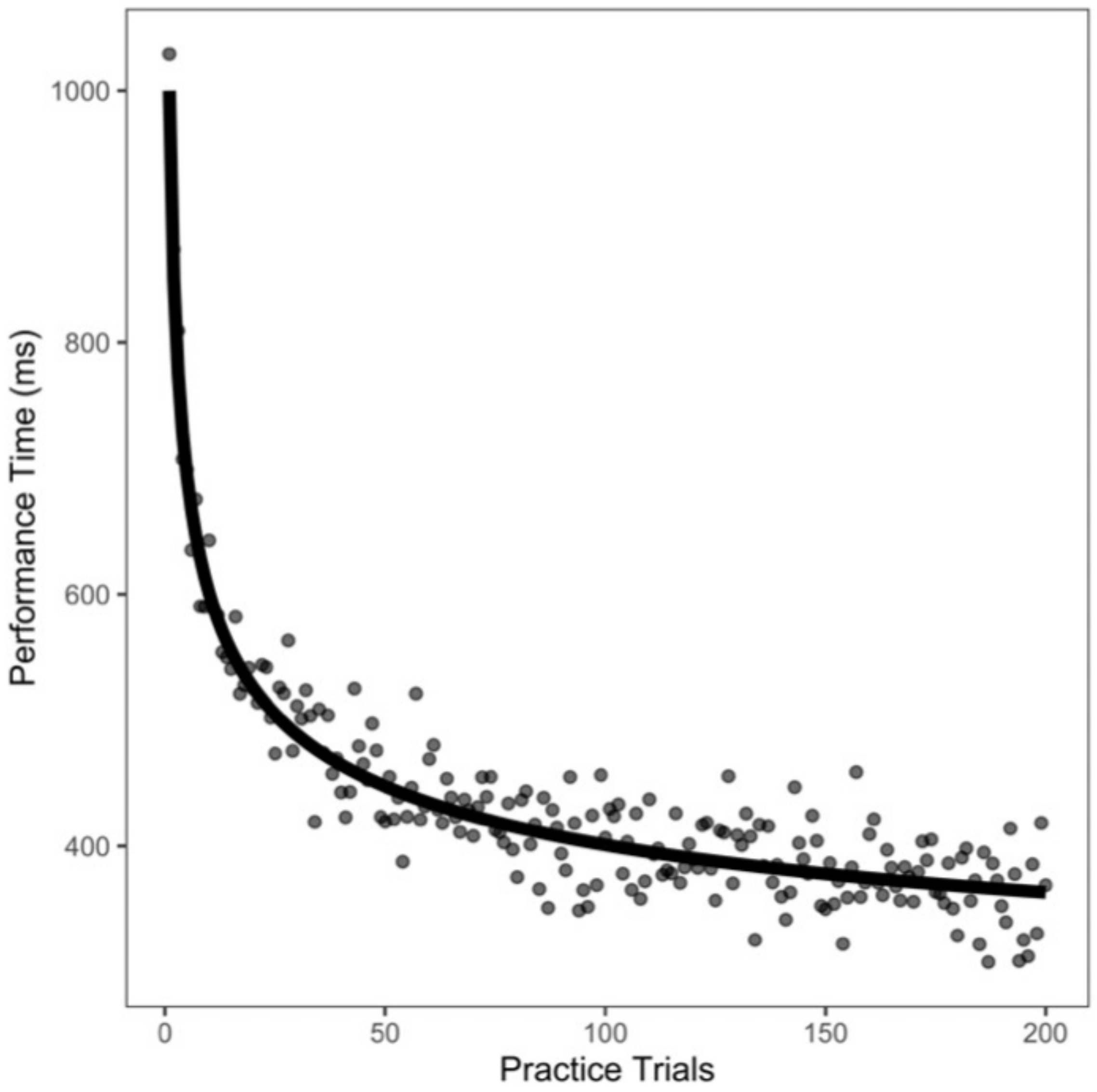
John Anderson (1983):

"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)*

Overall similar!

Cognitive →	Associative →	Autonomous	Fitts & Posner (1967)
Declarative →	Procedural →	Automatization	DeKeyser (2020) Suzuki (2022)
Declarative →	Transitional →	Procedural	Anderson (1982, 1983)

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)

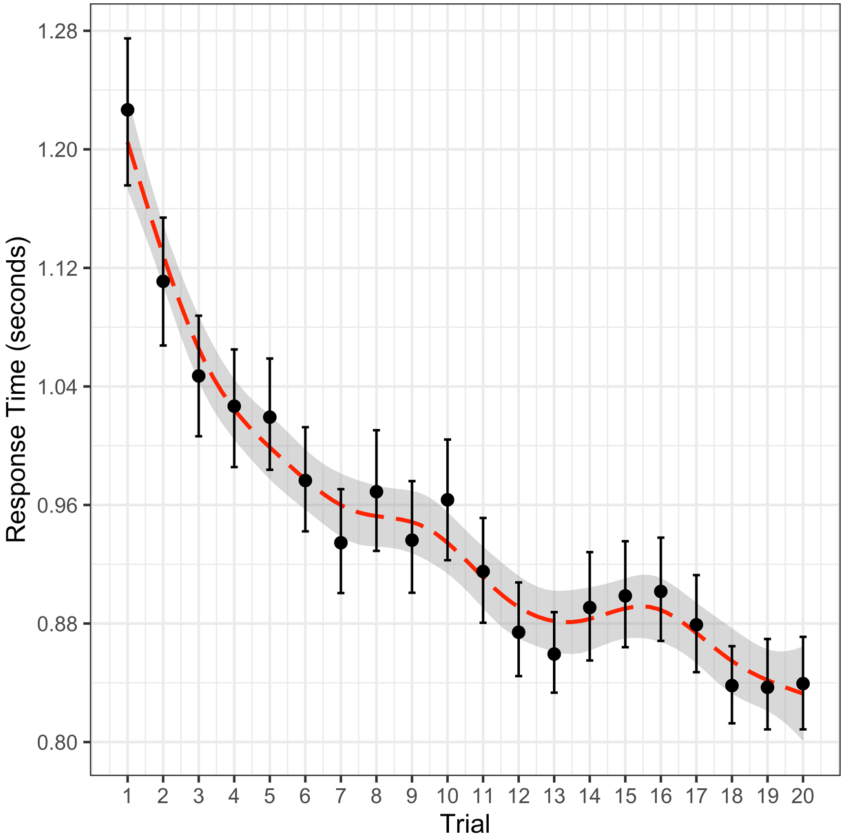
L2 automatization

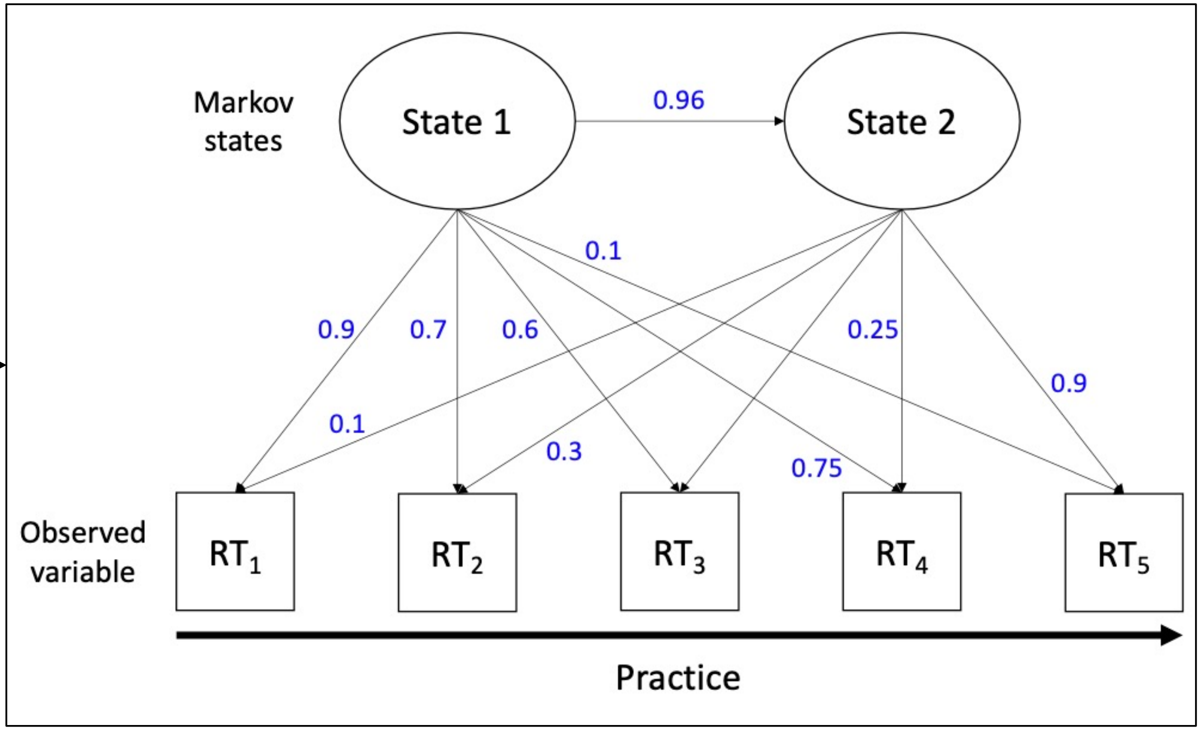
- Procedural learning ability predicting the degree of automatization from practice (Pili-Moss et al., 2020; Suzuki, 2017)

➡ The number of stages??

Skill acquisition in L2 vocabulary
(Maie, rejected)

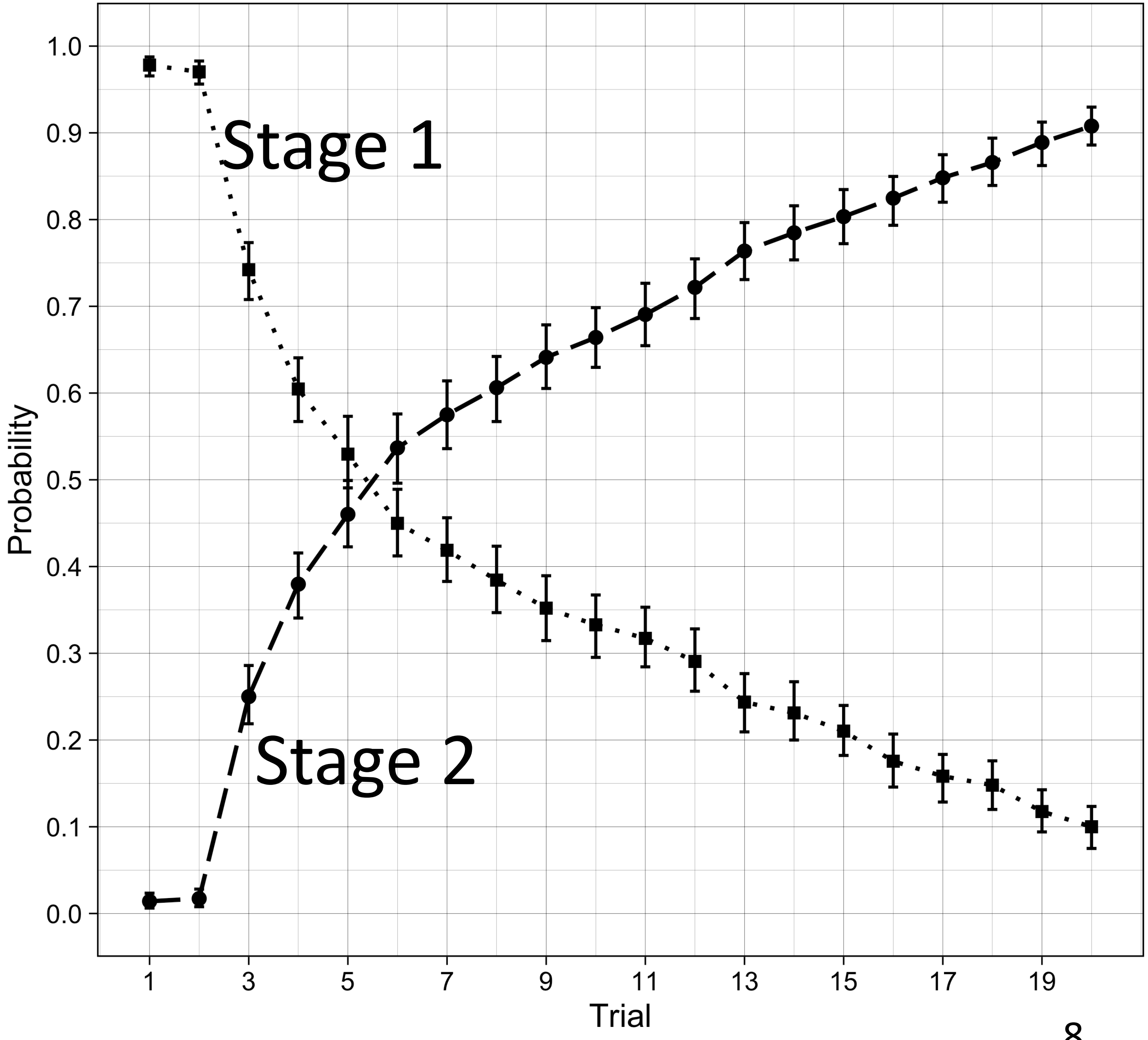
Applying cognitive modeling to reaction time data to test skill acquisition stages

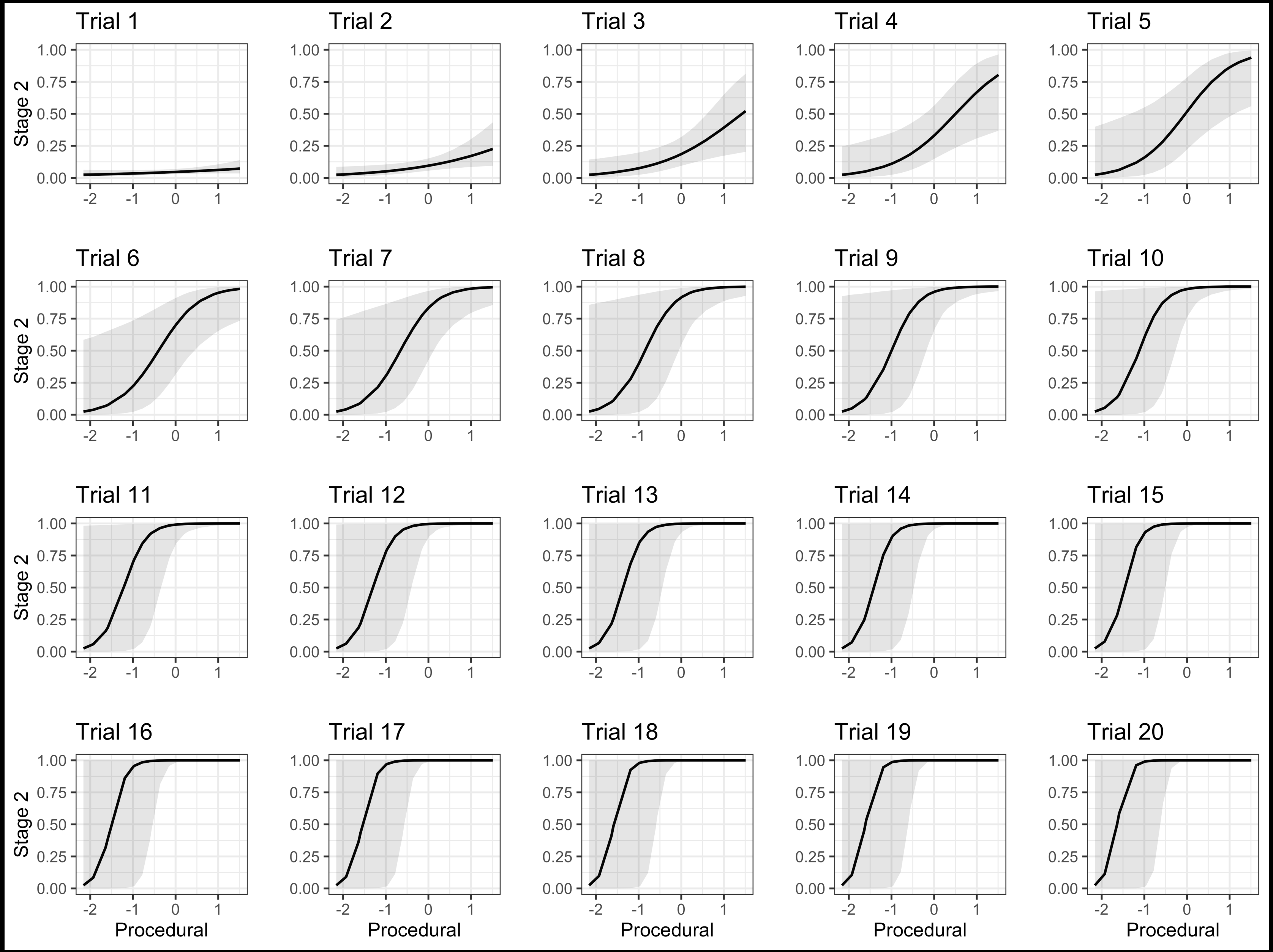




Hidden Markov Modeling

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?

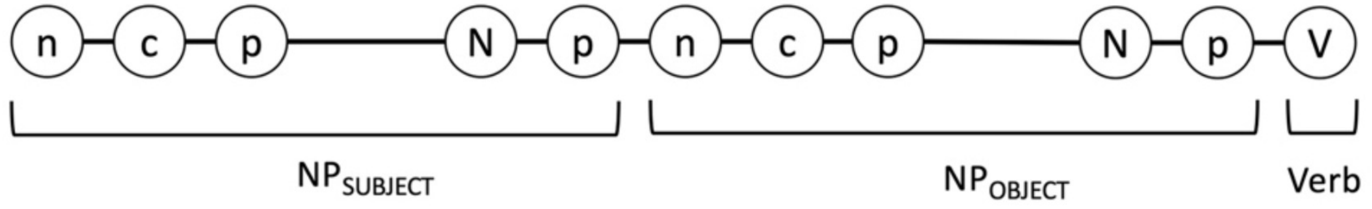
Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Cognitive Tests	**Explicit Instruction**	**Practice Session 1**	**Practice Session 2**	**Practice Session 3**	**Practice Session 4**

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

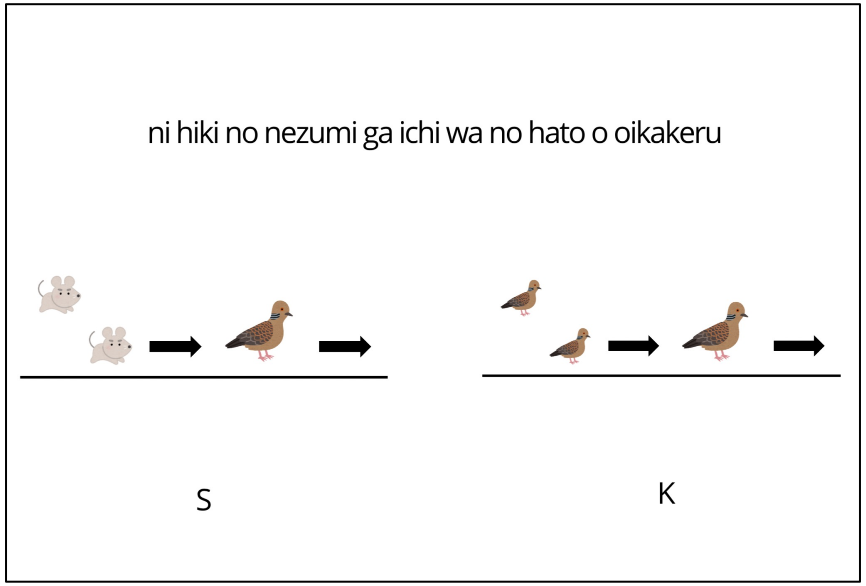
Grammar structure of Mini-Nihongo



Vocabulary items and case-markers of Mini-Nihongo

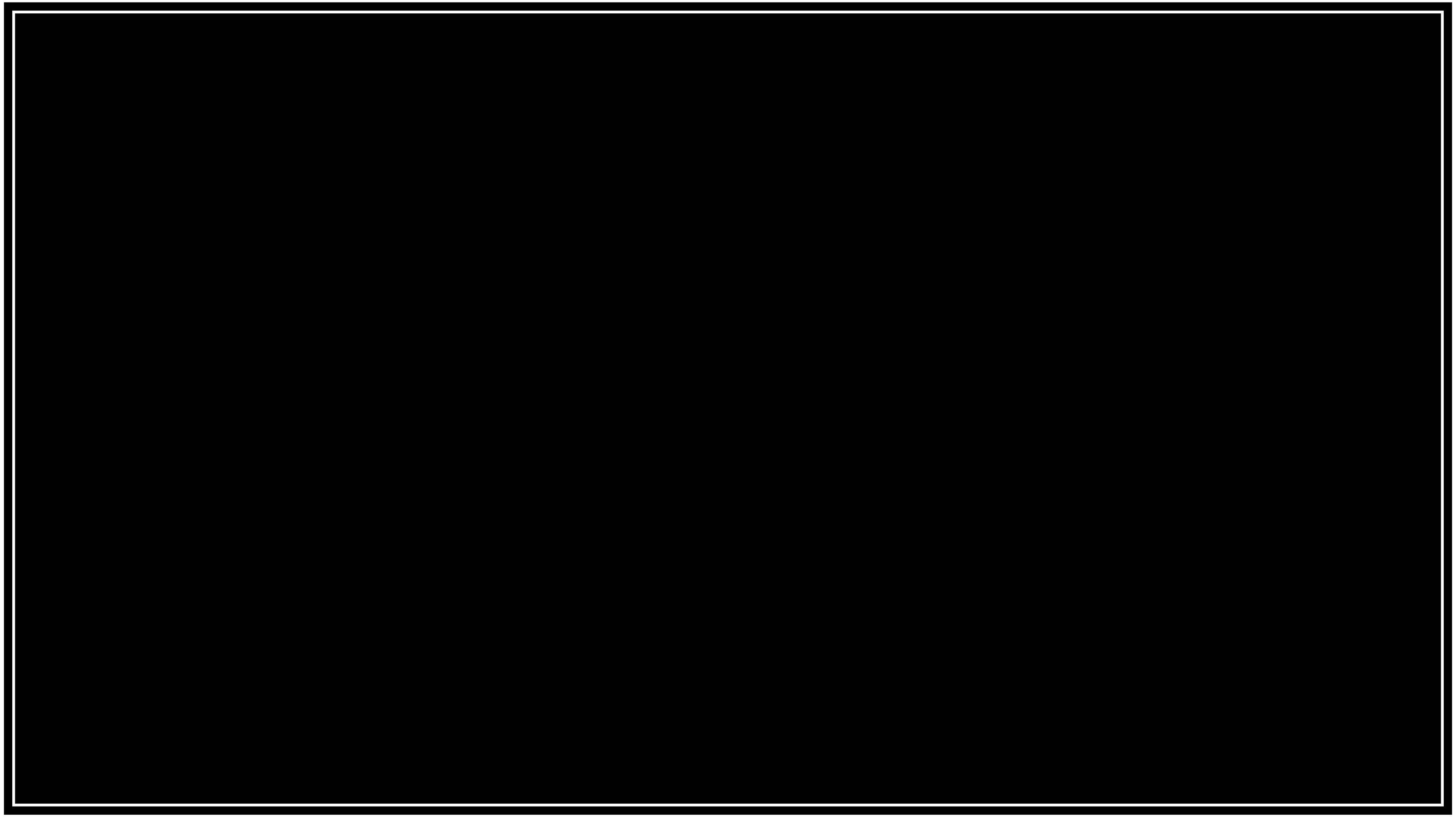
N [noun]	=	hato (pigeon), kamo (duck), nezumi (mouse), neko (cat)
V [verb]	=	tobikoeru (jump over), tsukamaeru (capture), oikakeru (chase away), otozureru (visit)
n [number]	=	ichi (one), ni (two)
c [classifier]	=	wa (bird class), hiki (small animal class)
p [postposition]	=	ga (nominative), o (accusative), no (genitive)

Language Practice (Comprehension Practice)



Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	
Cognitive Tests	**EI + Warmup practice**	**Practice Session 1**	**Practice Session 2**	**Practice Session 3**	**Practice Session 4**	
	16 trials →	128 trials →	128 trials →	128 trials →	128 trials —	**528 trials**

Language Practice (Comprehension Practice)

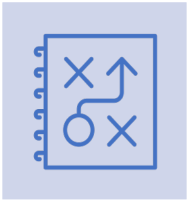


Cognitive Tests

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

Analysis

1. Hidden Markov modeling

- takes RT as the dependent variable
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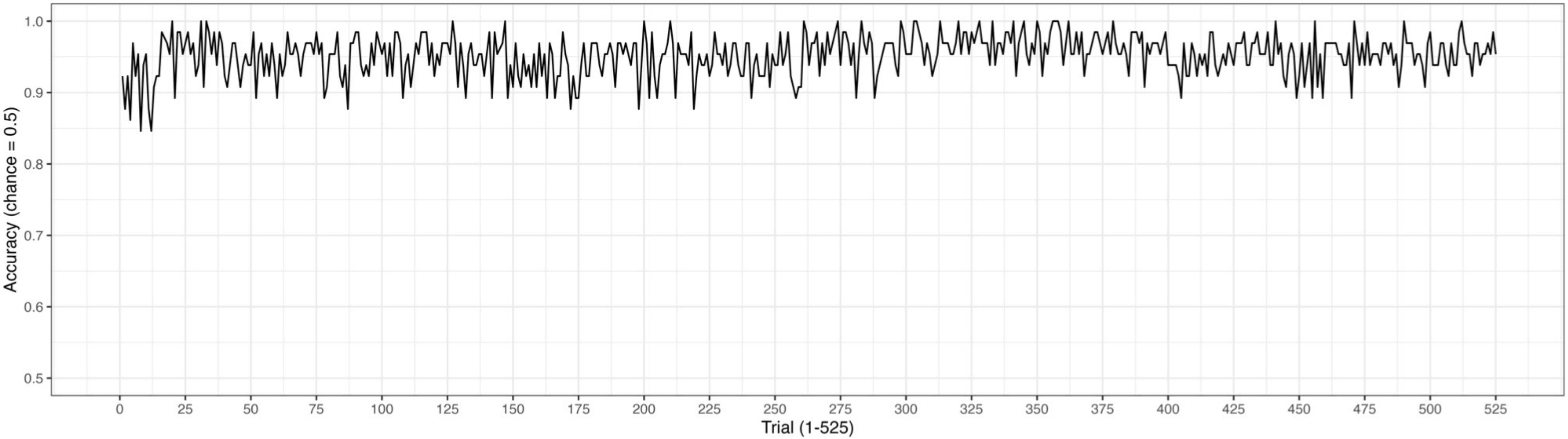
2. Regression modeling

- identifies **the nature** of skill acquisition stages by investigating which cognitive abilities predict learning in each learning stage
- Accuracy and RT as dependent variables, regressed on cognitive test scores and learning stage occupancy

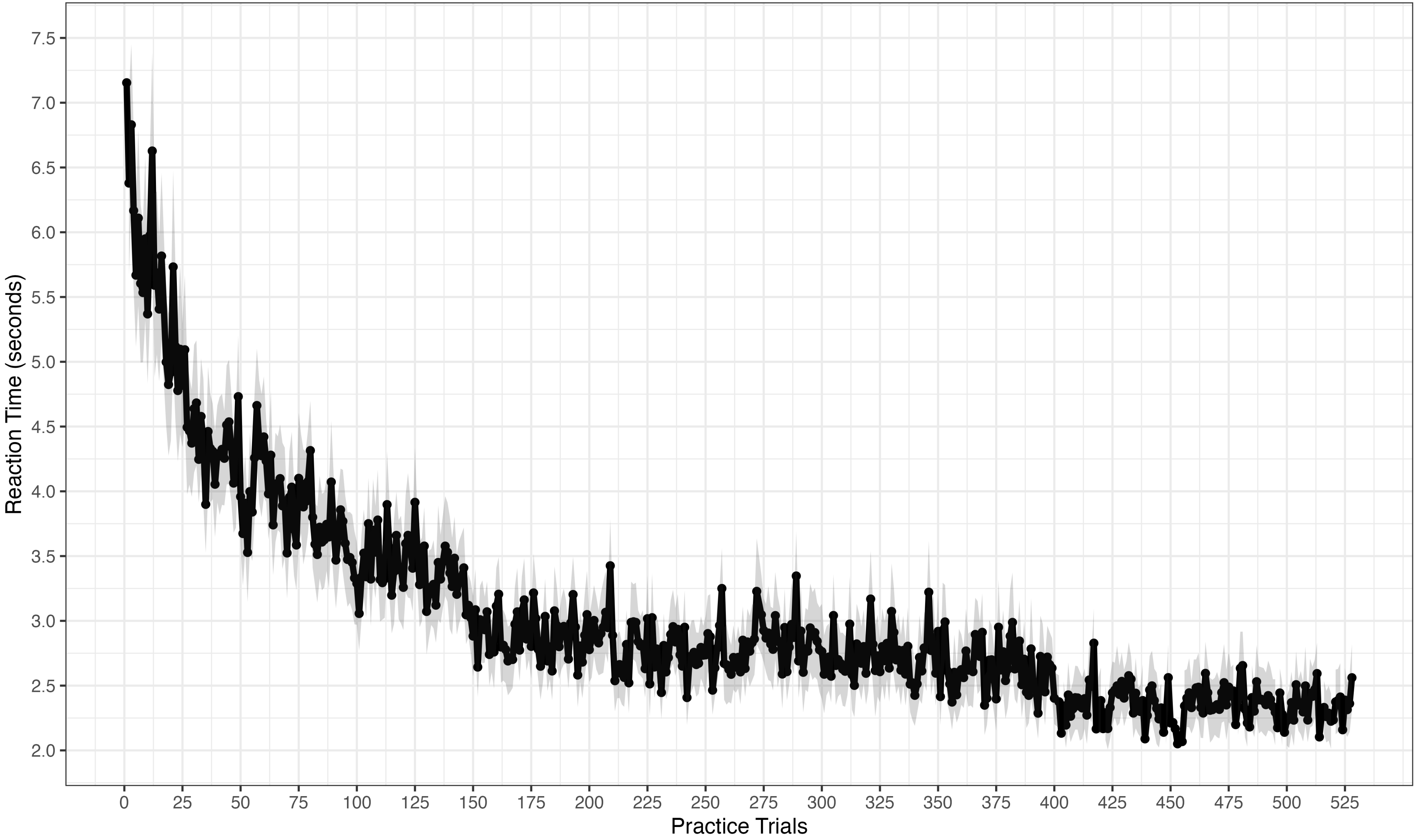
Results

Results: Accuracy



Even from the first few trials, participants showed very accurate performances (90%)

Results: Reaction Time



Hidden Markov Modeling:
The *number* of stages

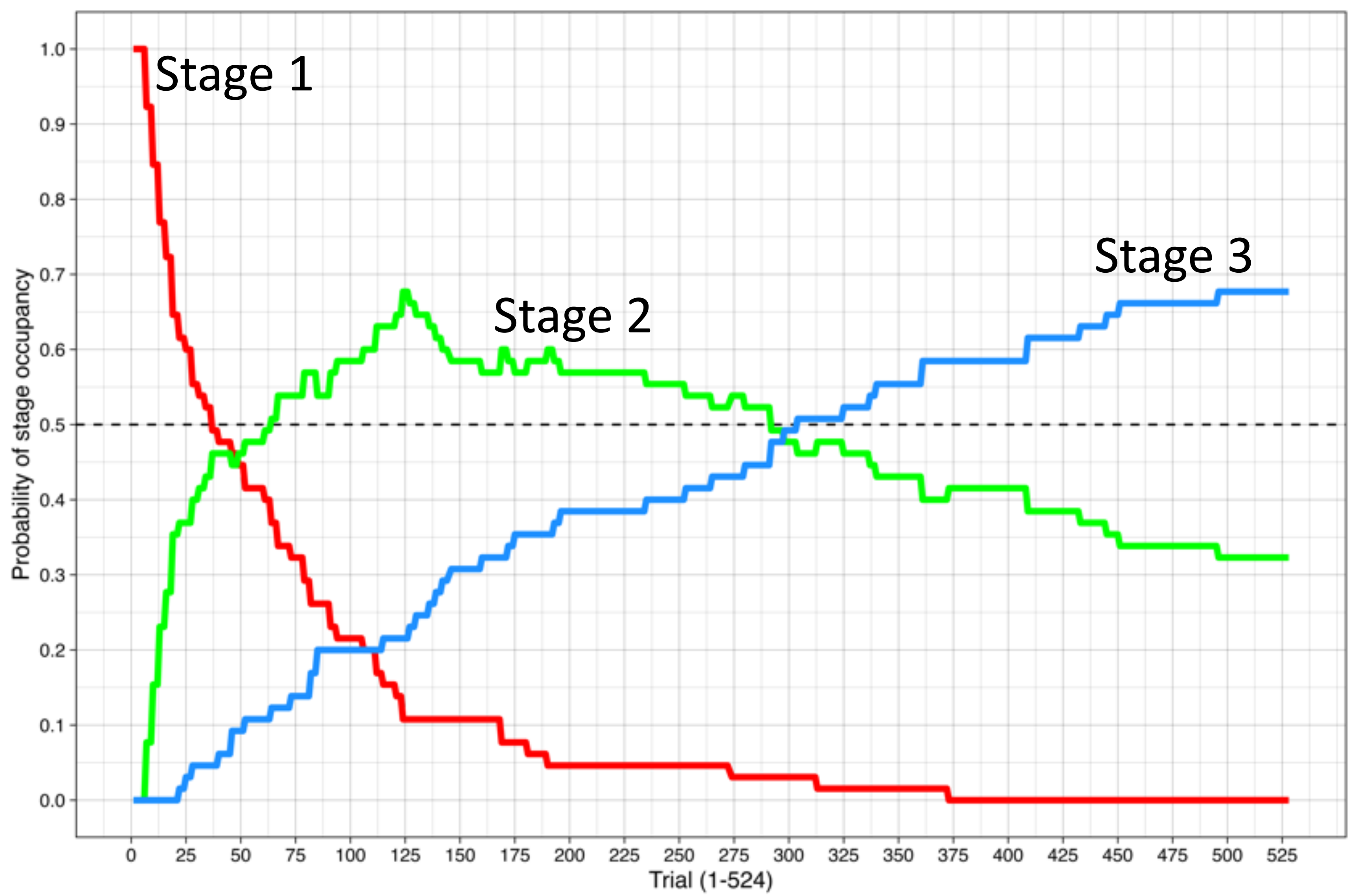
Hidden Markov Modeling

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

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

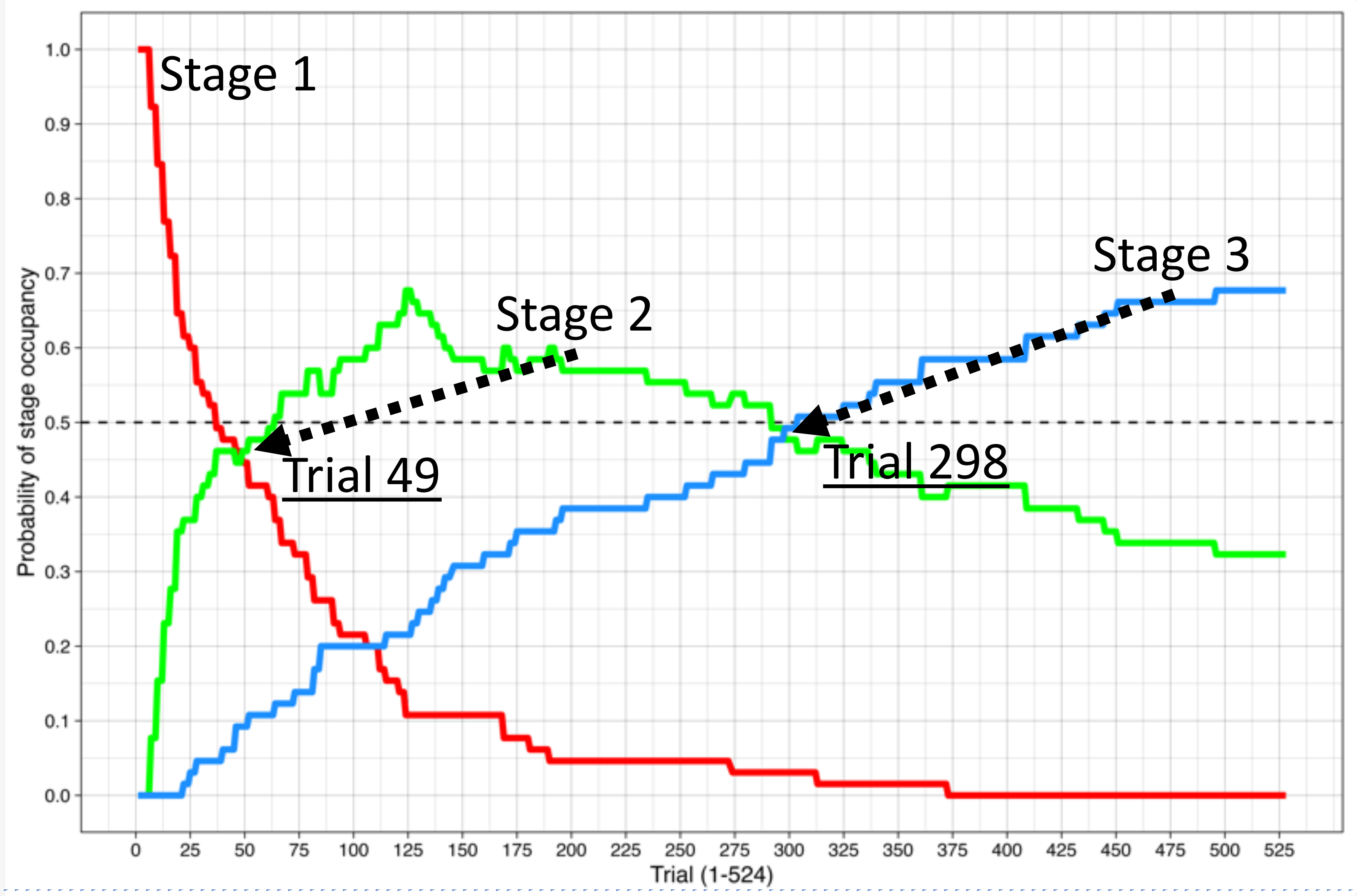
	Intercept	β_{Stage1}	β_{Stage2}	β_{Stage3}	α
One-stage	0.07	7.17	-	-	-0.23
Two-stage	0.50	6.70	4.25	-	-0.20
Three-stage	0.00	6.65	4.85	3.60	-0.12

Hidden Markov Modeling



<u>Note</u>: DeKeyser (1997) – proceduralization can take place as fast as 8-16 trials

Hidden Markov Modeling



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

Regression Modeling:

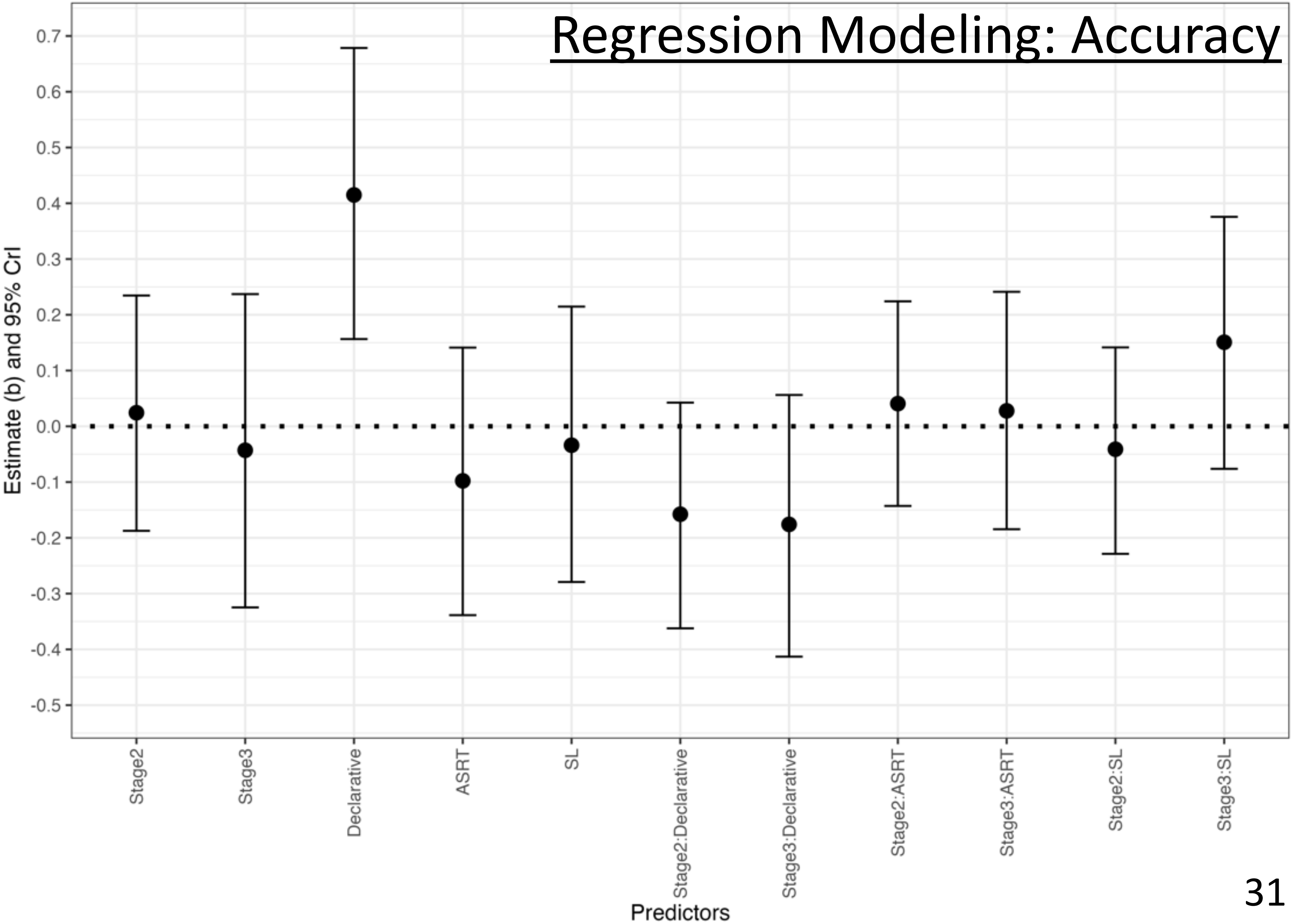
The nature of stages

Analysis

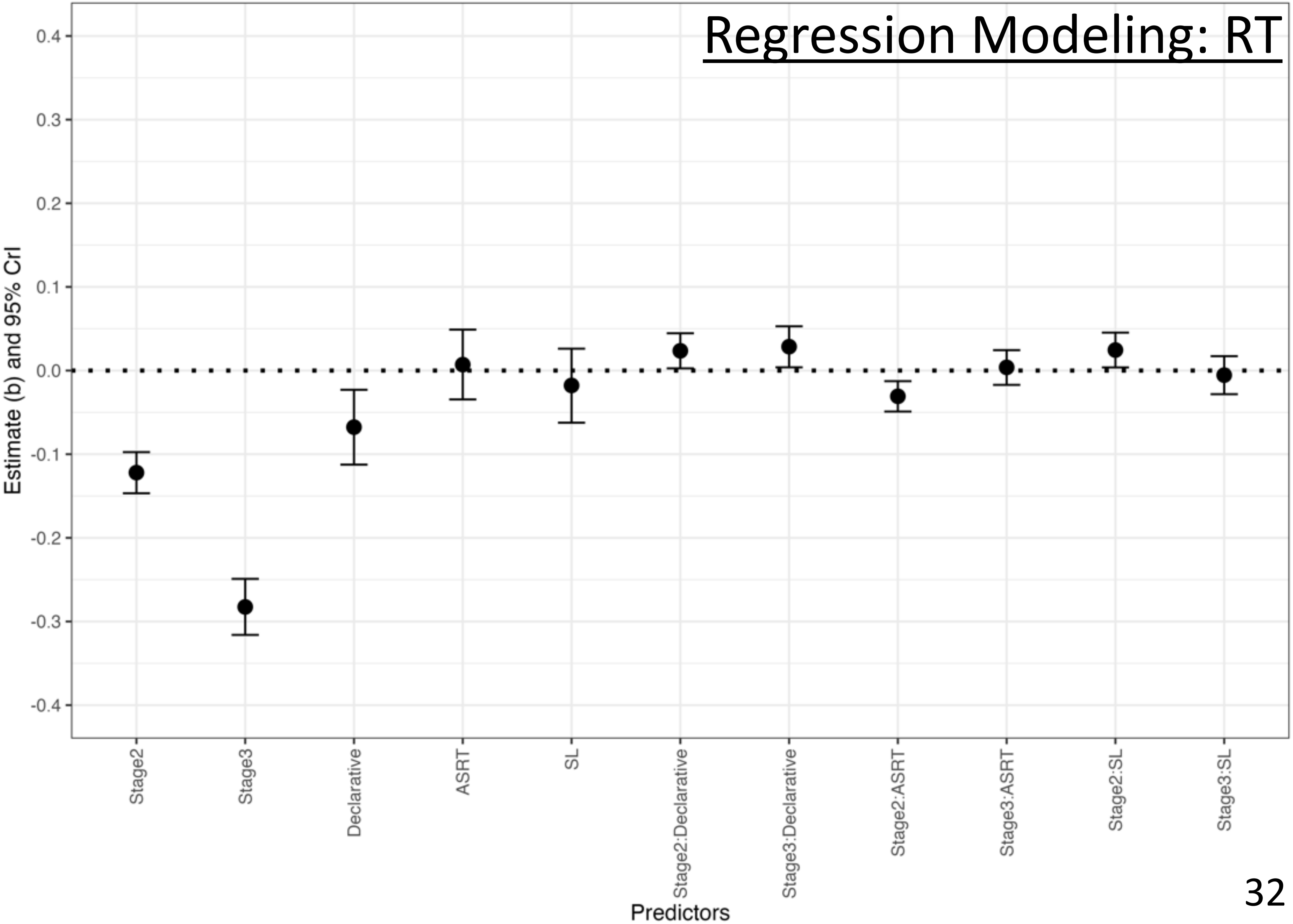
1. **Hidden Markov modeling**
   - takes RT as the dependent variable
   - estimates the probability of each participant residing in each learning stage on each practice trial
   - identifies **the number** of skill acquisition stages by comparing one, two, and three-states models

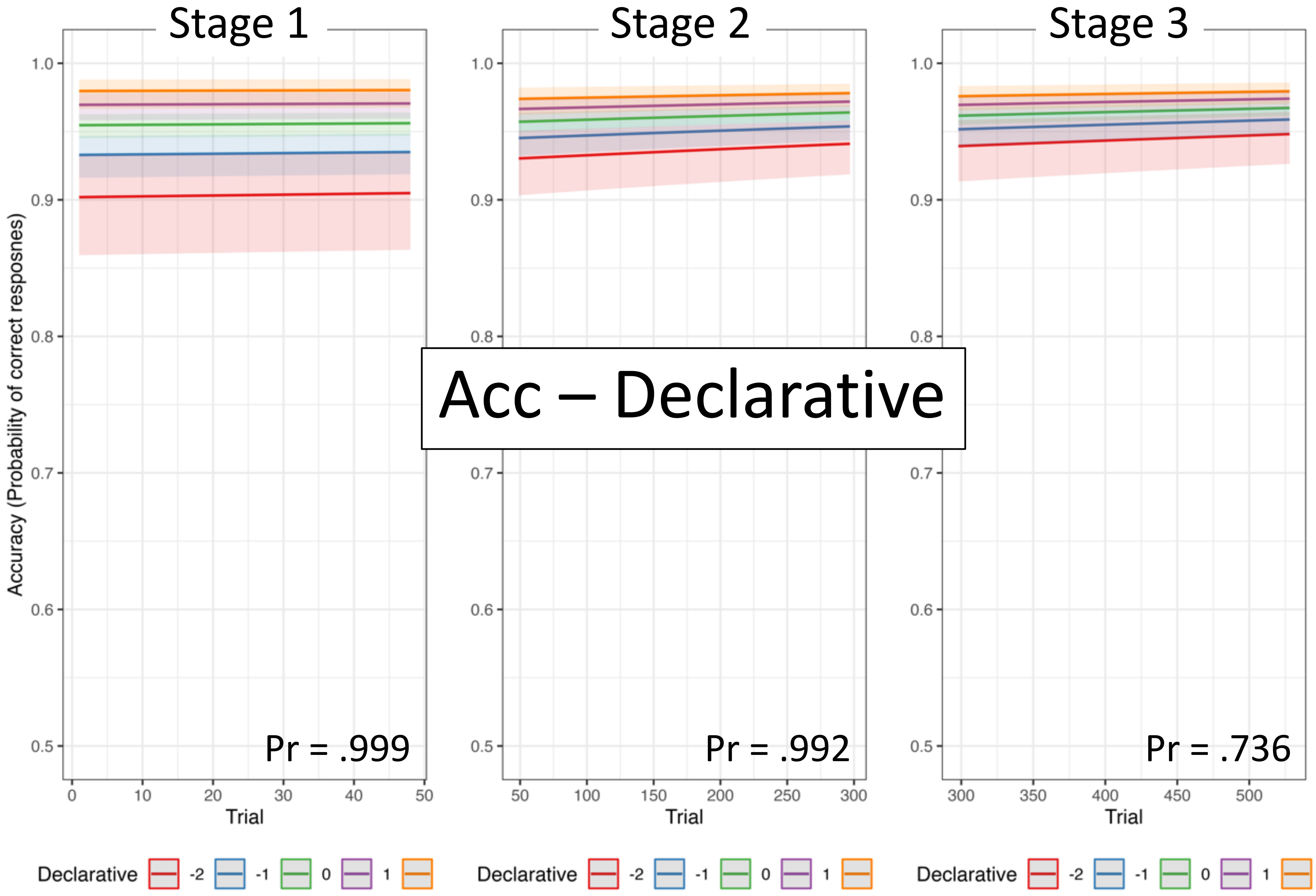
2. **Regression modeling**
   - identifies **the nature** of skill acquisition stages by investigating which cognitive abilities predict learning in each learning stage
   - Accuracy and RT as dependent variables, regressed on cognitive test scores and learning stage occupancy

Regression Modeling: Accuracy

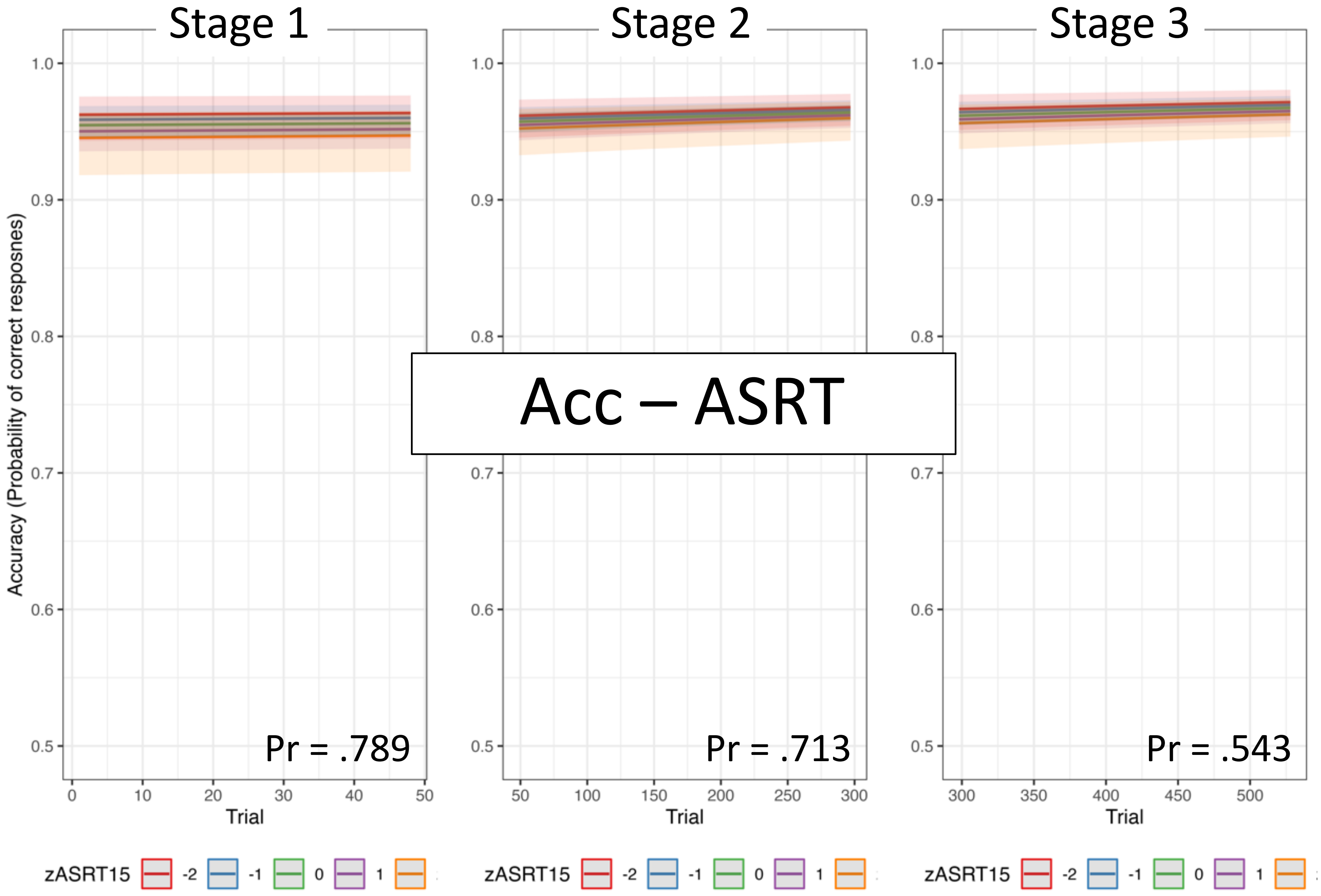


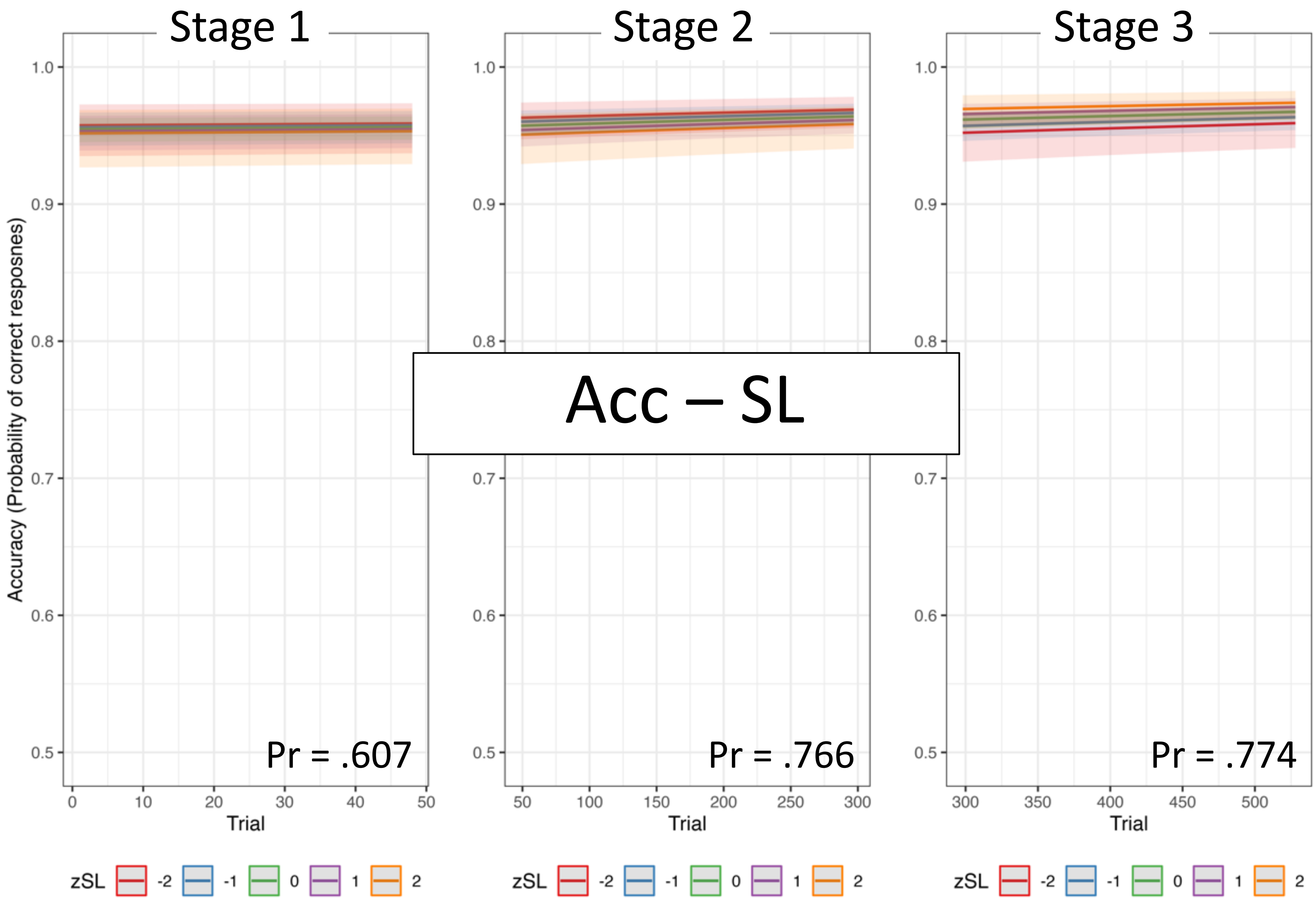
Regression Modeling: RT

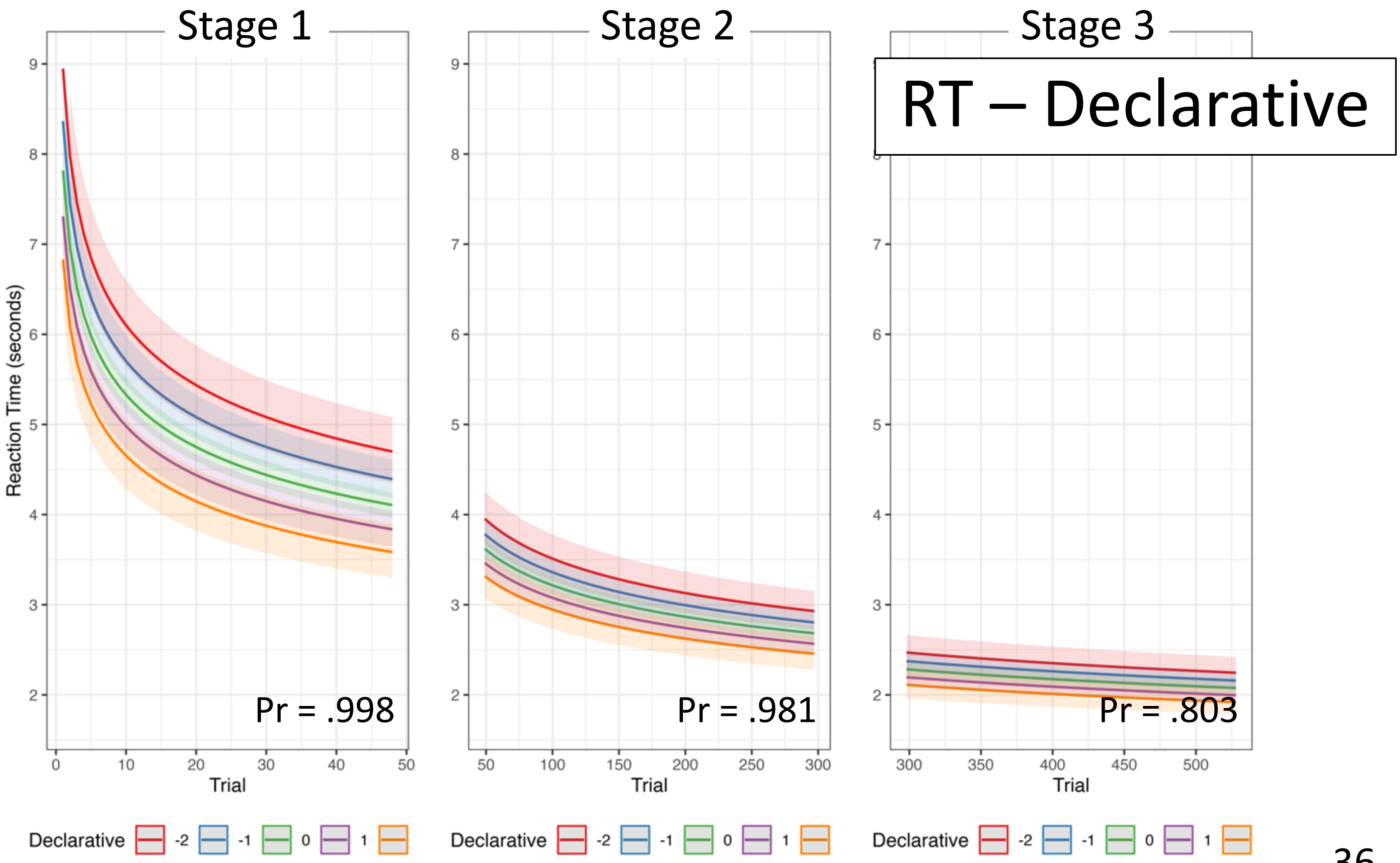




Stage 1
Stage 2
Stage 3
Accuracy (Probability of correct resposnes)
1.0
0.9
0.8
0.7
0.6
0.5
Acc – Declarative
Pr = .999
Pr = .992
Pr = .736
0 10 20 30 40 50
50 100 150 200 250 300
300 350 400 450 500
Trial
Declarative -2 -1 0 1

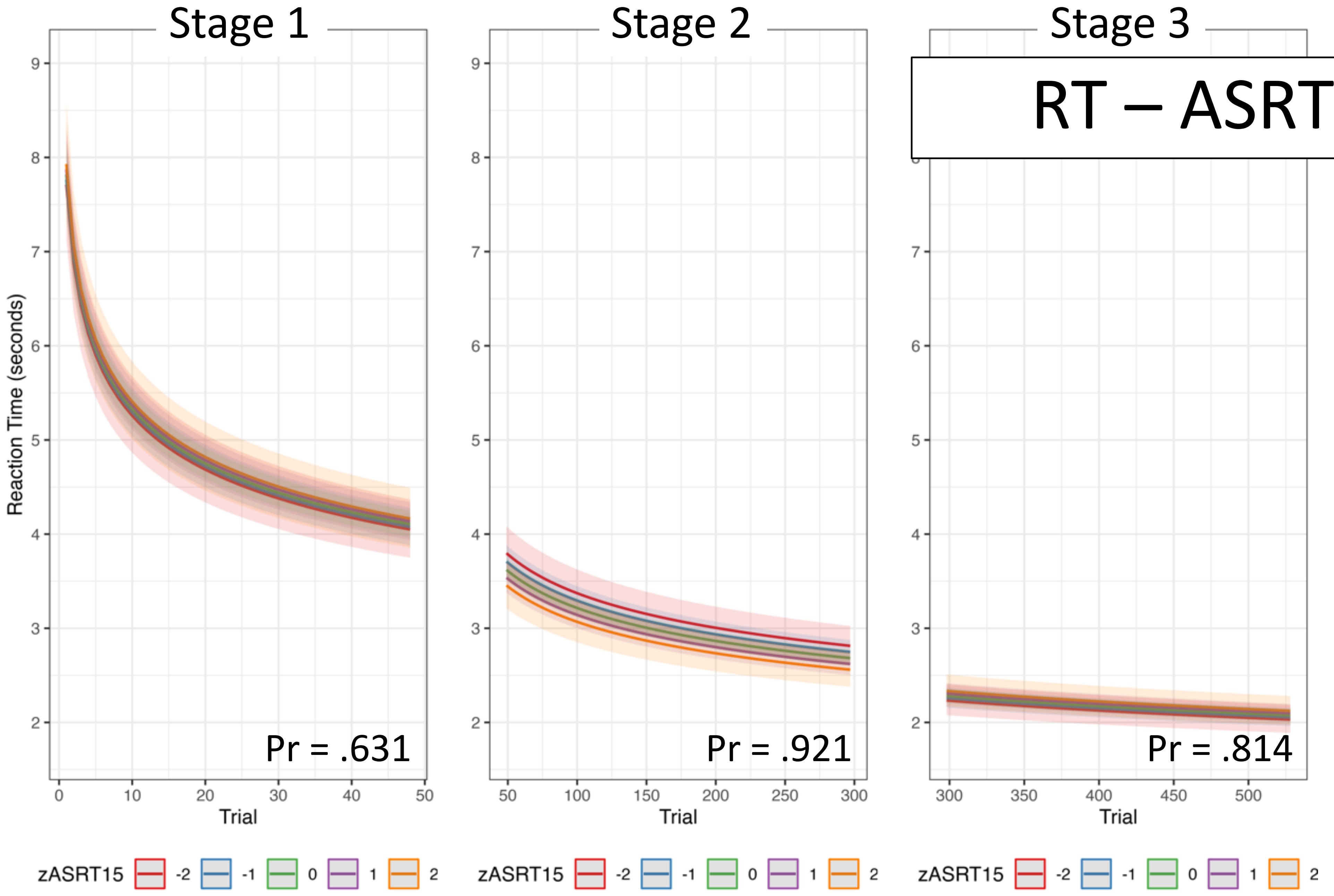

Stage 1
Stage 2
Stage 3
Acc – ASRT
Accuracy (Probability of correct resposnes)
1.0
0.9
0.8
0.7
0.6
0.5
Pr = .789
Pr = .713
Pr = .543
0 10 20 30 40 50
50 100 150 200 250 300
300 350 400 450 500
Trial
zASRT15 -2 -1 0 1


Stage 1
Stage 2
Stage 3
Acc – SL
Accuracy (Probability of correct resposnes)
1.0
0.9
0.8
0.7
0.6
0.5
Pr = .607
Pr = .766
Pr = .774
0 10 20 30 40 50
50 100 150 200 250 300
300 350 400 450 500
Trial
zSL -2 -1 0 1 2

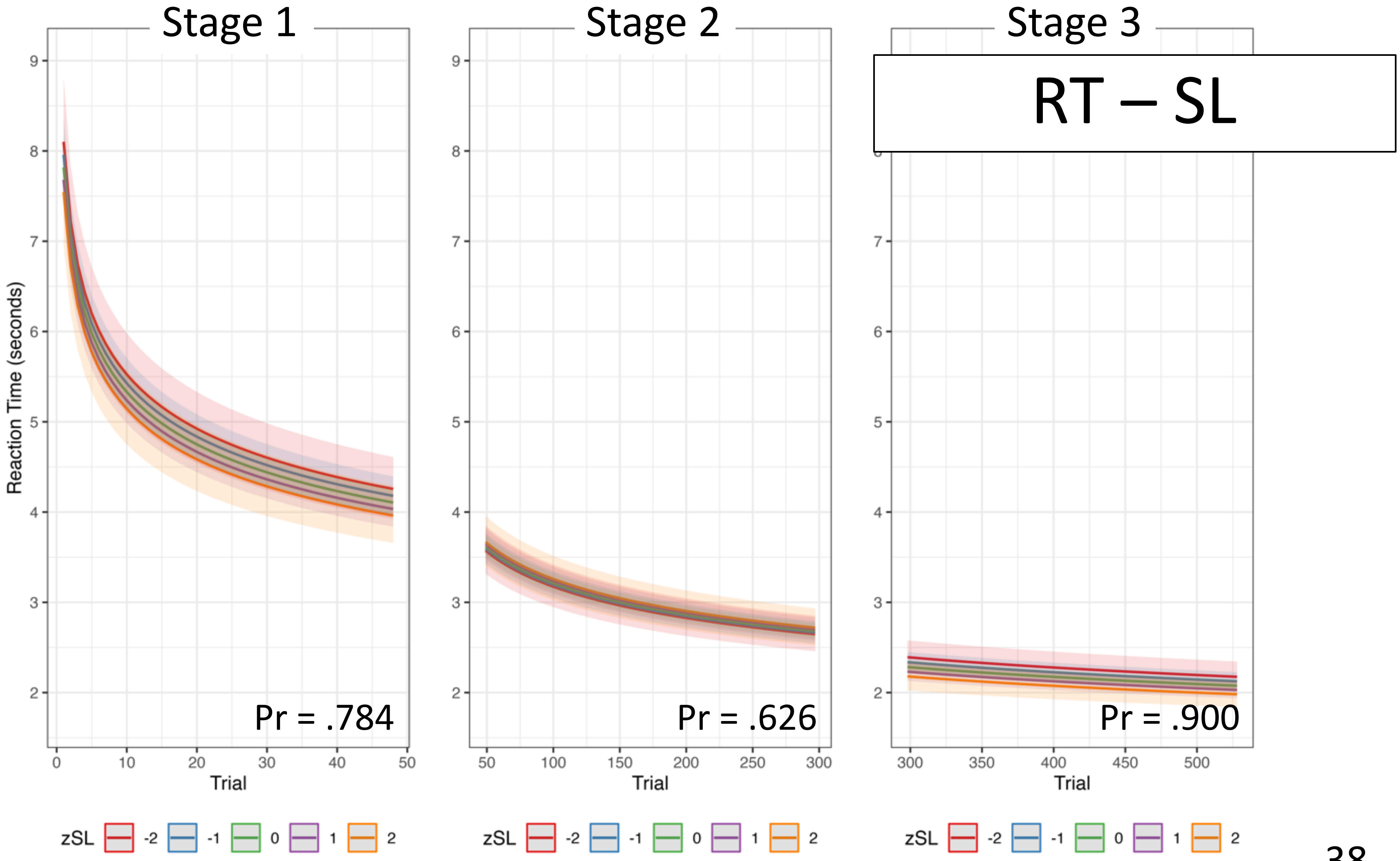


Stage 1
Stage 2
Stage 3
RT – Declarative
Reaction Time (seconds)
Trial
Pr = .998
Pr = .981
Pr = .803
Declarative -2 -1 0 1

RT – ASRT



Stage 1
Stage 2
Stage 3
Reaction Time (seconds)
Trial
Pr = .631
Pr = .921
Pr = .814
zASRT15 -2 -1 0 1 2



Stage 1
Stage 2
Stage 3
RT – SL
Reaction Time (seconds)
9
8
7
6
5
4
3
2
0
10
20
30
40
50
50
100
150
200
250
300
350
400
450
500
Trial
Pr = .784
Pr = .626
Pr = .900
zSL
-2
-1
0
1
2

Summary

	Stage 1		Stage 2		Stage 3
Accuracy	Declarative	→	Declarative	→	-

	Stage 1		Stage 2		Stage 3
Reaction Time	Declarative	→	Declarative Procedural	→	-

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

Future Direction: Empirical

SLA is citing skill acquisition theory of **40** **<u>years ago</u>**!

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**

Tenison et al. (2016)

5$3 → 5 + 4 + 3 = 12

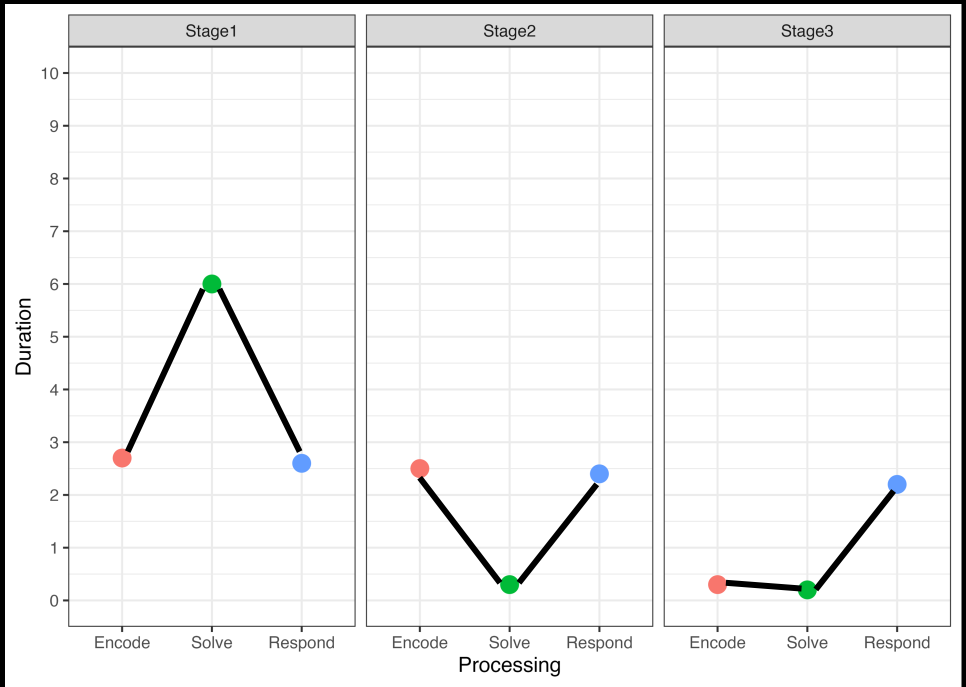
Skill acquisition in an arithmetic task (Pyramid problem)

Learning stages

- Cognitive
  - Encoding
  - Solving
  - Responding

  Cognitive processing stage

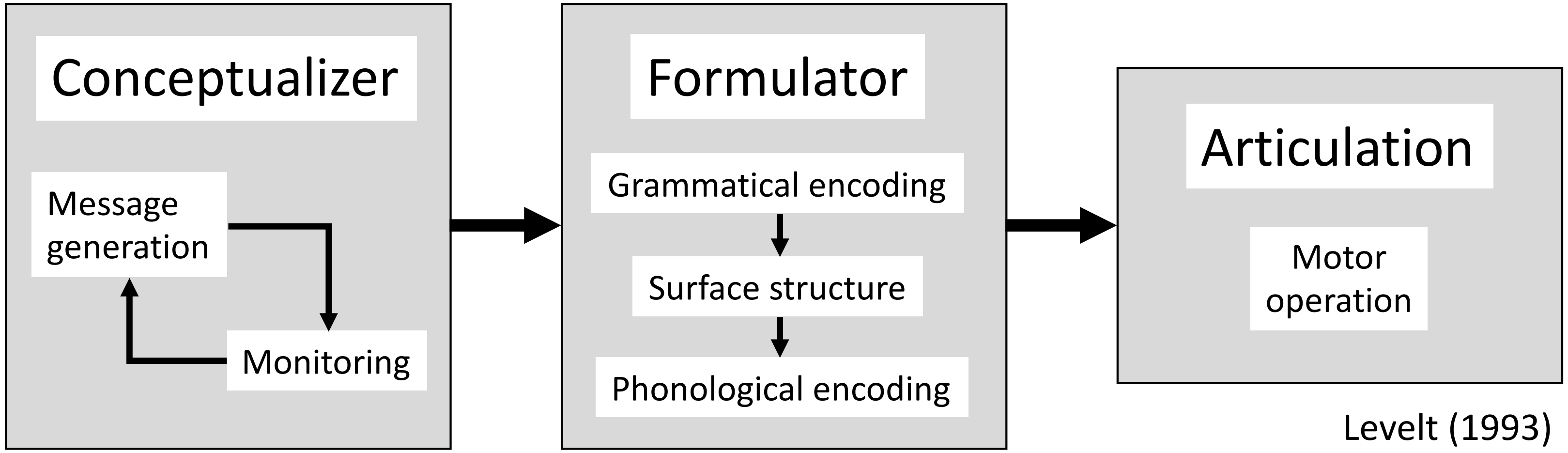
- Associative
  - Encoding
  - Solving
  - Responding
- Autonomous
  - Encoding
  - Solving
  - Responding



Future Direction: Theoretical

How do each process is affected by automatization?

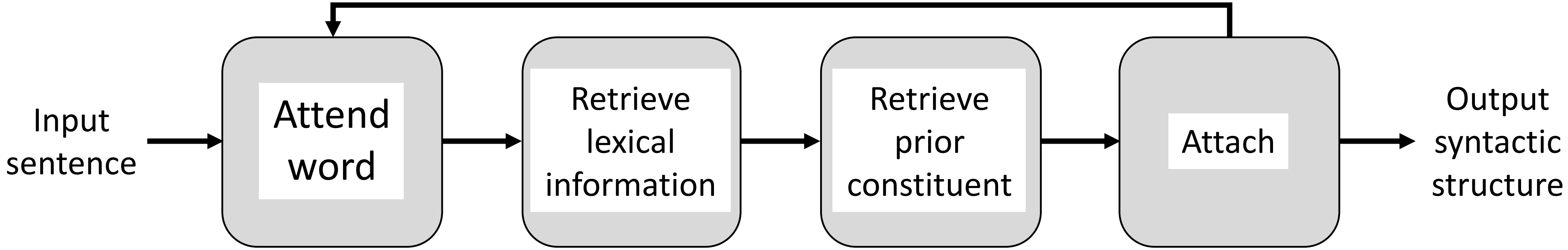
Production



Levelt (1993)

Proceduralization (restructuring)

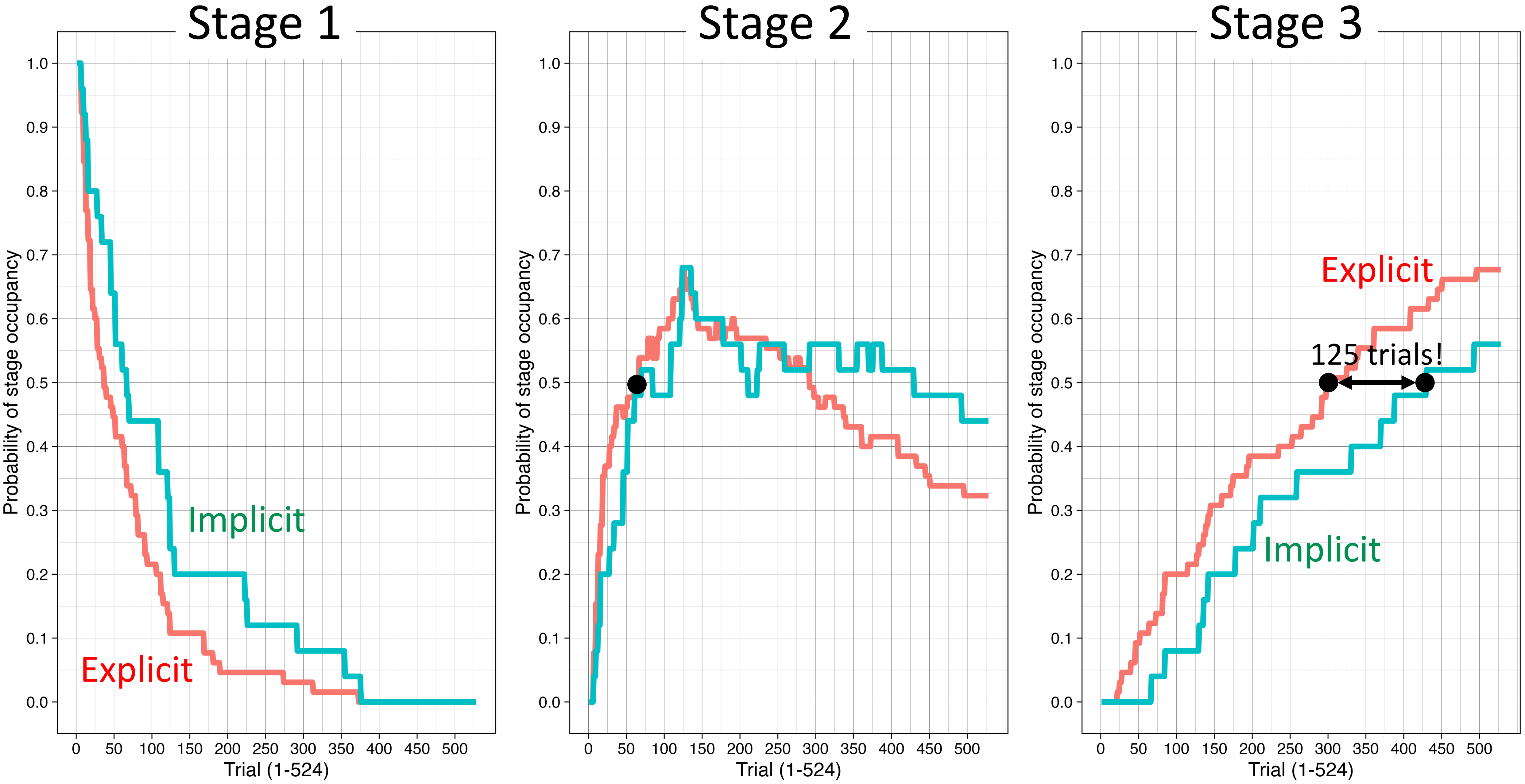
Comprehension



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

National Science Foundation

Explicit (Deductive) Implicit (Inductive)?


Stage 1
Stage 2
Stage 3
Probability of stage occupancy
Trial (1-524)
Implicit
Explicit
125 trials!
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
50
100
150
200
250
300
350
400
450
500

Thank you!

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My dissertation:

https://github.com/maieryo/research/blob/papers/RyoMaiePhDSLS.pdf

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