



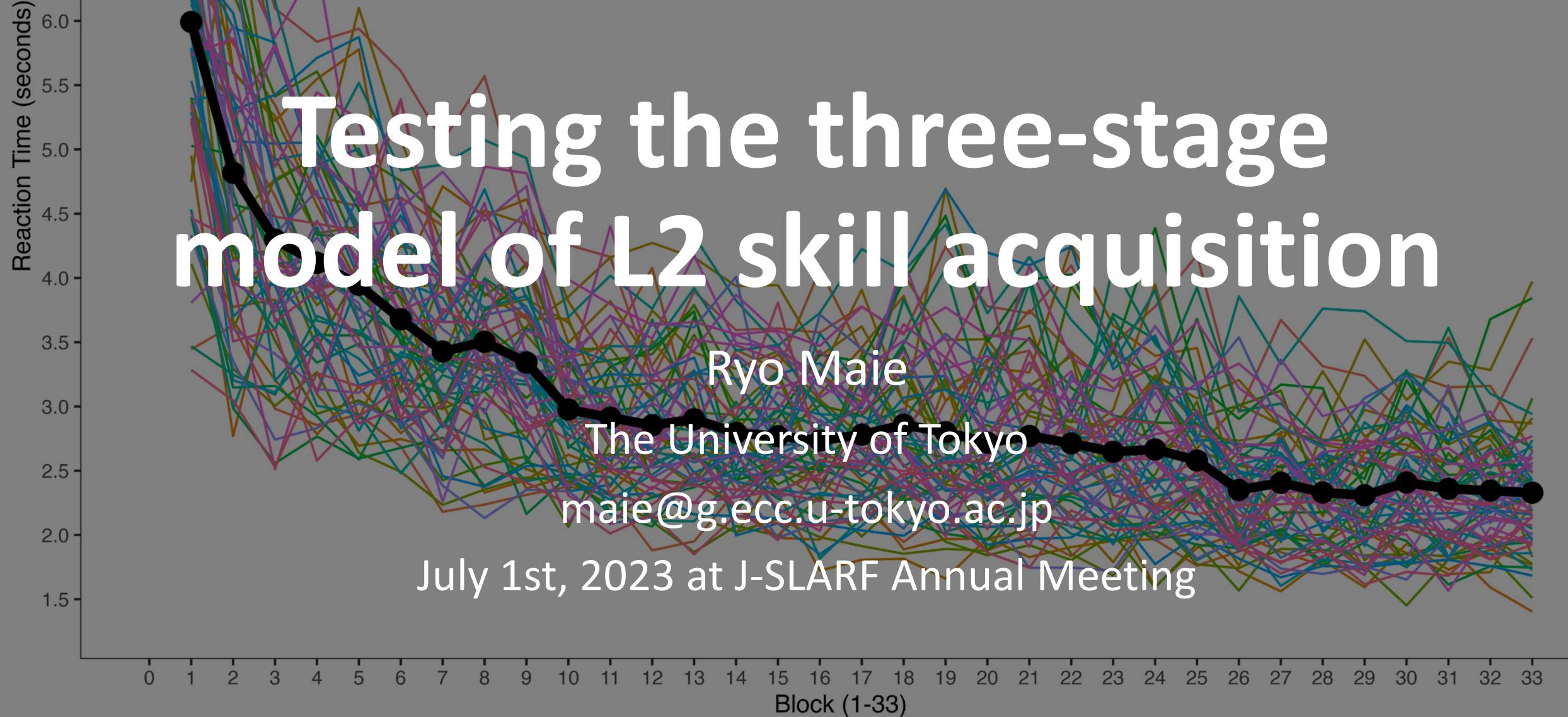
Testing the three-stage model of L2 skill acquisition

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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)

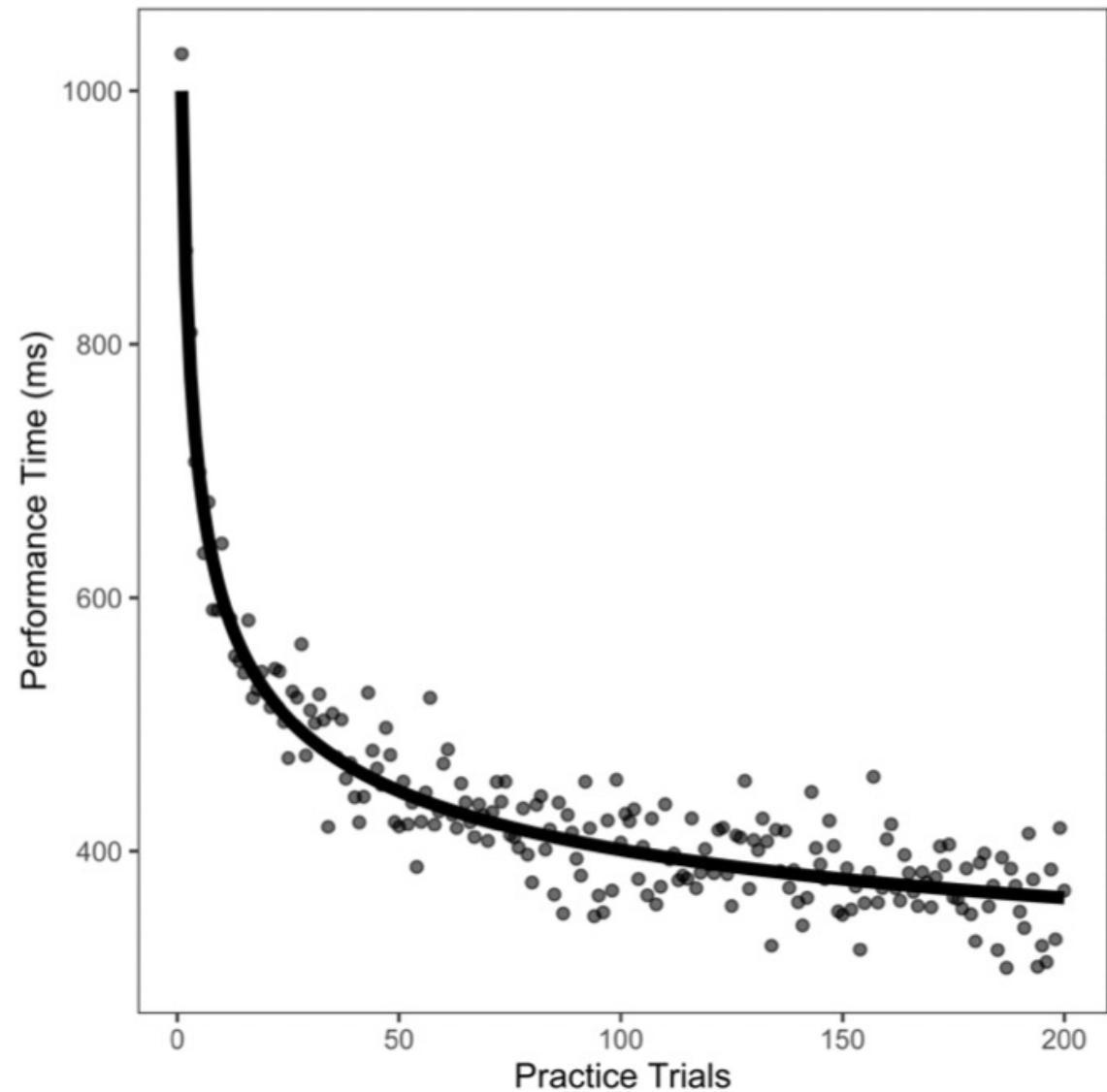
John Anderson (1983):

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

Evidence on **L2** skill acquisition

Skill acquisition ...

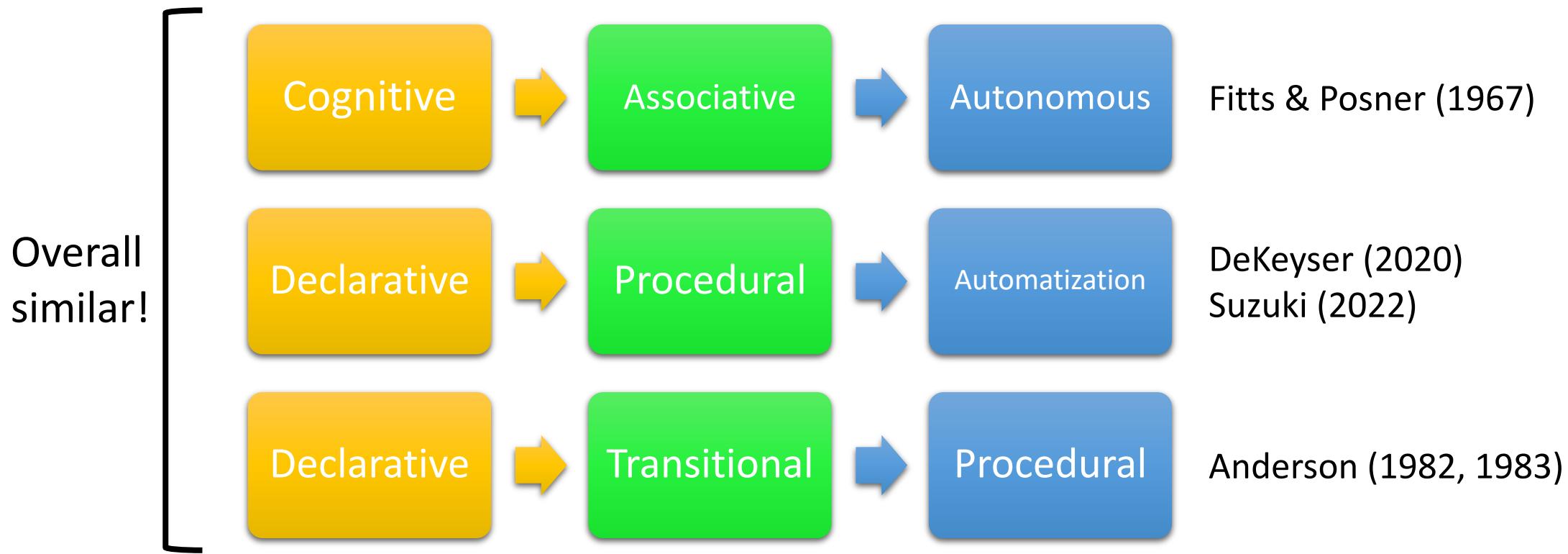
1. follows **the power-law of practice**
 - DeKeyser (1997), Ferman et al. (2009), Hui (2020), Maie (2020)
2. leads to **skill-specific** competence
 - comprehension vs. production
 - DeKeyser (1997), DeKeyser & Sokalski (1996), Li & DeKeyser (2017), Suzuki & Sunada (2019)



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)



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

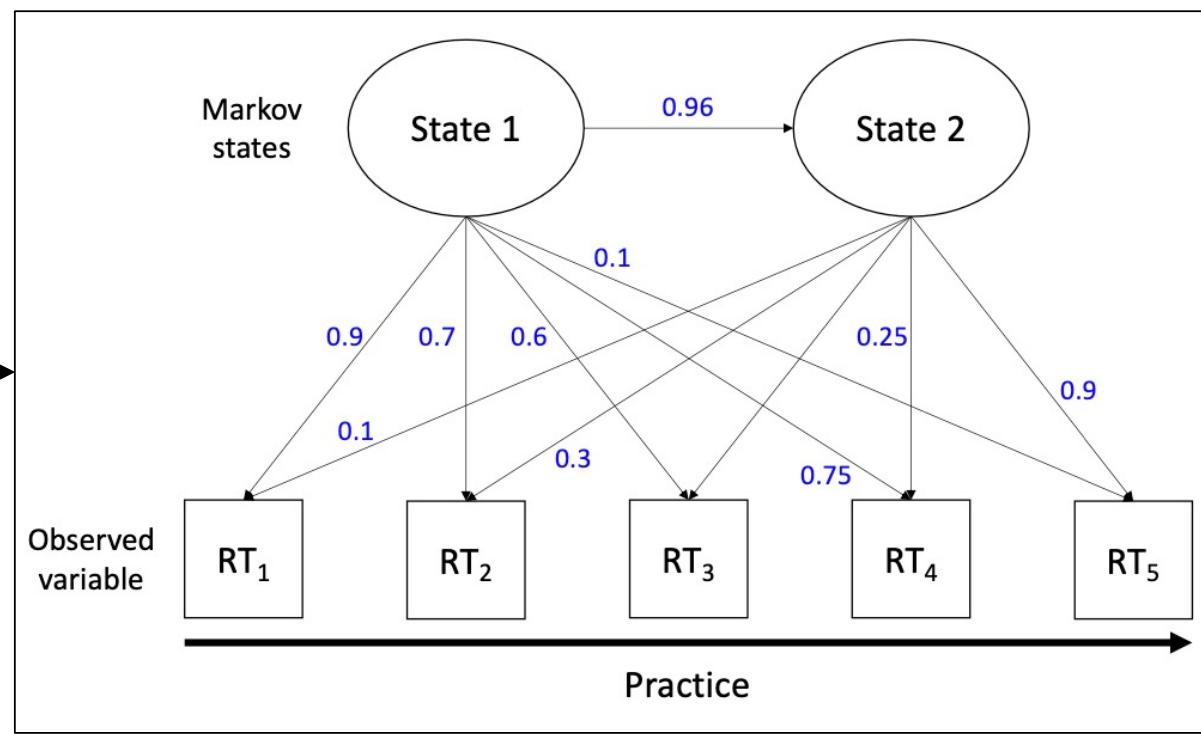
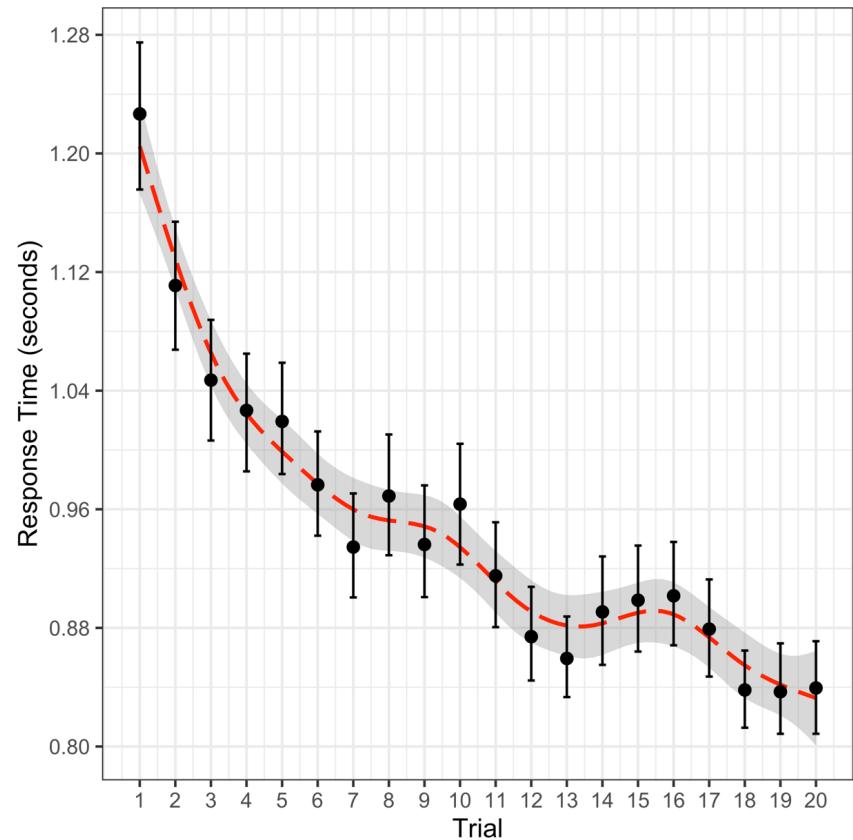
- Procedural learning ability predicting the degree of automatization from practice (Pili-Moss et al., 2020; Suzuki, 2017)



The number of stages??

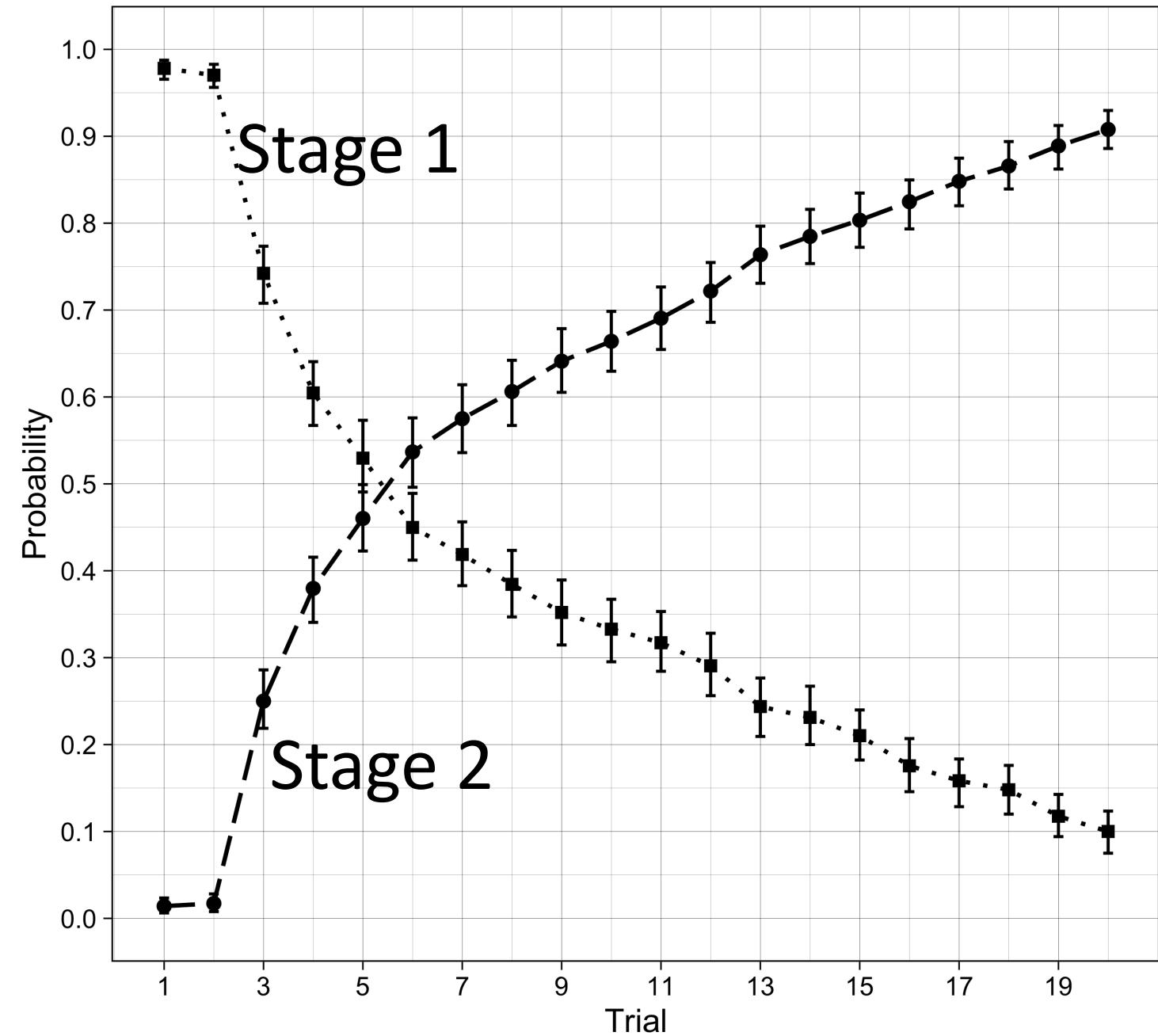
Skill acquisition in L2 vocabulary (Maie, rejected)

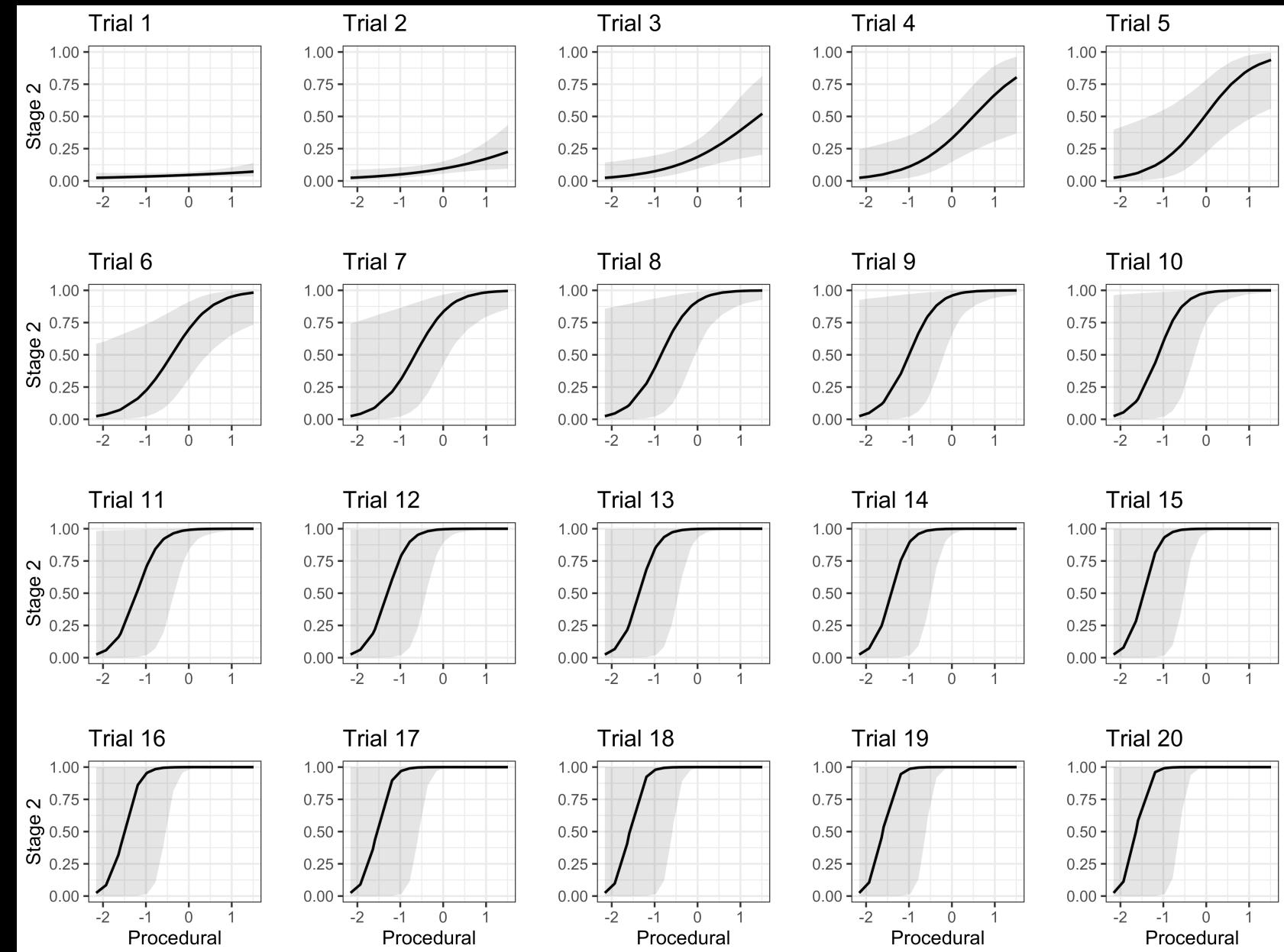
Applying cognitive modeling to reaction time data to test skill acquisition stages



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 ...

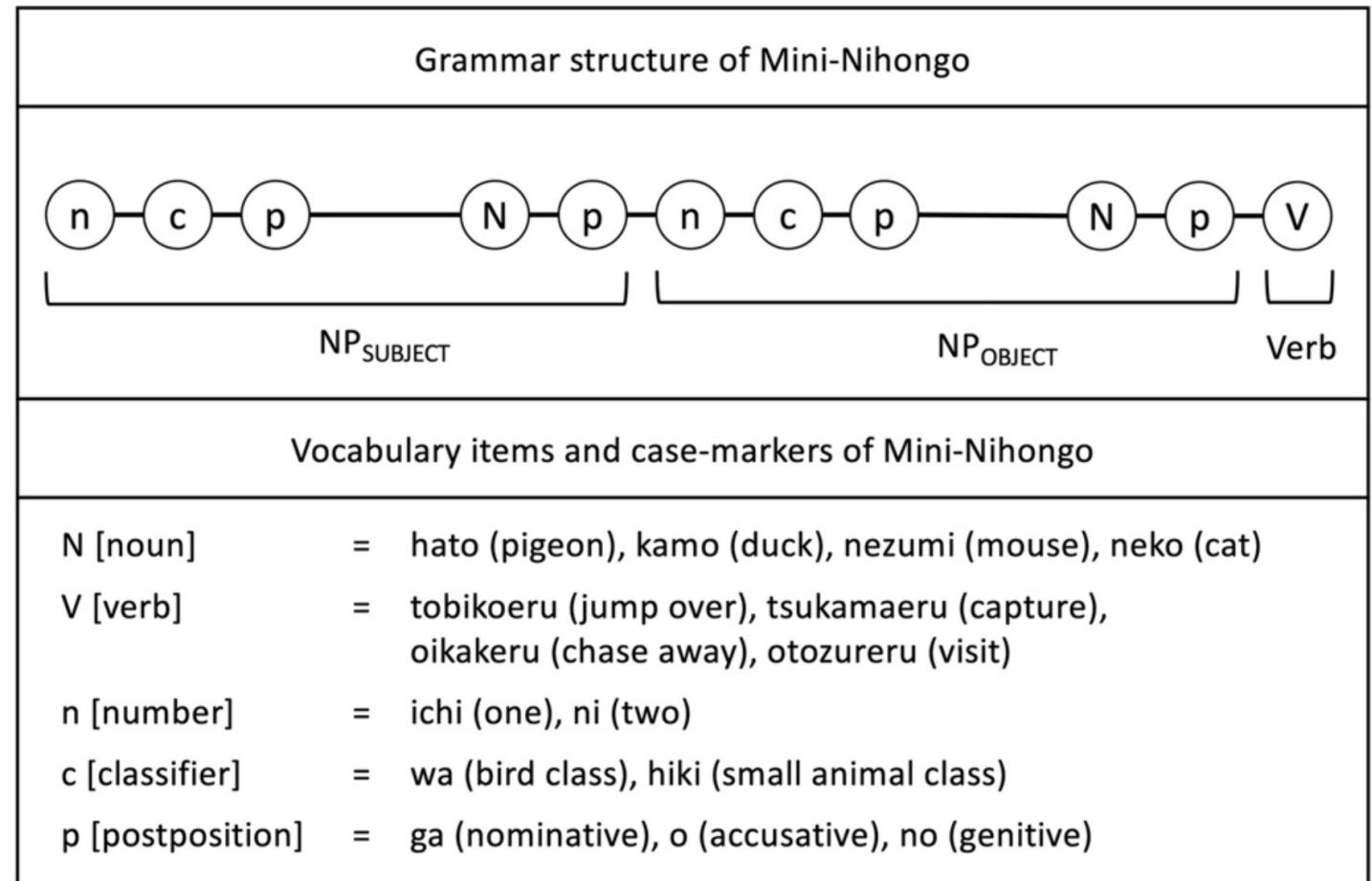
1. How many stages of skill acquisition do L2 learners go through?
2. Which memory systems, declarative and/or procedural memory, are implicated in each learning stage?



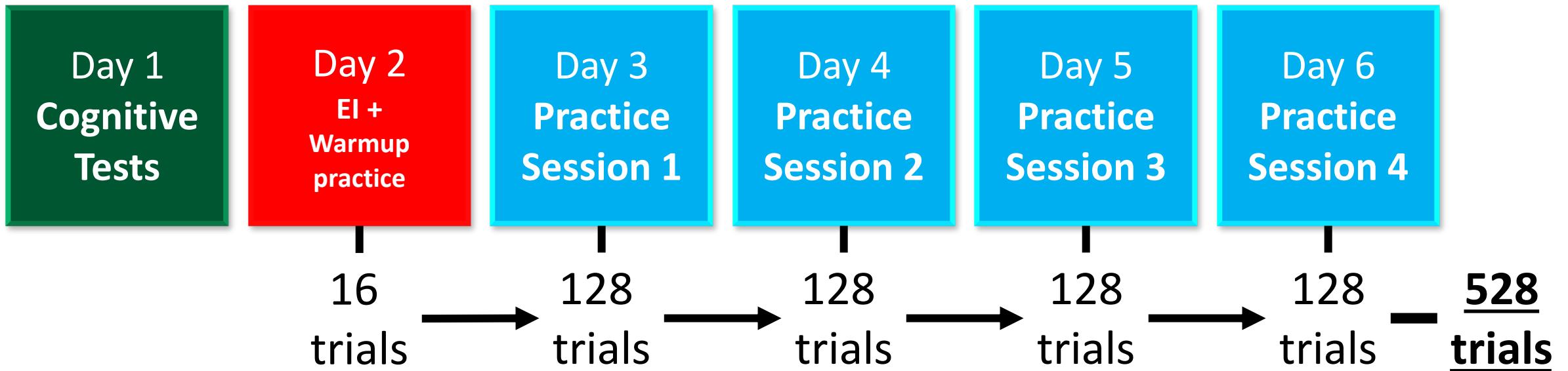
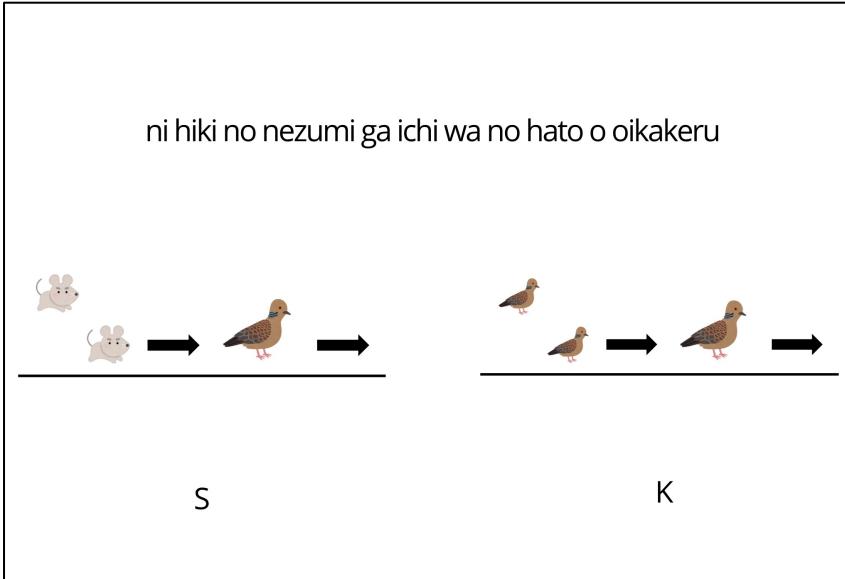
6 days (6 hours in total)

Language

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



Language Practice (Comprehension Practice)



Language Practice (Comprehension Practice)



Cognitive Tests

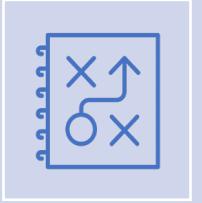


Declarative Memory

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

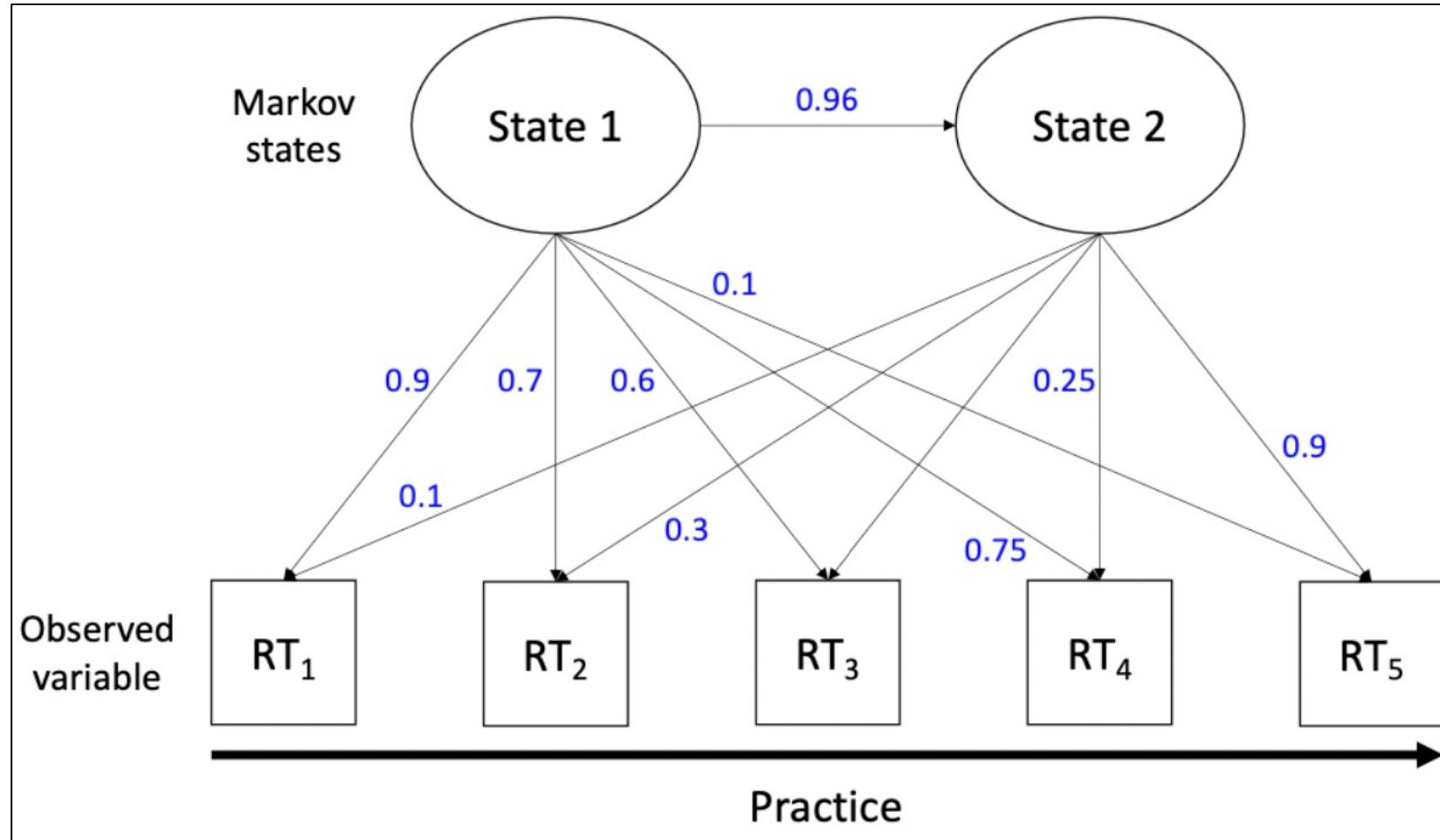
1. Hidden Markov modeling

- 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



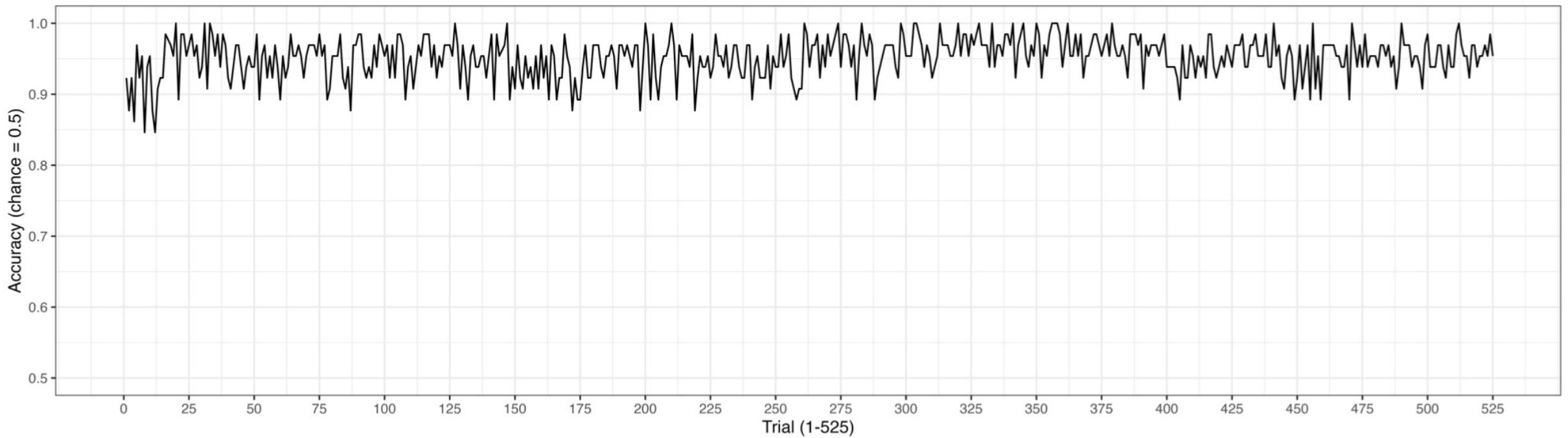
Model comparison

- Log-likelihood
- AICc
- BIC

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

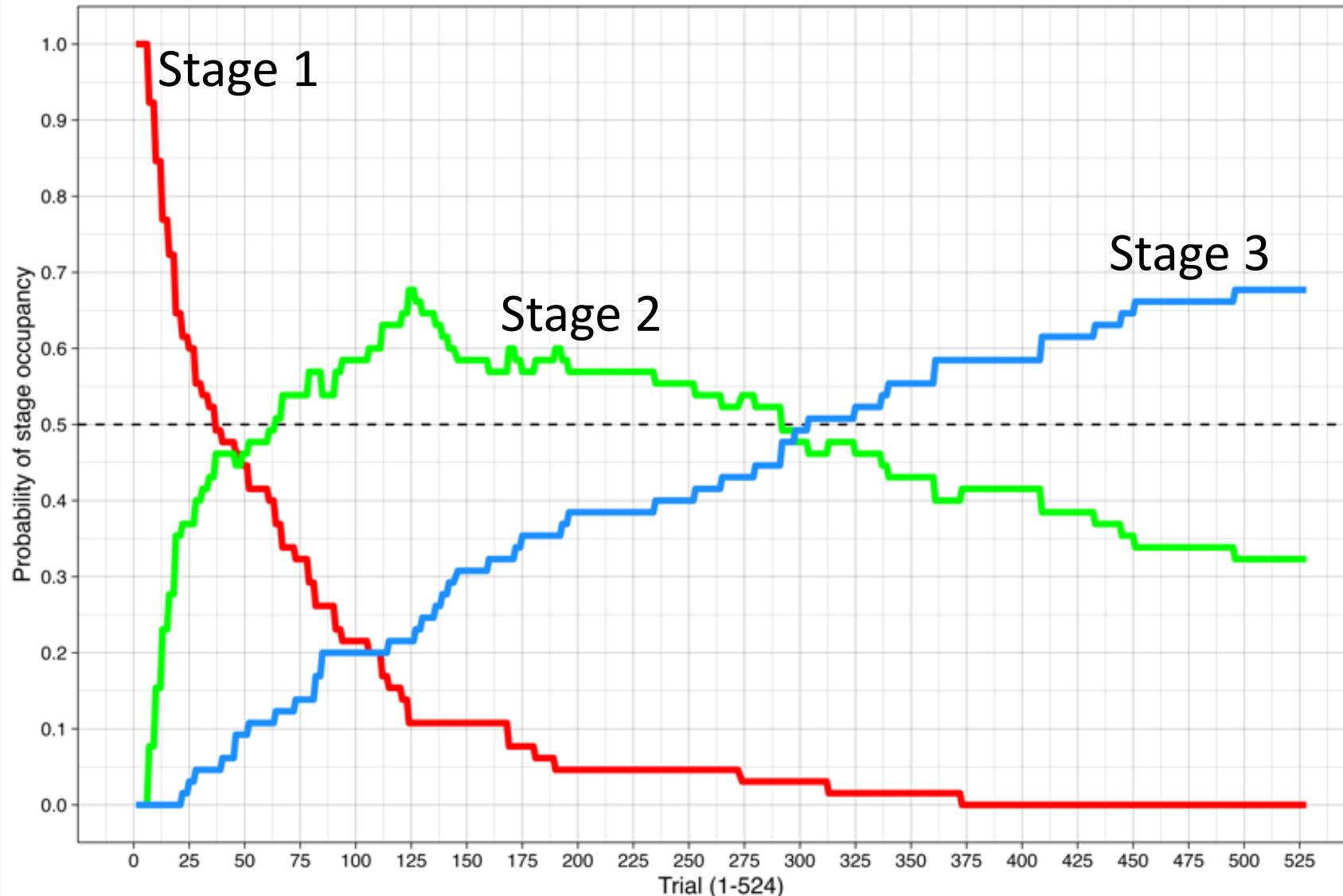
	BIC	Diff	Pr(M)
One-stage	39902	3239	.000
Two-stage	36700	37	.000
Three-stage	36663	0	≈ 1.000

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



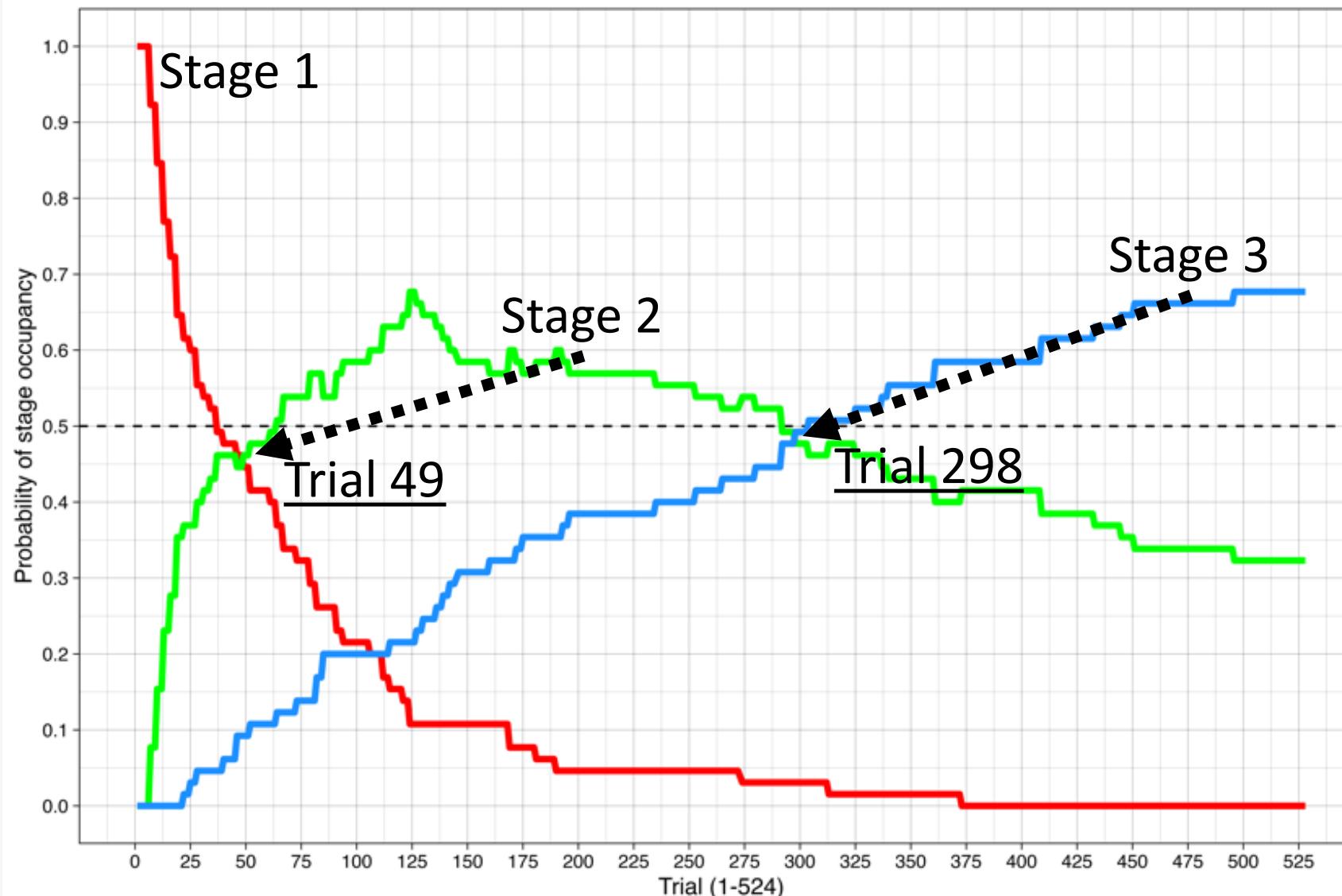
	Intercept	β_{Stage1}	β_{Stage2}	β_{Stage3}	α
One-stage	0.07	7.17	-	-	-0.23
Two-stage	0.50	6.70	4.25	-	-0.20
Three-stage	0.00	6.65	4.85	3.60	-0.12

Hidden Markov Modeling



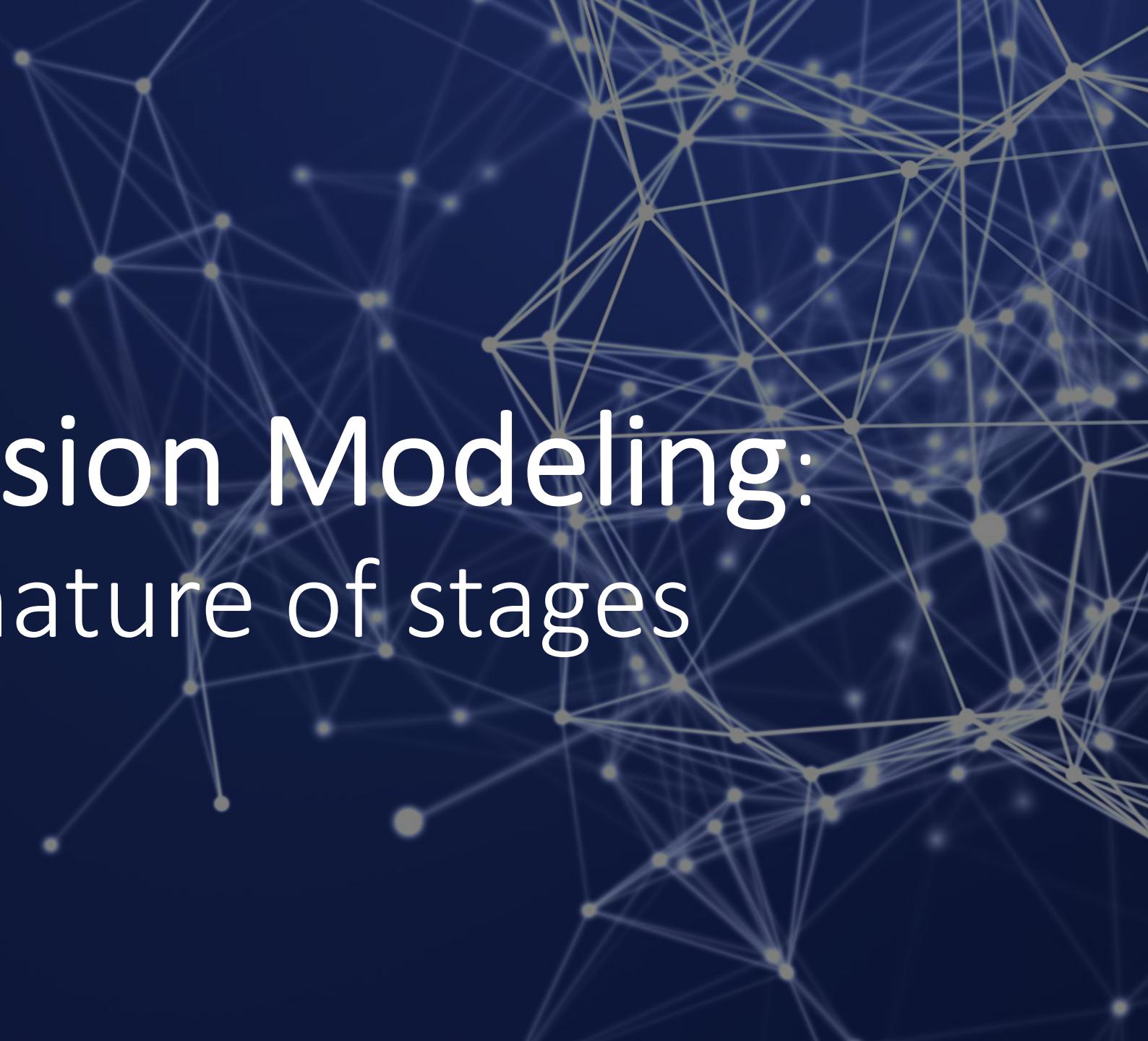
Note: DeKeyser (1997) – proceduralization can take place as fast as 8-16 trials

Hidden Markov Modeling

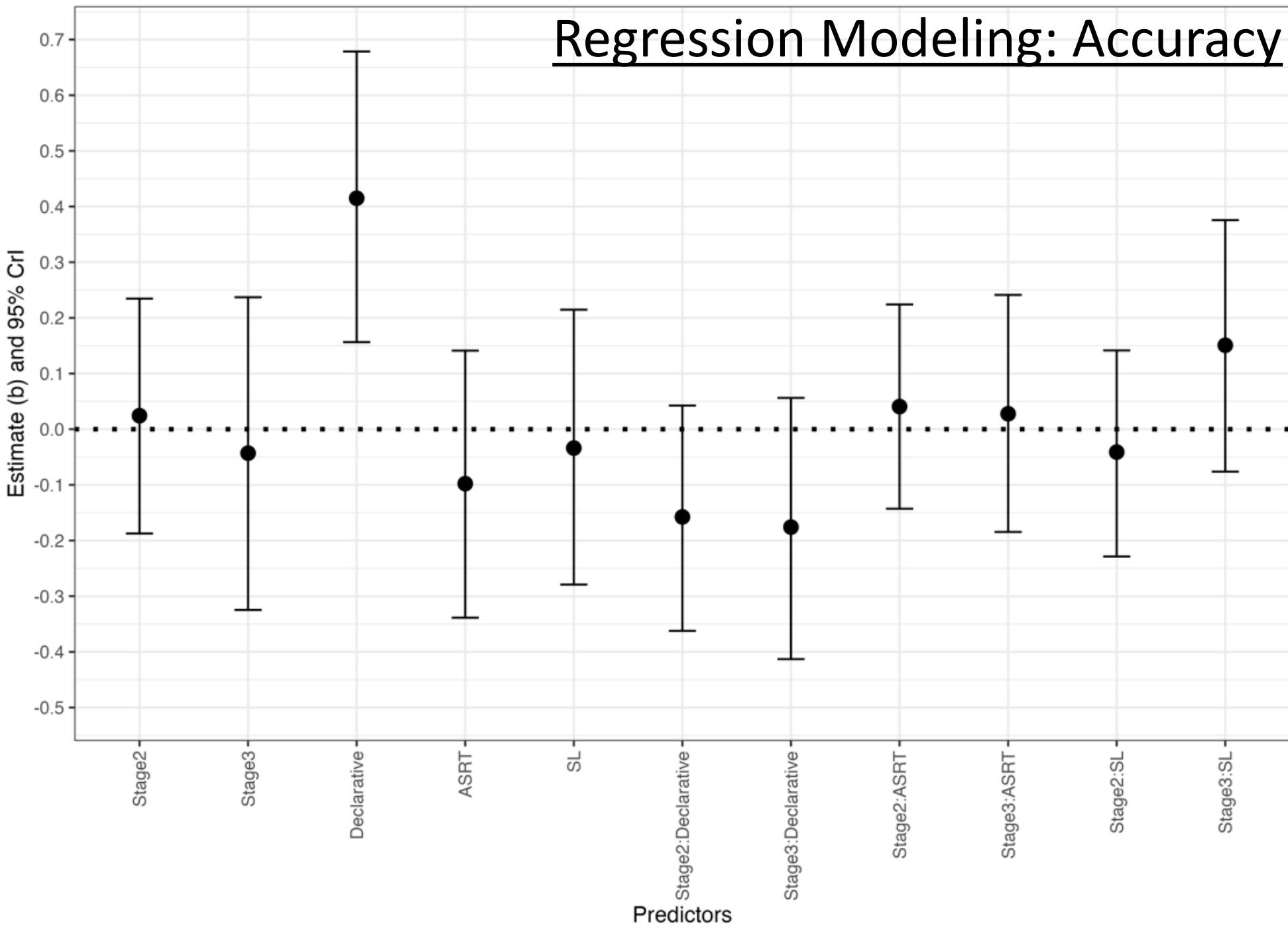


Note: DeKeyser (1997) – proceduralization can take place as fast as 8-16 trials

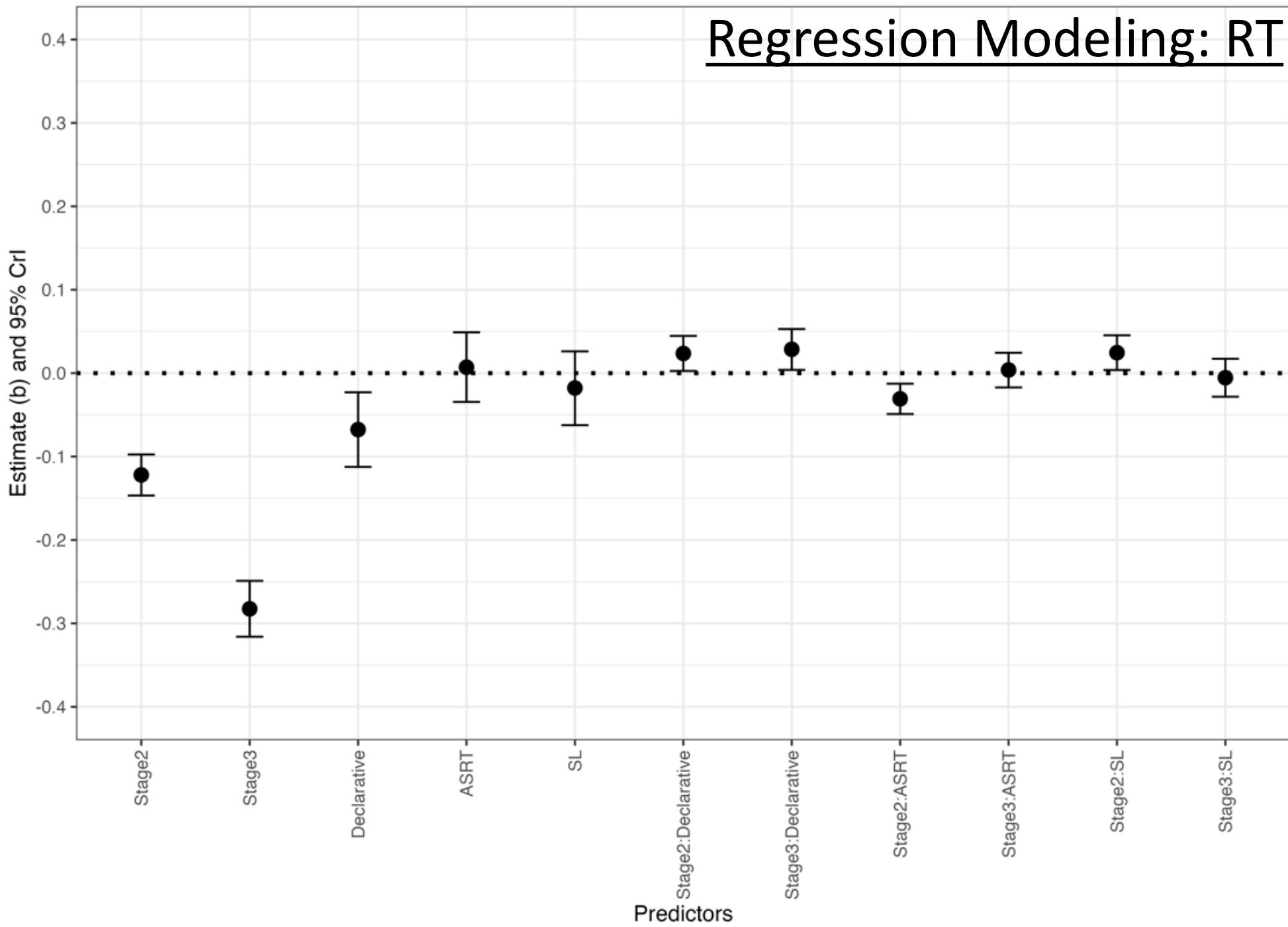
Regression Modeling: The nature of stages

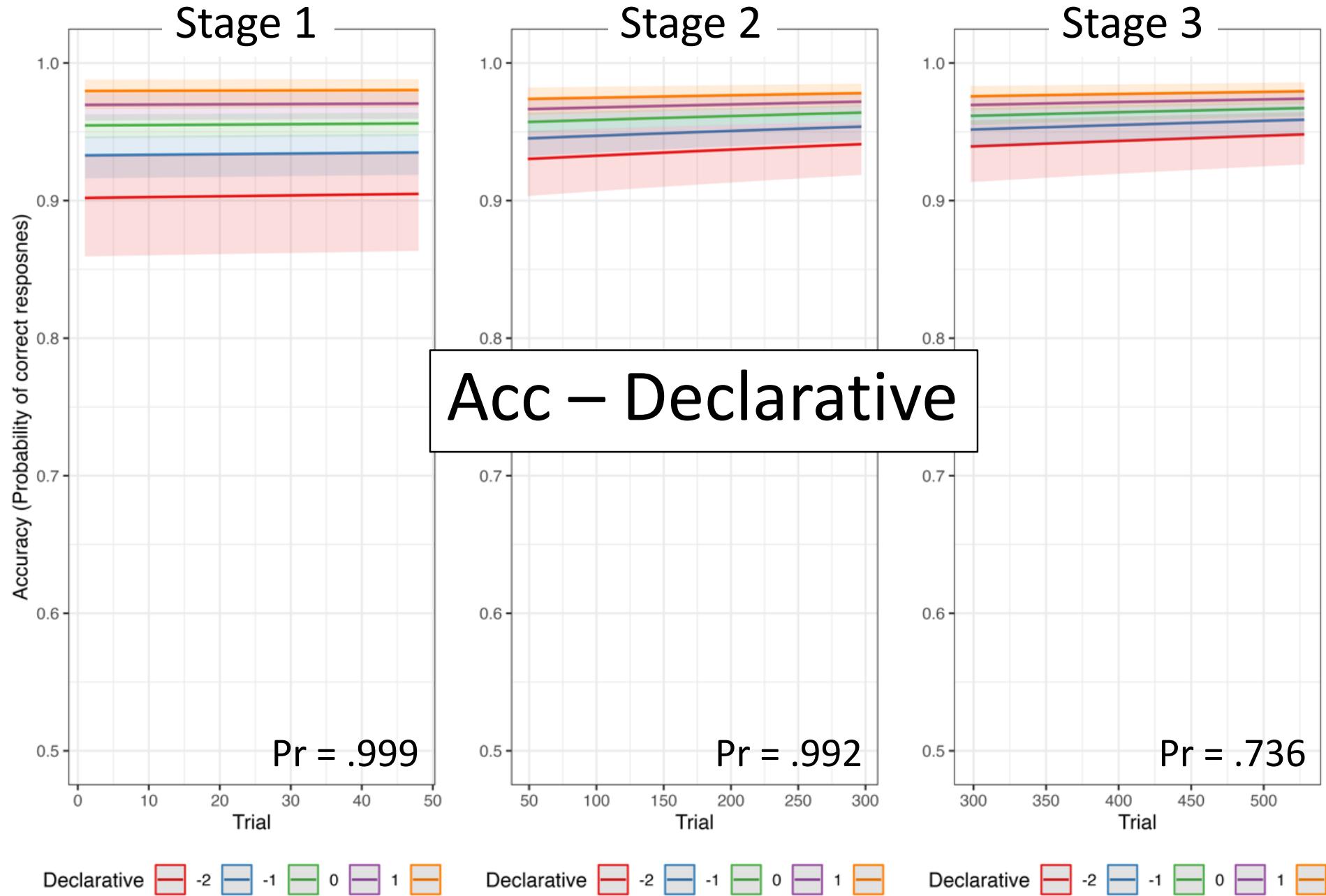


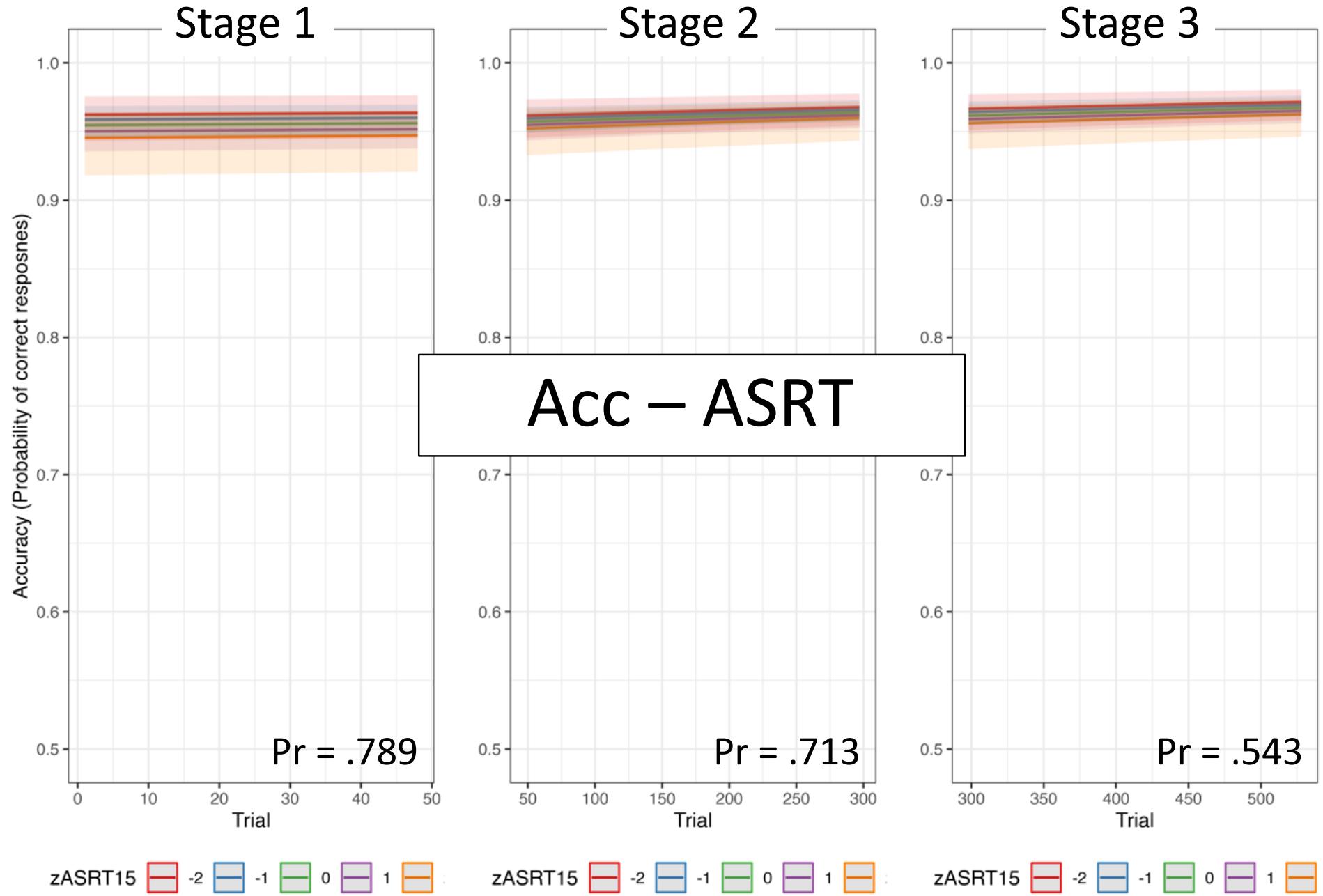
Regression Modeling: Accuracy

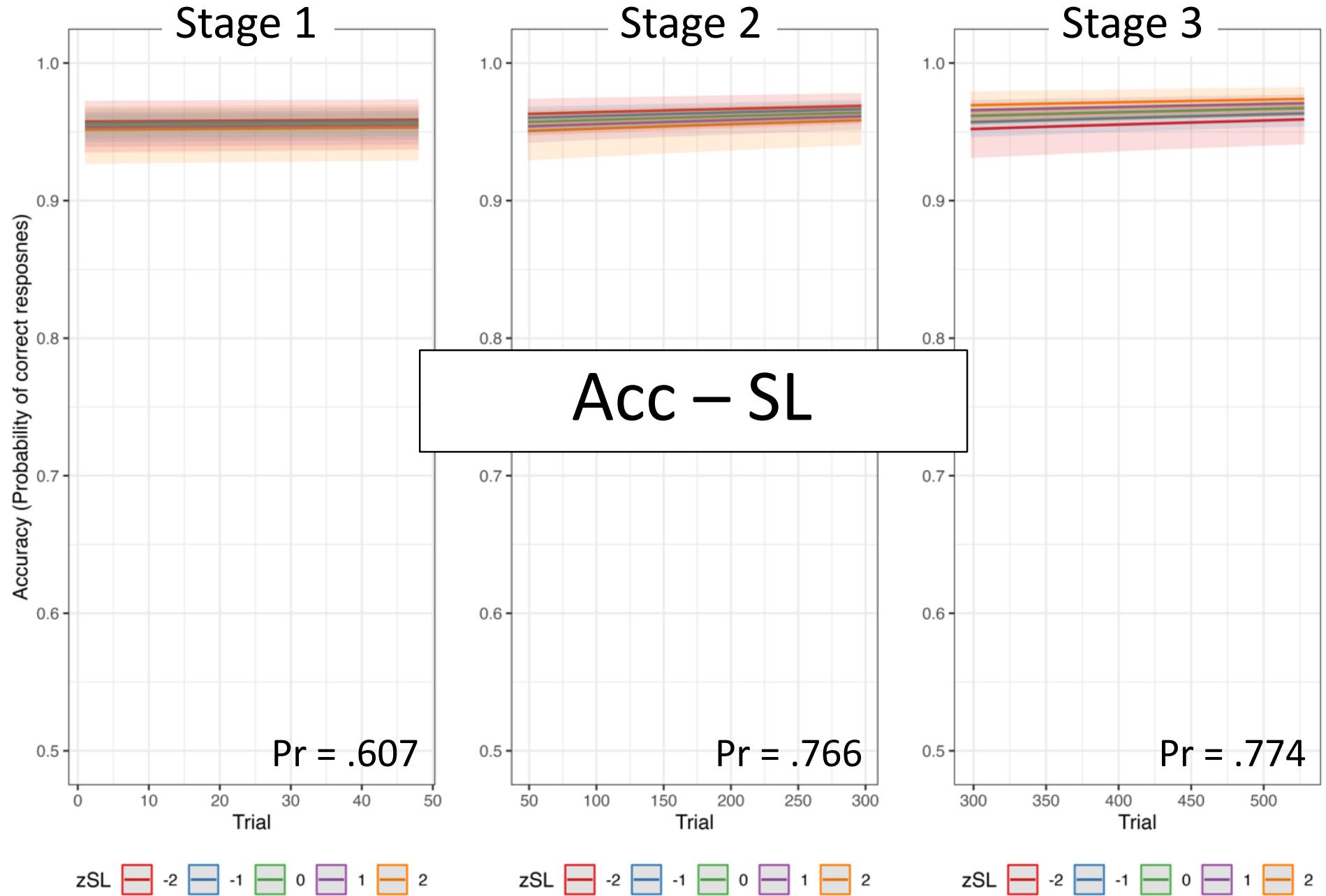


Regression Modeling: RT

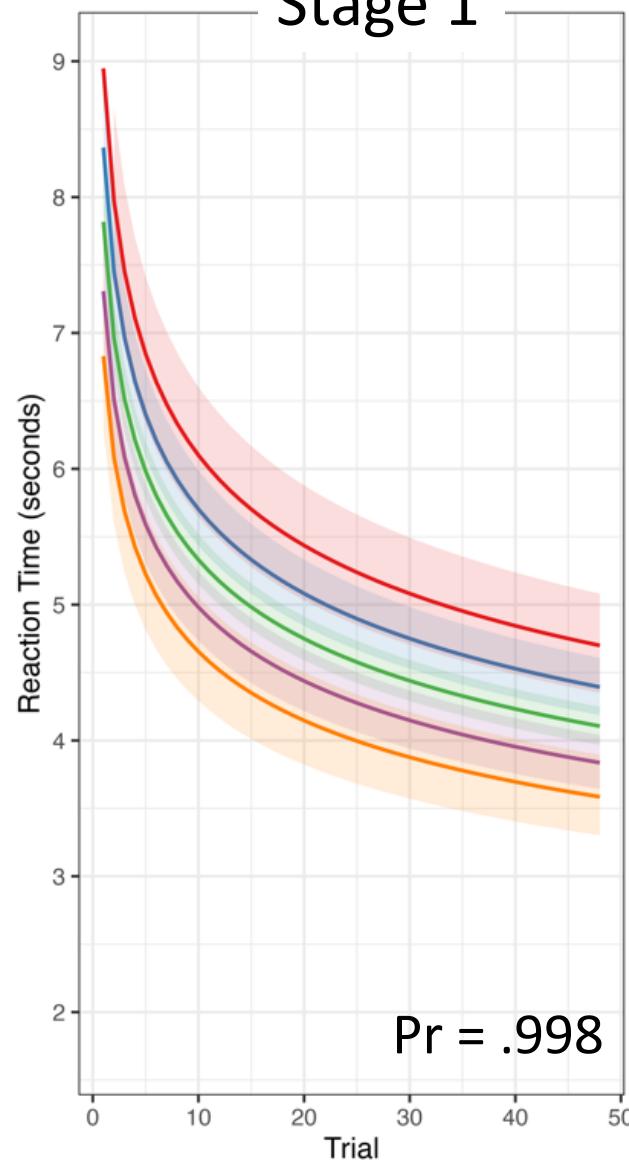




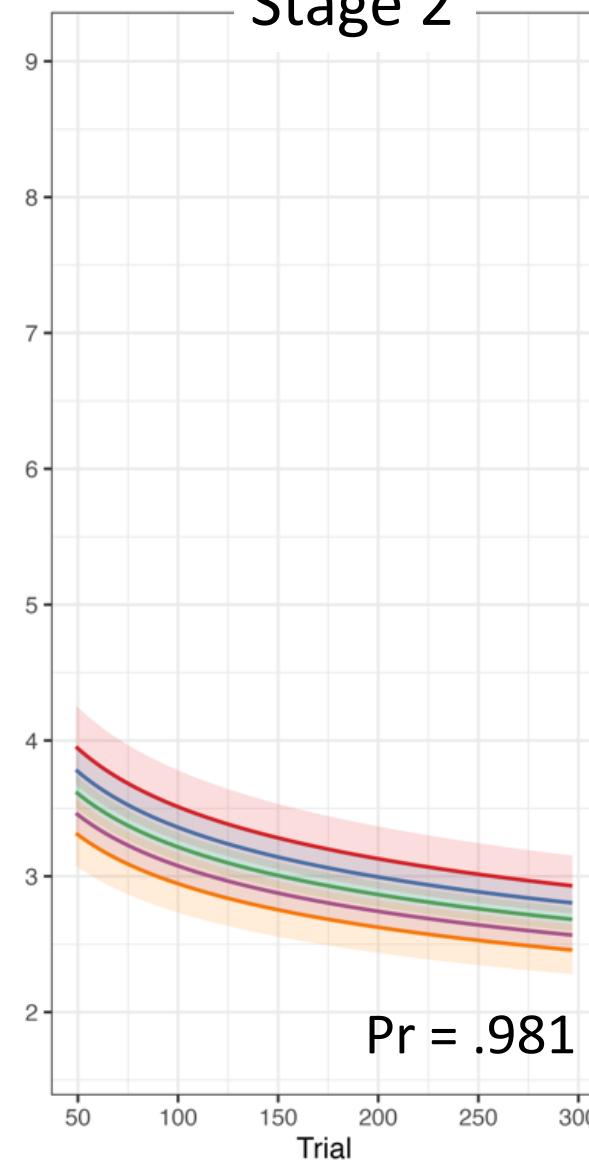




Stage 1

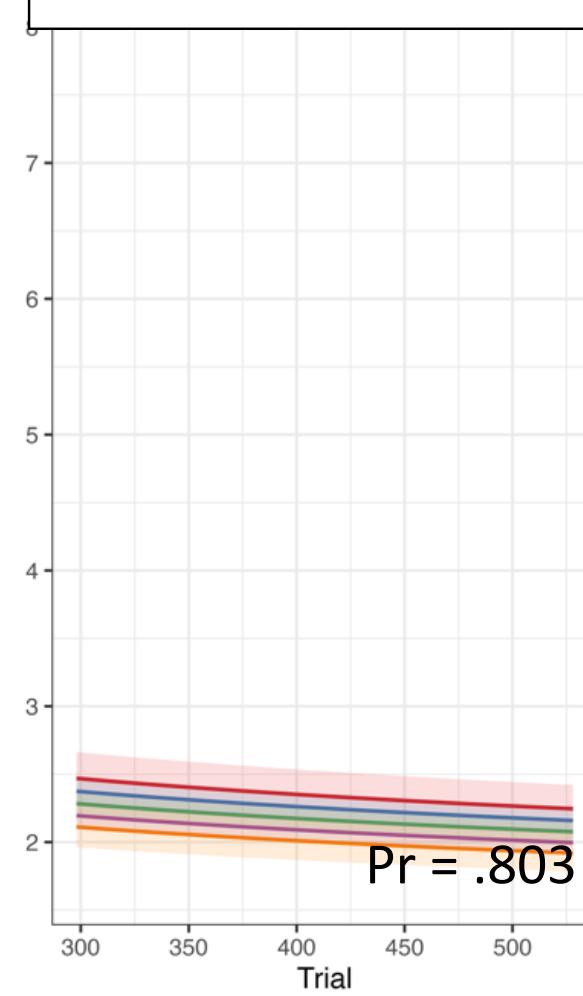


Stage 2

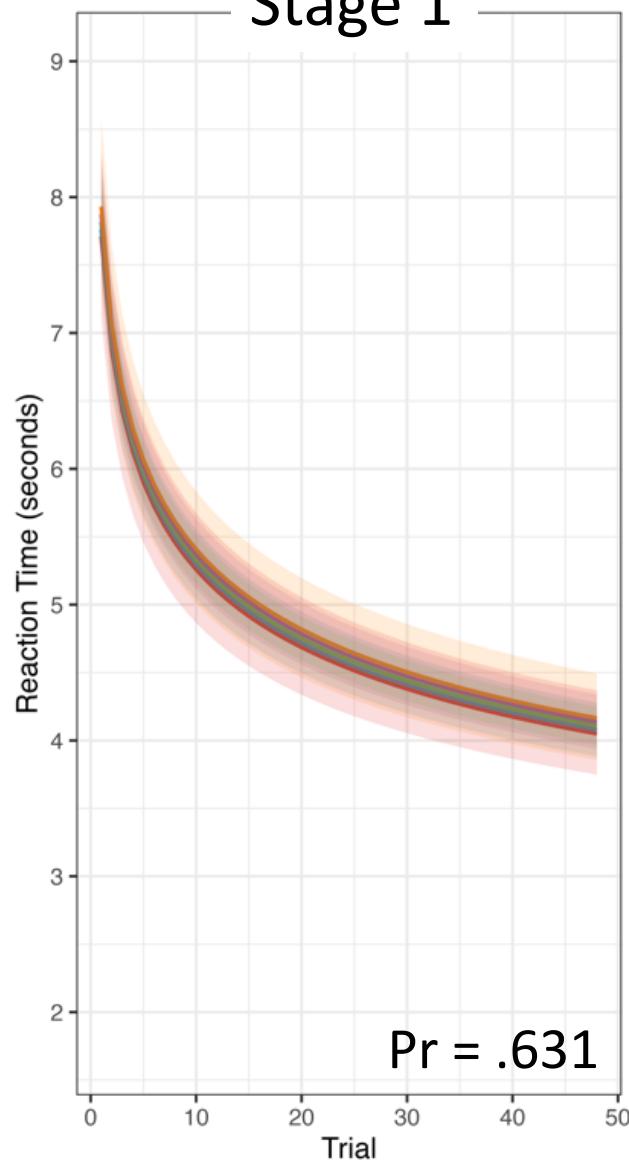


Stage 3

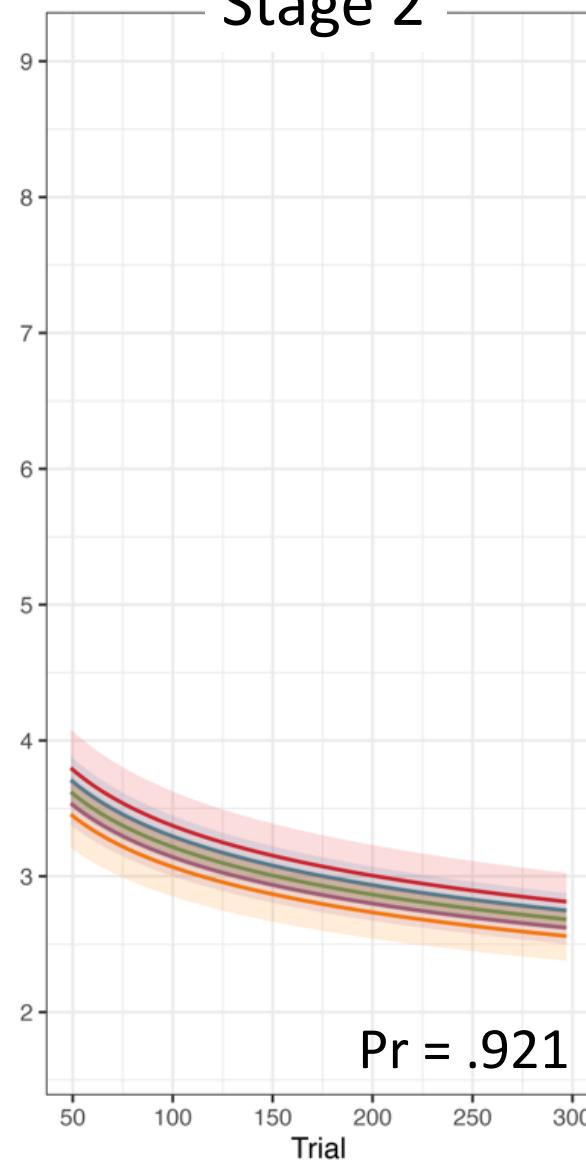
RT – Declarative



Stage 1

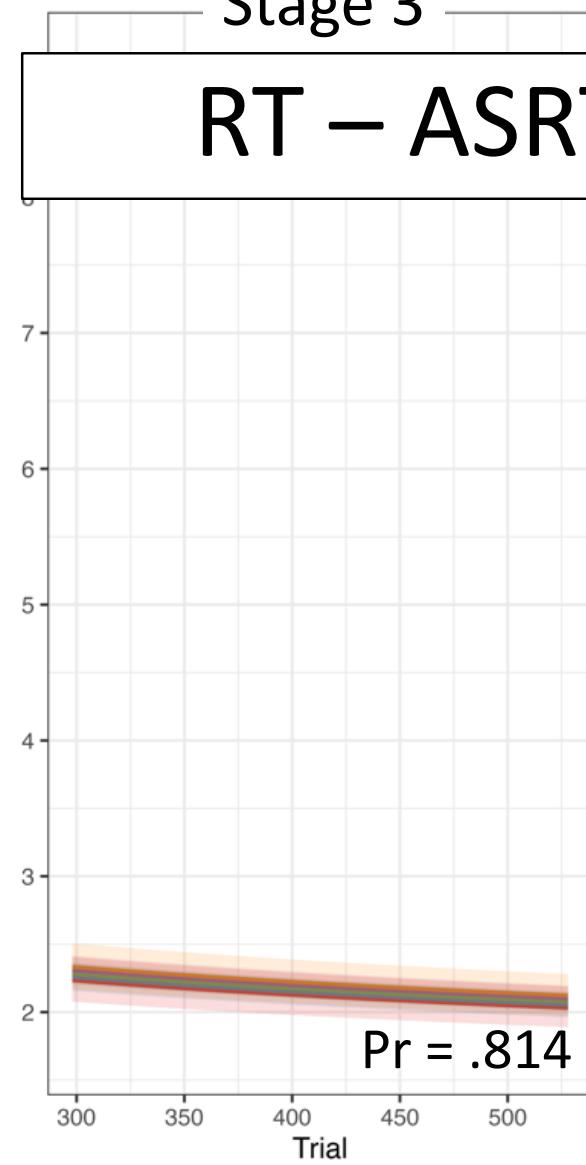


Stage 2



Stage 3

RT – ASRT

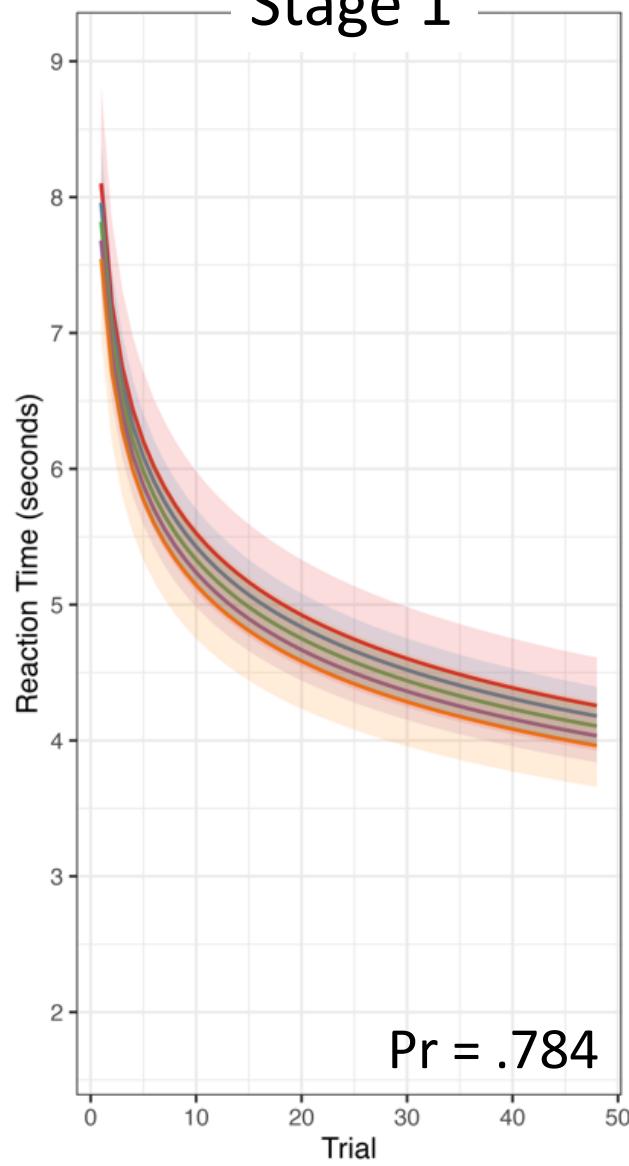


zASRT15 -2 -1 0 1 2

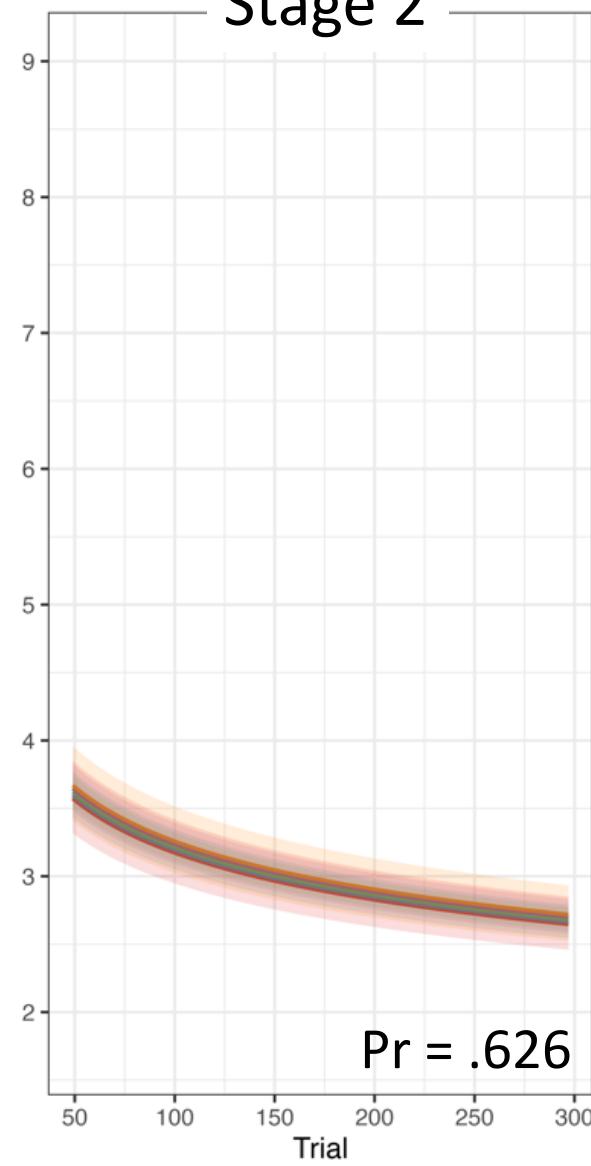
zASRT15 -2 -1 0 1 2

zASRT15 -2 -1 0 1 2

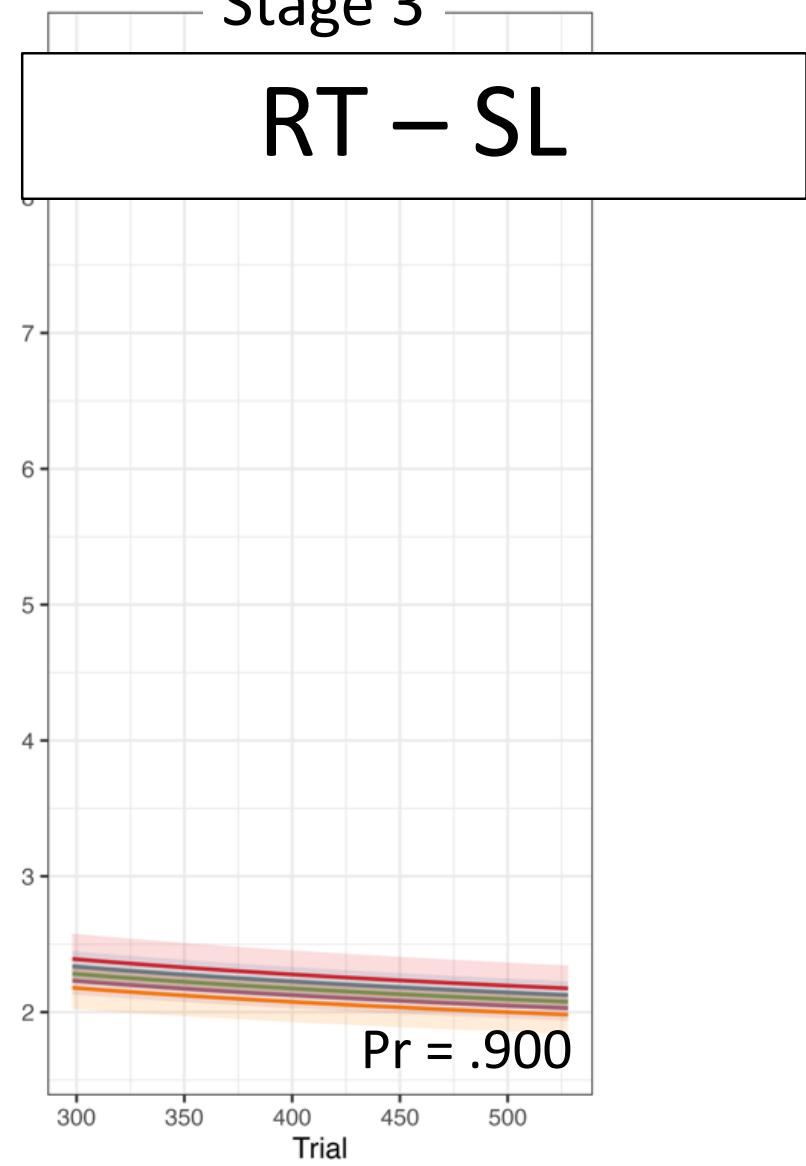
Stage 1



Stage 2

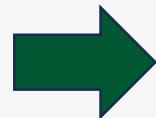
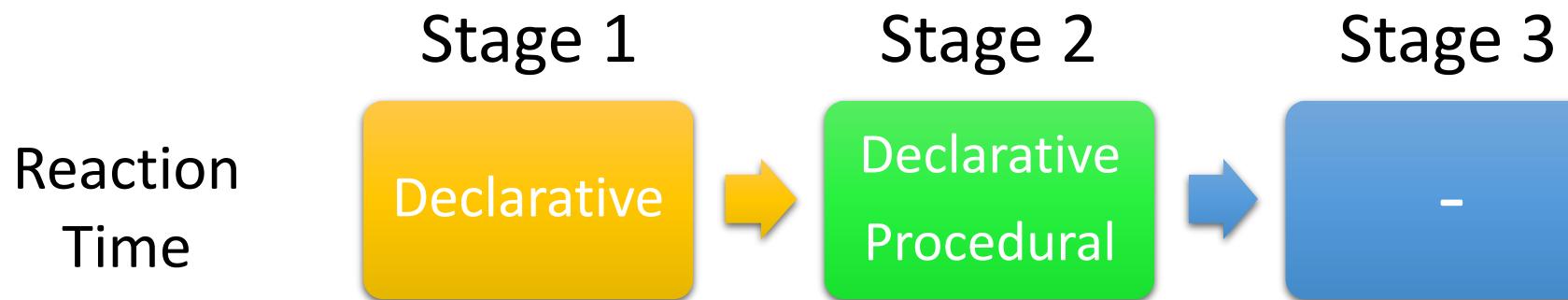
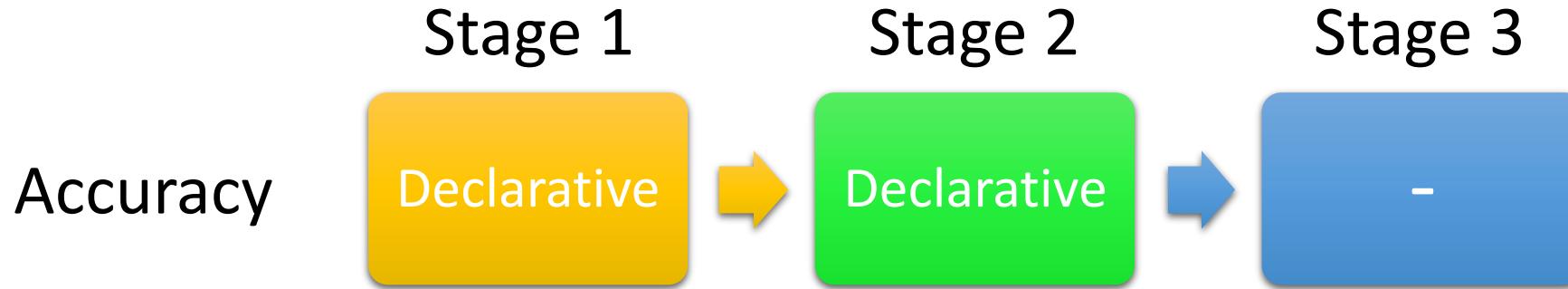


Stage 3



RT - SL

Summary



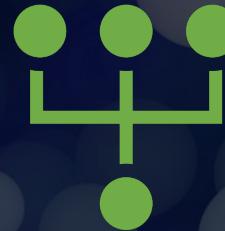
Evidence for skill acquisition theory (the three-stage model & ACT-R)

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**

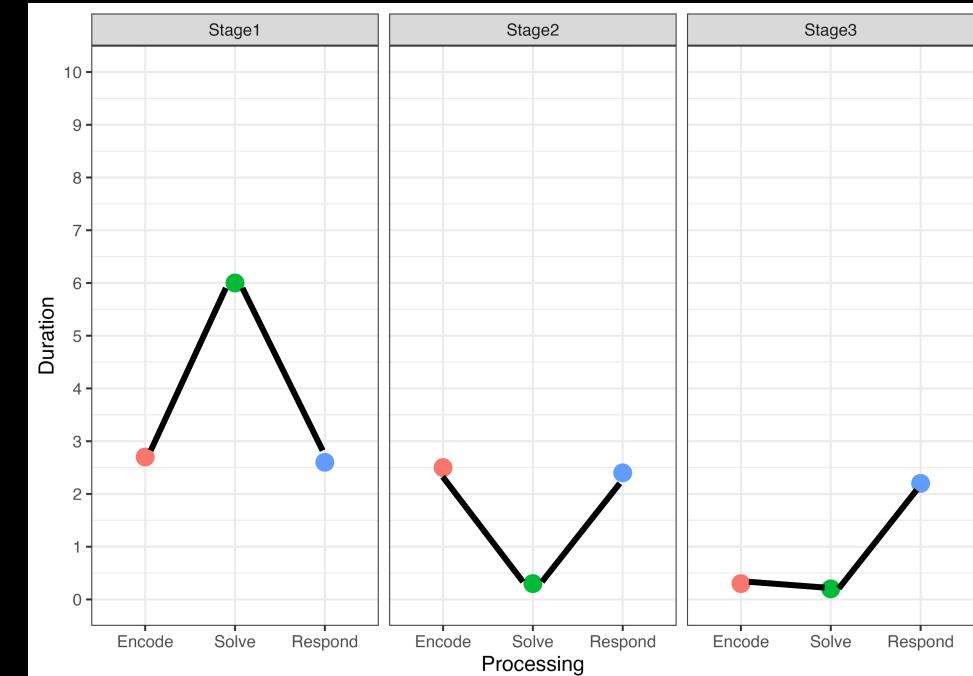
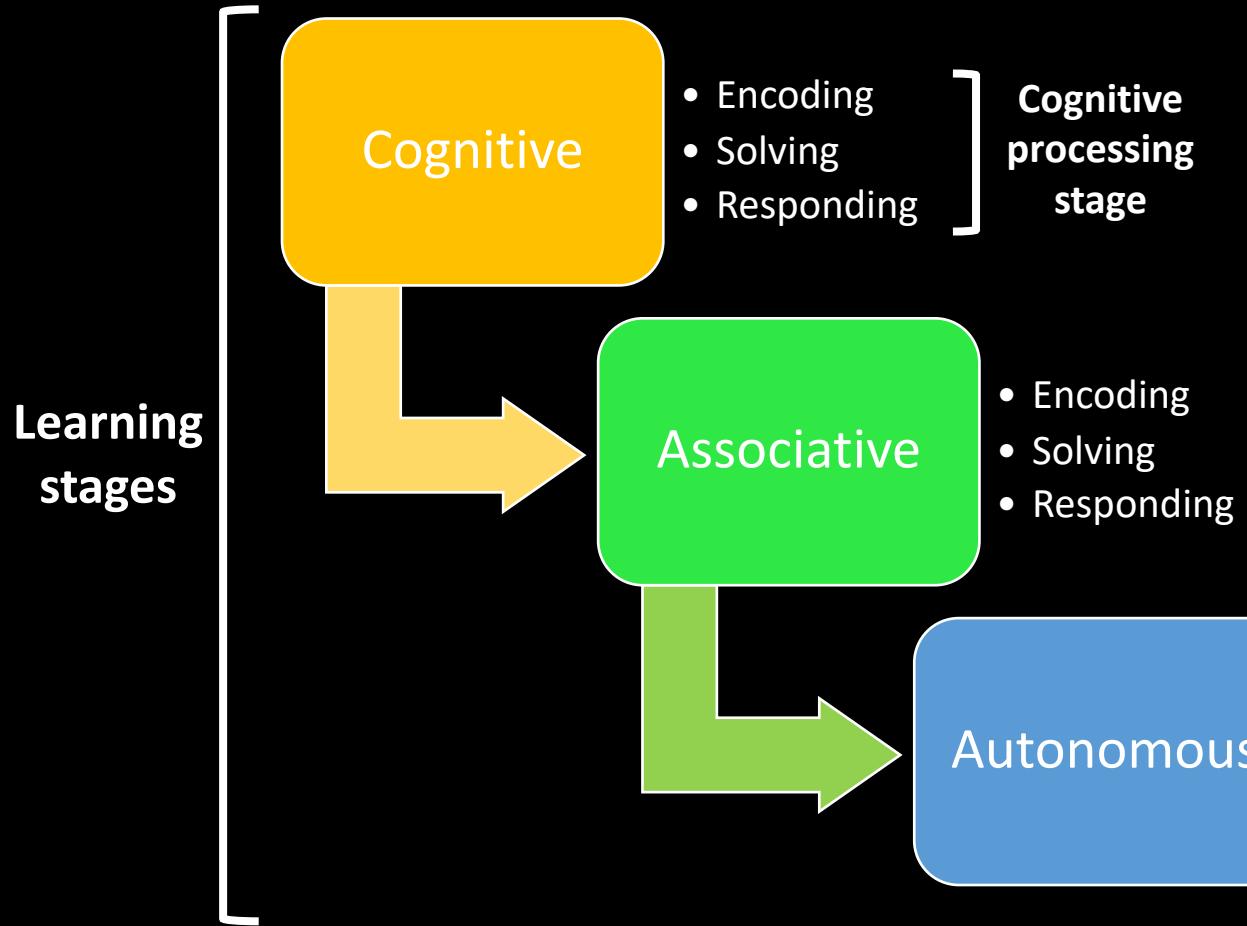
SLA is citing skill acquisition theory of **40 years ago!**

Tenison et al. (2016)

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

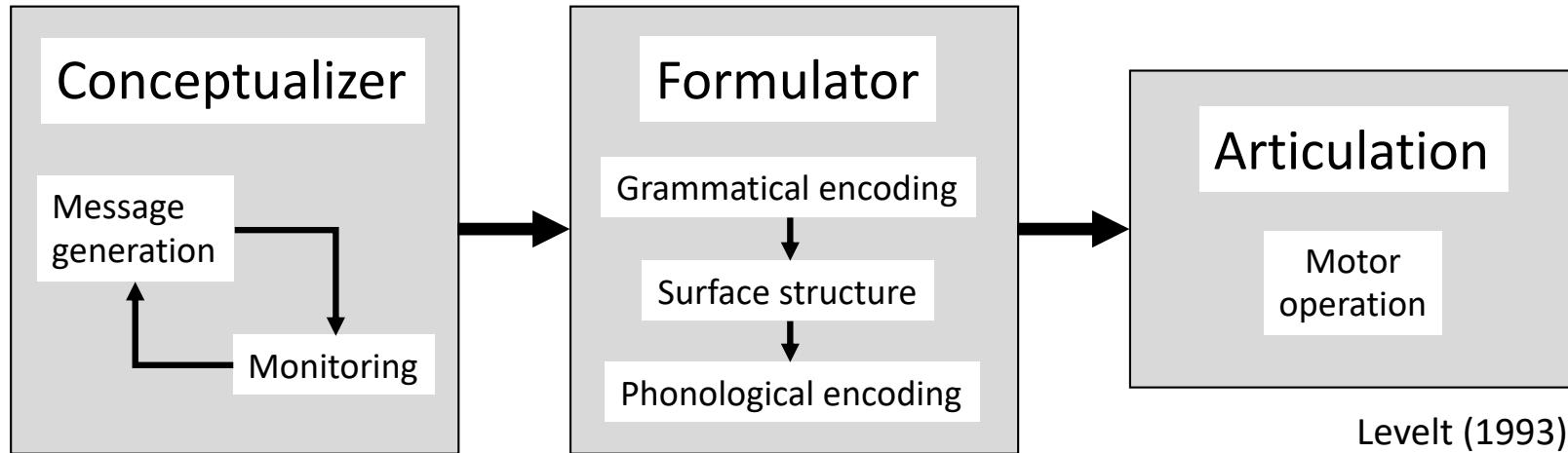


Skill acquisition in an arithmetic task (Pyramid problem)



Future Direction: Theoretical

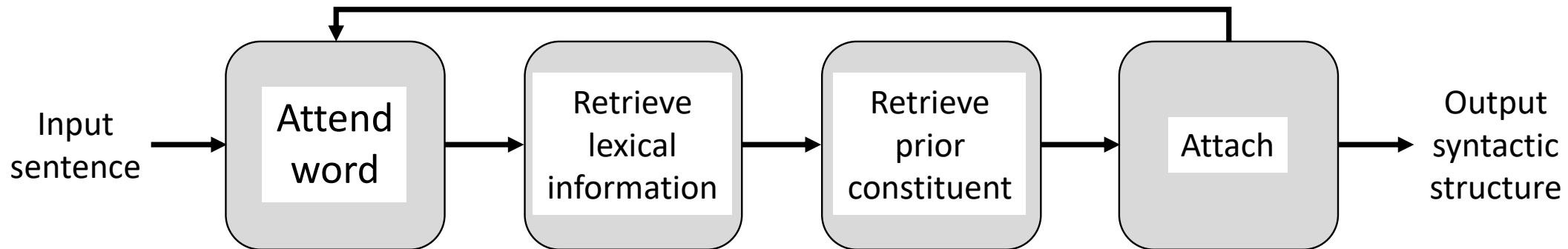
Production



How do each process is affected by automatization?

Proceduralization
(restructuring)

Comprehension



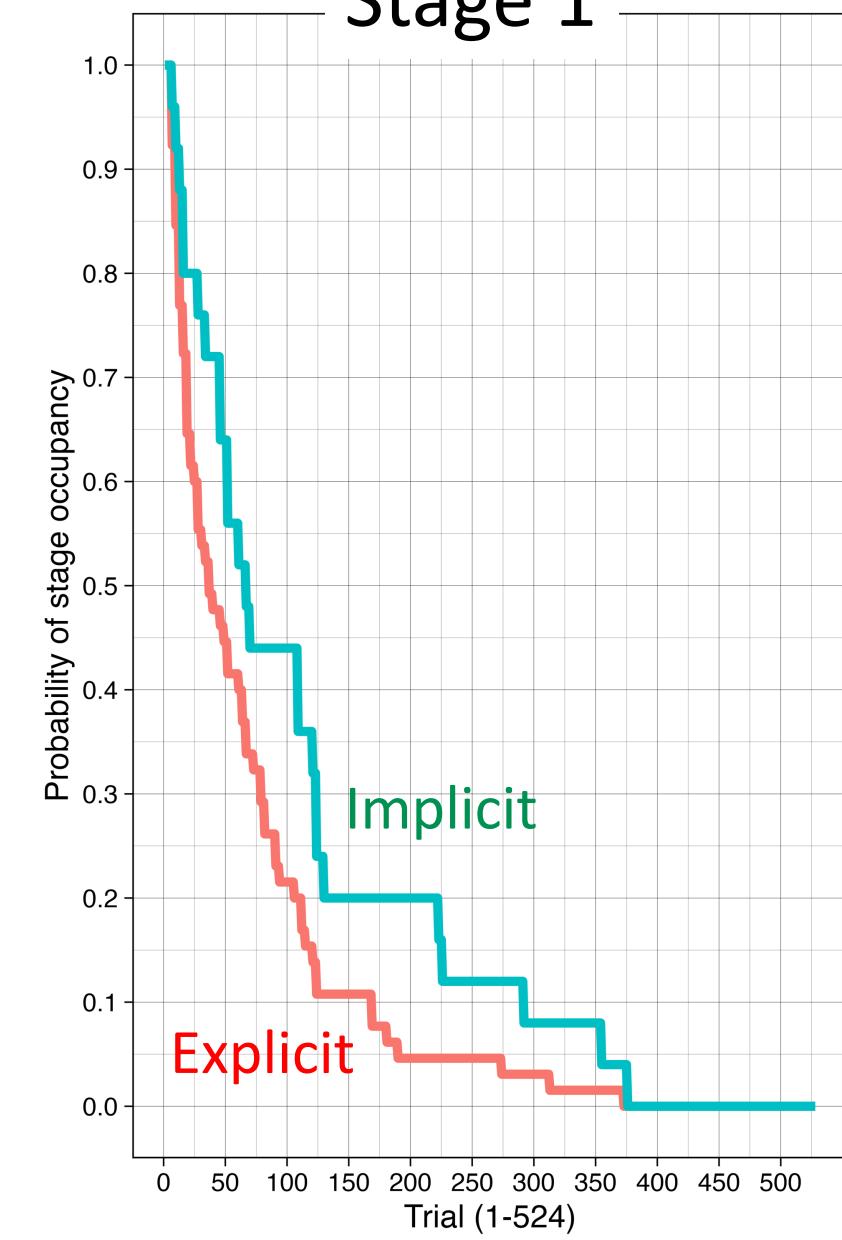
Lewis & Vasishth (2005)
Vogelzang et al. (2017)



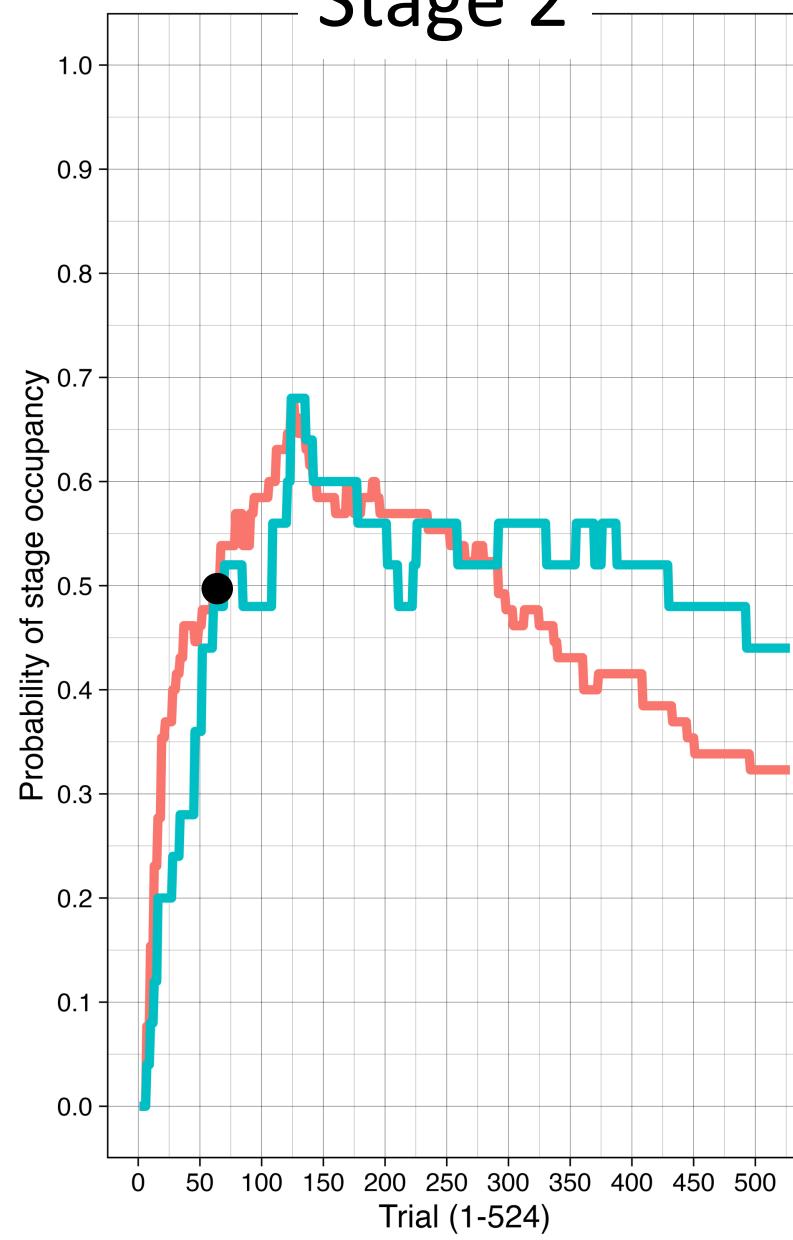
Explicit (Deductive) Implicit (Inductive)?



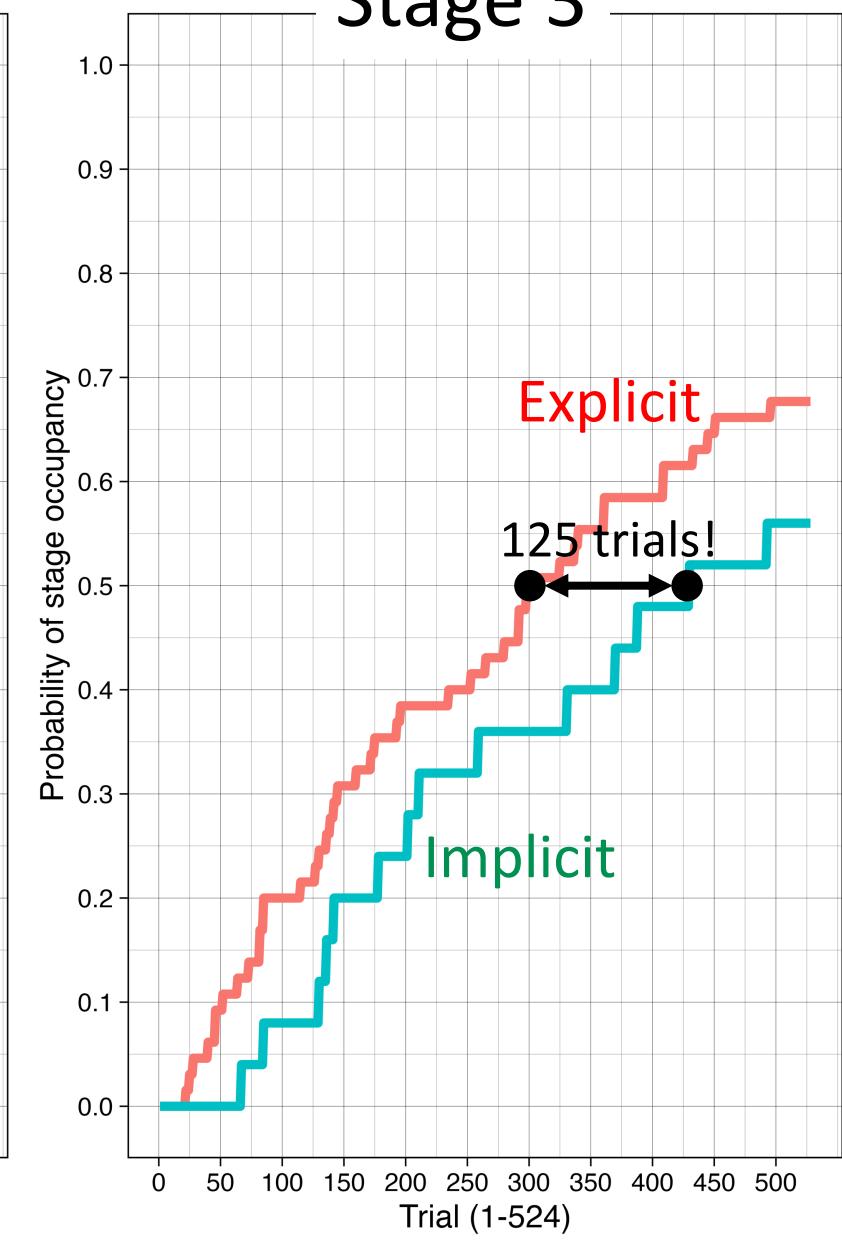
Stage 1



Stage 2



Stage 3





References

- Anderson, J. R. (1982). Acquisition of cognitive skill. *Psychological Review*, 89(4), 369–406.
- Anderson, J. R. (1983). *The architecture of cognition*. Mahwah, NJ: Lawrence Erlbaum.
- Anderson, J. R. (2007). *How can the human mind occur in the physical universe?* New York, NY: Oxford University Press.
- DeKeyser, R. M. (1997). Beyond explicit rule learning: Automatizing second language morphosyntax. *Studies in Second Language Acquisition*, 19(2), 195-221.
- DeKeyser, R. M. (2017). Knowledge and skill in ISLA. In S. Loewen & M. Sato (Eds.), *The Routledge handbook of instructed second language acquisition* (pp. 15–32). New York, NY: Routledge.
- DeKeyser, R. M. (2020). Skill acquisition theory. In B. VanPatten, G. D. Keating, & S. Wulff (Eds.), *Theories in second language acquisition. An introduction* (3rd ed., pp. 83–104). New York, NY: Routledge.
- DeKeyser, R. M., & Sokalski, K. J. (1996). The differential role of comprehension and production practice. *Language Learning*, 46(4), 613–642.
- Ferman, S., Olshtain, E., Schechtman, E., & Karni, A. (2009). The acquisition of a linguistic skill by adults: Procedural and declarative memory interact in the learning of an artificial morphological rule. *Journal of Neurolinguistics*, 22(4), 382–412.
- Fitts, P. M. (1964). Perceptual-motor skill learning. In A. W. Melton (Ed.), *Categories of human learning* (pp. 243–285). Cambridge, MA: Academic Press.
- Hamrick, P., Lum, J. A. G., & Ullman, M. T. (2018). Child first language and adult second language are both tied to general-purpose learning systems. *Proceedings of the National Academy of Sciences*, 115(7), 1487–1492.

References

- Hui, B. (2020). Processing variability in intentional and incidental word learning: An extension of Solovyeva and DeKeyser (2018). *Studies in Second Language Acquisition*, 42(2), 327–357.
- Levelt, W. J. M. (1989). *Speaking: From intention to articulation*. Cambridge, MA: The MIT Press.
- Lewis, R. L., & Vasishth, S. (2005). An activation-based model of sentence processing as skilled memory retrieval. *Cognitive Science*, 29(3), 375-419.
- Logan, G. D. (1988). Towards an instance theory of automatization. *Psychological Review*, 95(4), 492–527.
- Logan, G. D. (2002). An instance theory of attention and memory. *Psychological Review*, 109(2), 376–400.
- Maie, R. (2021). *Testing skill acquisition stages in language learning: A case of L2 vocabulary learning and practice*. Unpublished qualifying paper. Michigan State University, East Lansing, MI.
- Maie, R., & Godfroid, A. (in progress). Testing the three-stage model of second language skill acquisition.
- Mueller, J. L. (2006). L2 in a nutshell: The investigation of second language processing in the miniature language model. *Language Learning*, 56(s1), 235–270.
- Pili-Moss, D., Brill-Schuetz, K., Faretta-Stutenberg, M., & Morgan-Short, K. (2020). Contributions of declarative and procedural memory to accuracy and automatization during second language practice. *Bilingualism: Language and Cognition*, 23, 639–651.
- Rickard, T. C. (1997). Bending the power law: A CMPL theory of strategy shifts and the automatization of cognitive skills. *Journal of Experimental Psychology: General*, 126(3), 288–311.
- Rickard, T. C. (2004). Strategy execution in cognitive skill learning: An item-level test of candidate models. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 30(1), 65–82.

References

- Suzuki, Y. (2018). The role of procedural learning ability in automatization of L2 morphology under different learning schedules: An exploratory study. *Studies in Second Language Acquisition*, 40(4), 923–937.
- Suzuki, Y. (2022). Automatization and practice. In A. Godfroid & H. Hopp (Eds.), *The Routledge handbook of second language acquisition and psycholinguistics* (pp. 308-321). New York, NY: Routledge.
- Suzuki, Y., & Sunada, M. (2018). Automatization in second language sentence processing: Relationship between elicited imitation and maze tasks. *Bilingualism: Language and Cognition*, 21(1), 32–46.
- Tenison, C., & Anderson, J. R. (2016). Modeling the distinct phases of skill acquisition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 42(5), 749–767.
- Tenison, C., Fincham, J. M., & Anderson, J. R. (2016). Phases of learning: How skill acquisition impacts cognitive processing. *Cognitive Psychology*, 87, 1–28.
- Ullman M. T. (2004) Contributions of memory circuits to language: The declarative/procedural model. *Cognition*, 92(1–2), 231–270.
- Ullman, M. T. (2016). The declarative/procedural model: A neurobiological model of languagelearning, knowledge, and use. In G. Hickok & S. Small (Eds.), *Neurobiology of language* (pp. 953–968). Cambridge, MA: Academic Press.
- Ullman M. T. (2020) The declarative/procedural model: A neurobiologically-motivated theory of first and second language. In B. VanPatten, G. D. Keating, & S. Wulff (Eds.), *Theories in second language acquisition. An introduction* (3rd ed., pp. 83–104). New York, NY: Routledge.
- Vogelzang, M., Mills, A. C., Reitter, D., Rij, J. V., Hendriks, P., & Rijn, H. V. (2017). Toward cognitively constrained models of language processing: A Review. *Frontiers in Communication*, 2, 1-18.