Evoked Response Potential Latency Modeling and Production Time Prediction

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ACT-R Post-Graduate Summer School

TIME SCALE OF HUMAN ACTION (Newell, 1990)

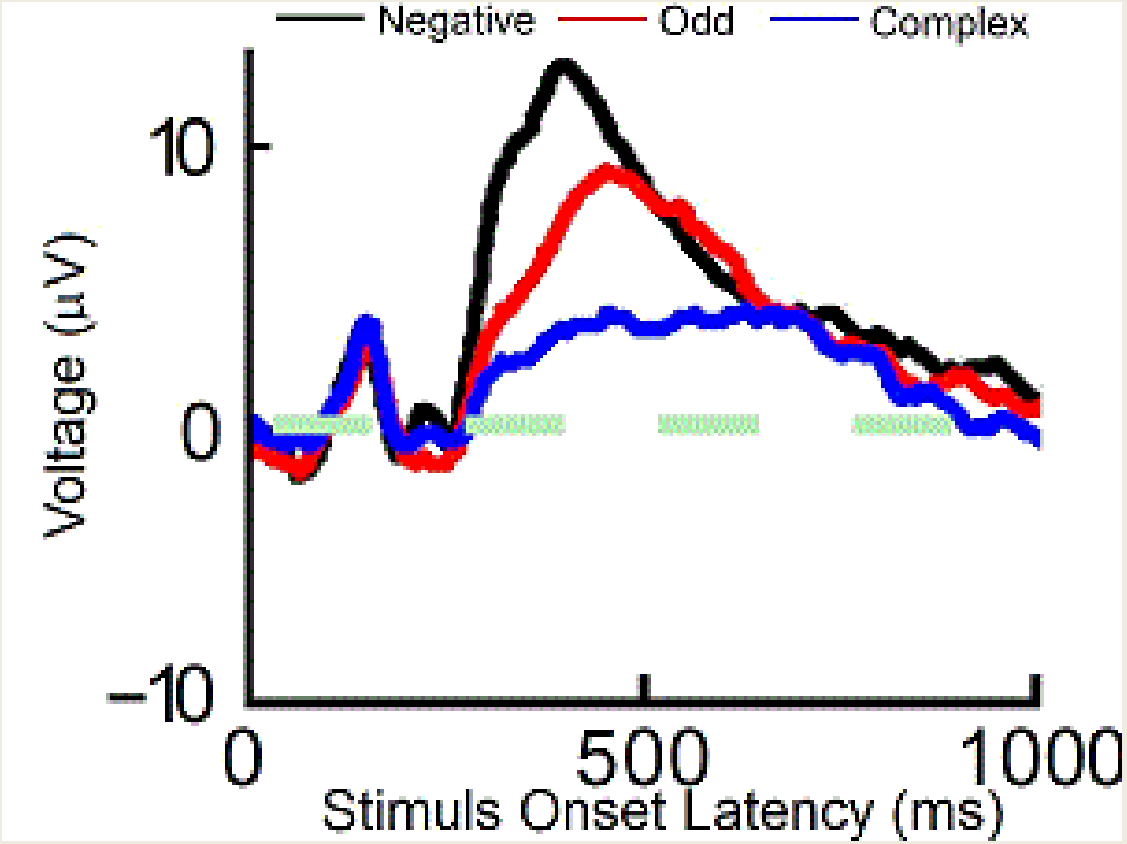
Scale (sec)	Time Units	System	World (theory)
10^{7}	Months		Social Band
10^{6}	Weeks		
10^{5}	Days		
10^{4}	Hours	Task	Rational Band
10^{3}	10 min	Task	
10^{2}	Minutes	Task	
10^{1}	10 sec	Unit task	Cognitive Band
10^{0}	1 sec	Operations	
10^{-1}	100 ms	Deliberate act	
10^{-2}	10 ms	Neural circuit	Biological Band
10^{-3}	1 ms	Neuron	
10^{-4}	100 μs	Organelle	

ACT-R Neuro Integration

- The neuro-ACT-R integration settles into the cross-over between the biological and cognitive bands at the ACT-R sub-symbolic layer
- Spatial: BOLD models
- Temporal: EEG models
  - Phase and power analysis (e.g., van Rugt, 2012)
  - ERPs (e.g., Cassenti et al., 2011)

Event Related Potentials

- Amplitude
- Latency
- N1, P2, P3…



ERP-Production Links

- N1 – Perceptual Recognition
- P3 – Context Updating
- Production chain maps out initial to goal state
- Equate ERP latency with timing of cognitive step
- Timing of ACT-R productions

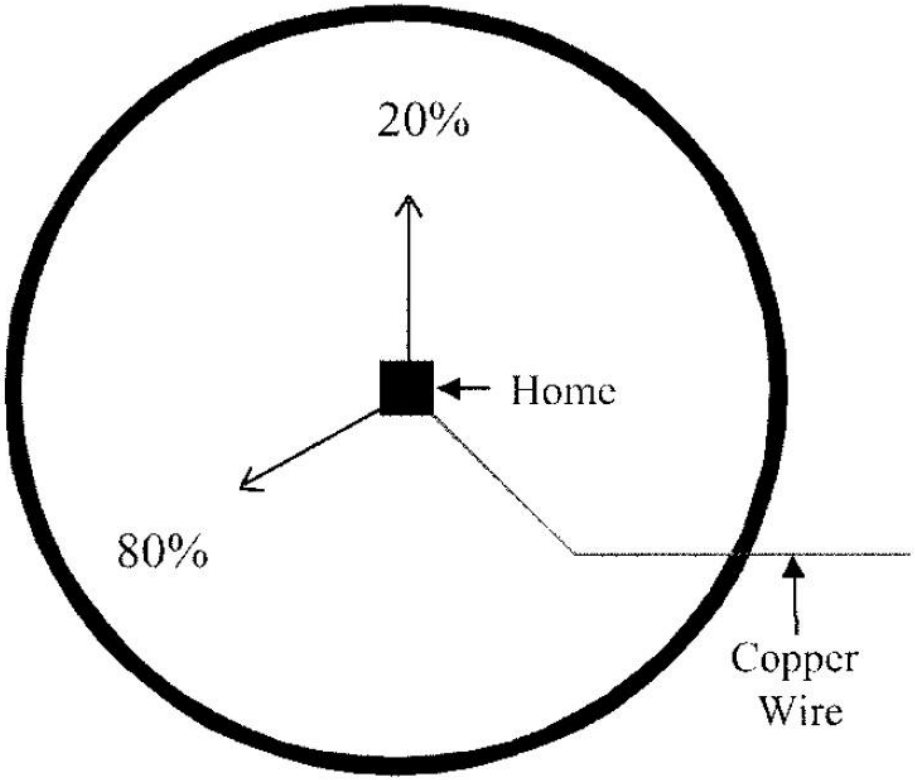
Iterative Test-Model

Higher-level strategy

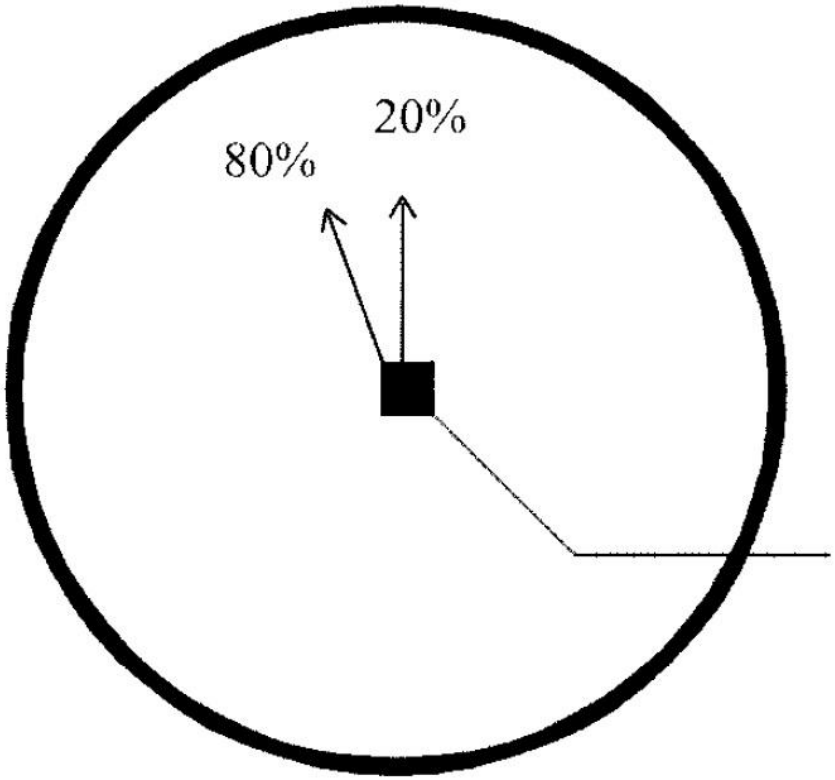
- Experiment → Model
  - Model gives production times for one cog process
- Experiment → Model
  - More production times
- (Experiment-Model)*N
  - N cognitive processes
- Get to point where production times are based on empirical data more than guesswork

Visual Perception EEG Test

McDowell, Jeka, Schoner, & Hatfield (2002)



Wide Condition



Narrow Condition

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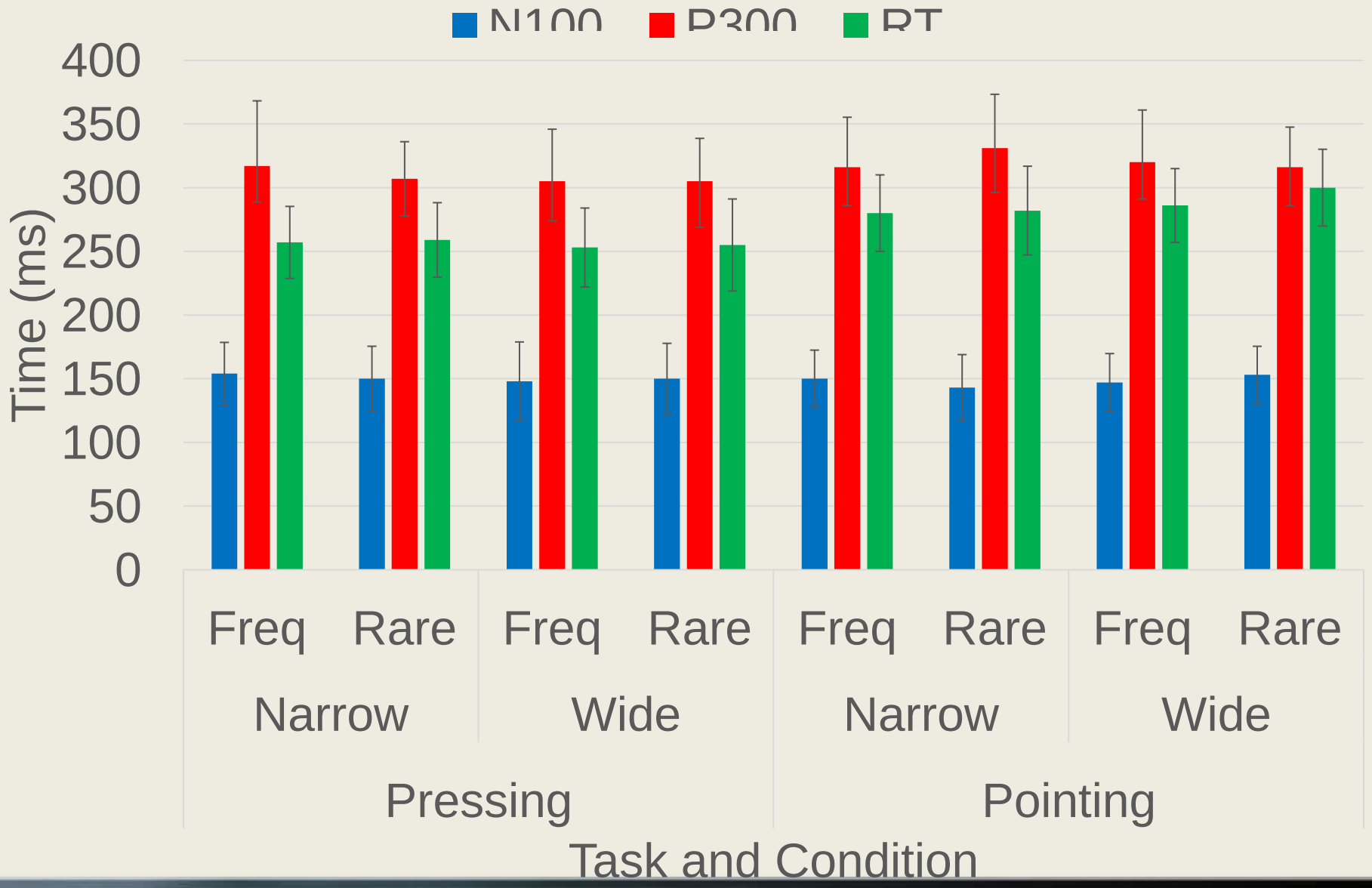
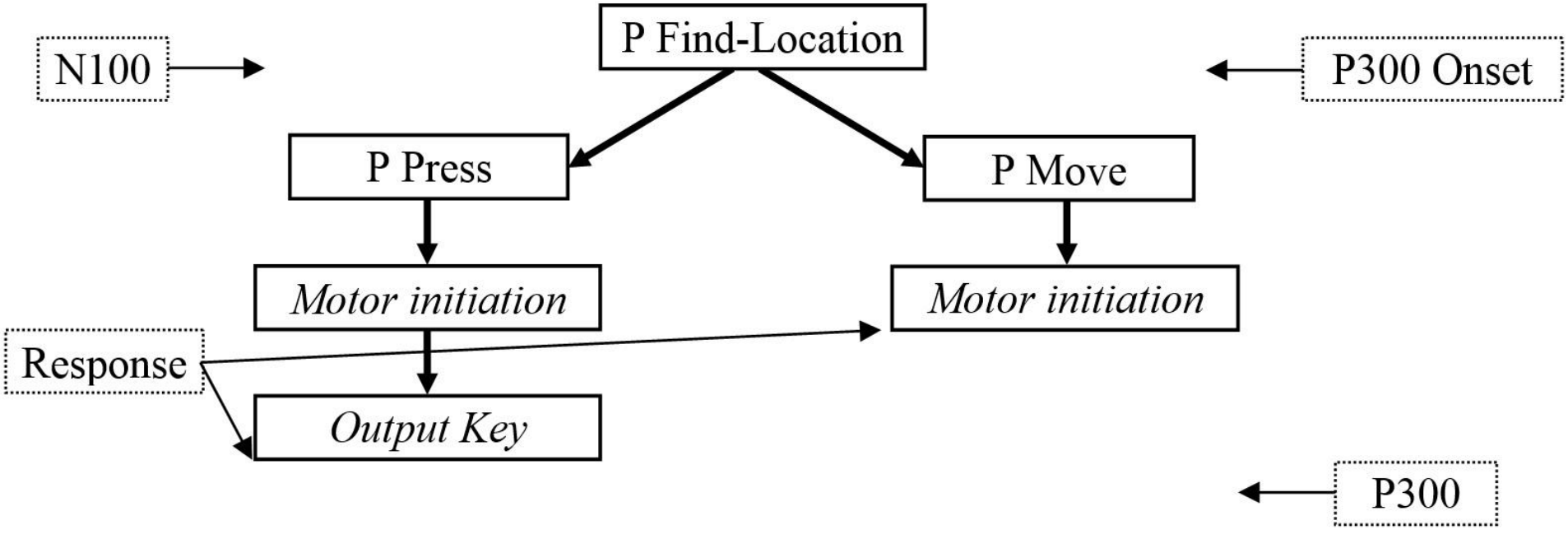
Visual Test Results

ARL



Visual Model



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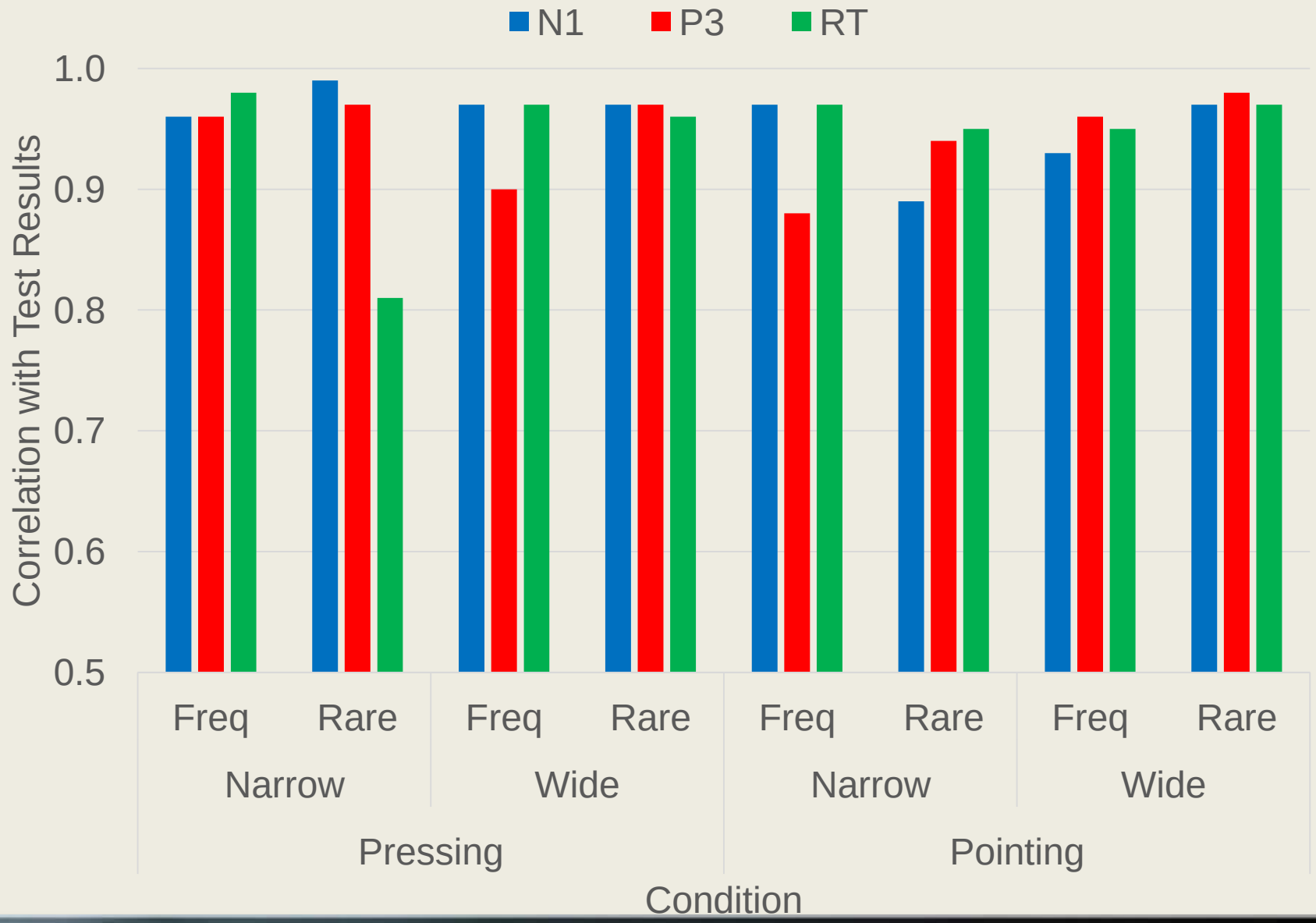
Visual Model Results

ARL



Auditory Test

Kerick, Oie, & McDowell (2009)

High Pitch (20%)

Press Button

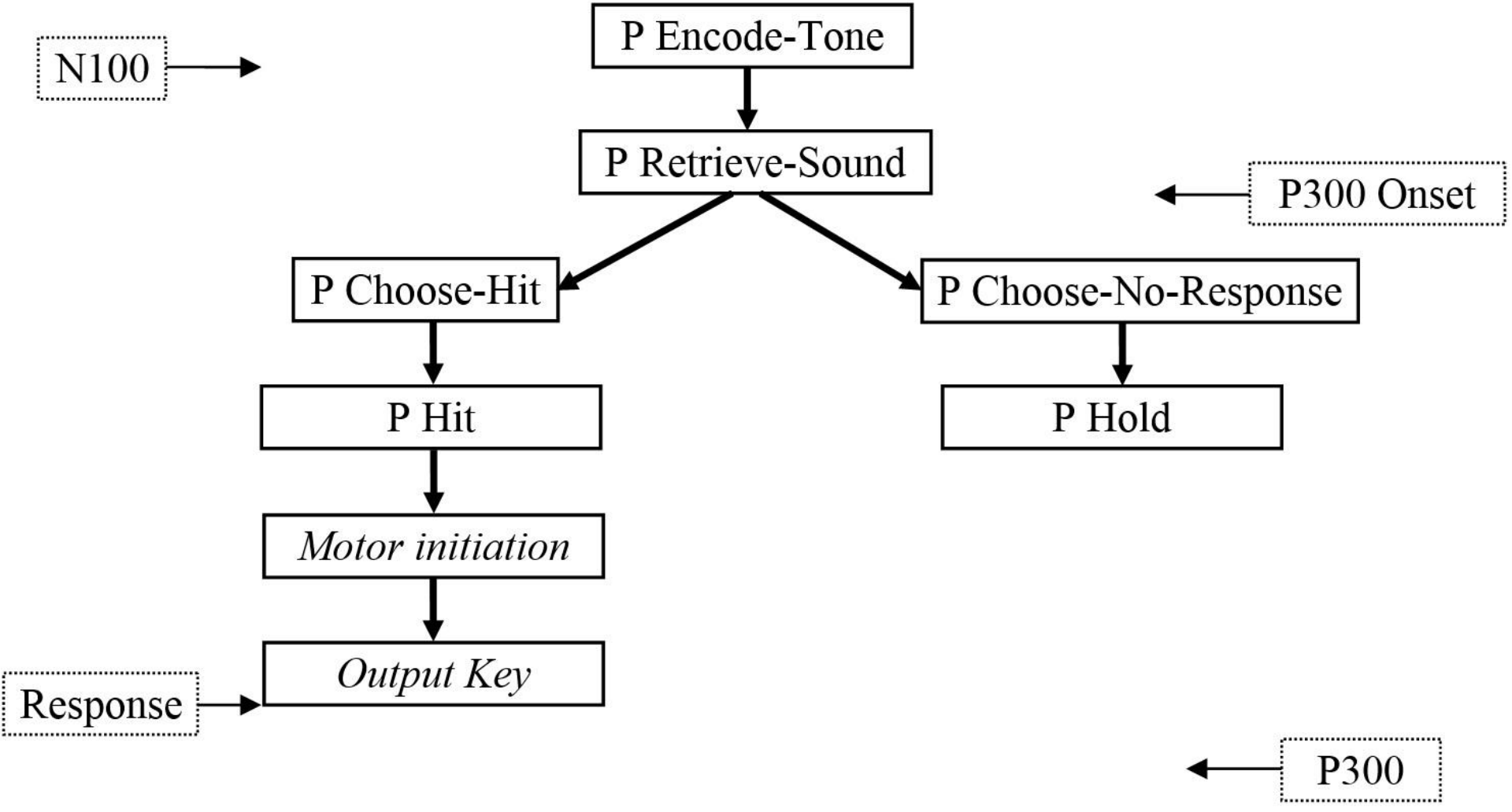
Low Pitch (80%)

Don’t Press

Auditory Results

	Mean Time in ms (St.Dev)	
	Low	High
N100	165 (16)	155 (21)
P300	352 (36)	384 (40)
RT		600 (177)

Auditory Model



Auditory Model Results

	Correlation	
	Low	High
N100	0.97	0.89
P300	0.97	0.95
RT		0.95

Decision Making Test

Rule	Yes, No
Negative	-9,-8,-7,-6,-5,-4,-3,-2,-1,1,2,3,4,5,6,7,8,9
Odd	-9,-8,-7,-6,-5,-4,-3,-2,-1,1,2,3,4,5,6,7,8,9
Complex	-9,-8,-7,-6,-5,-4,-3,-2,-1,1,2,3,4,5,6,7,8,9

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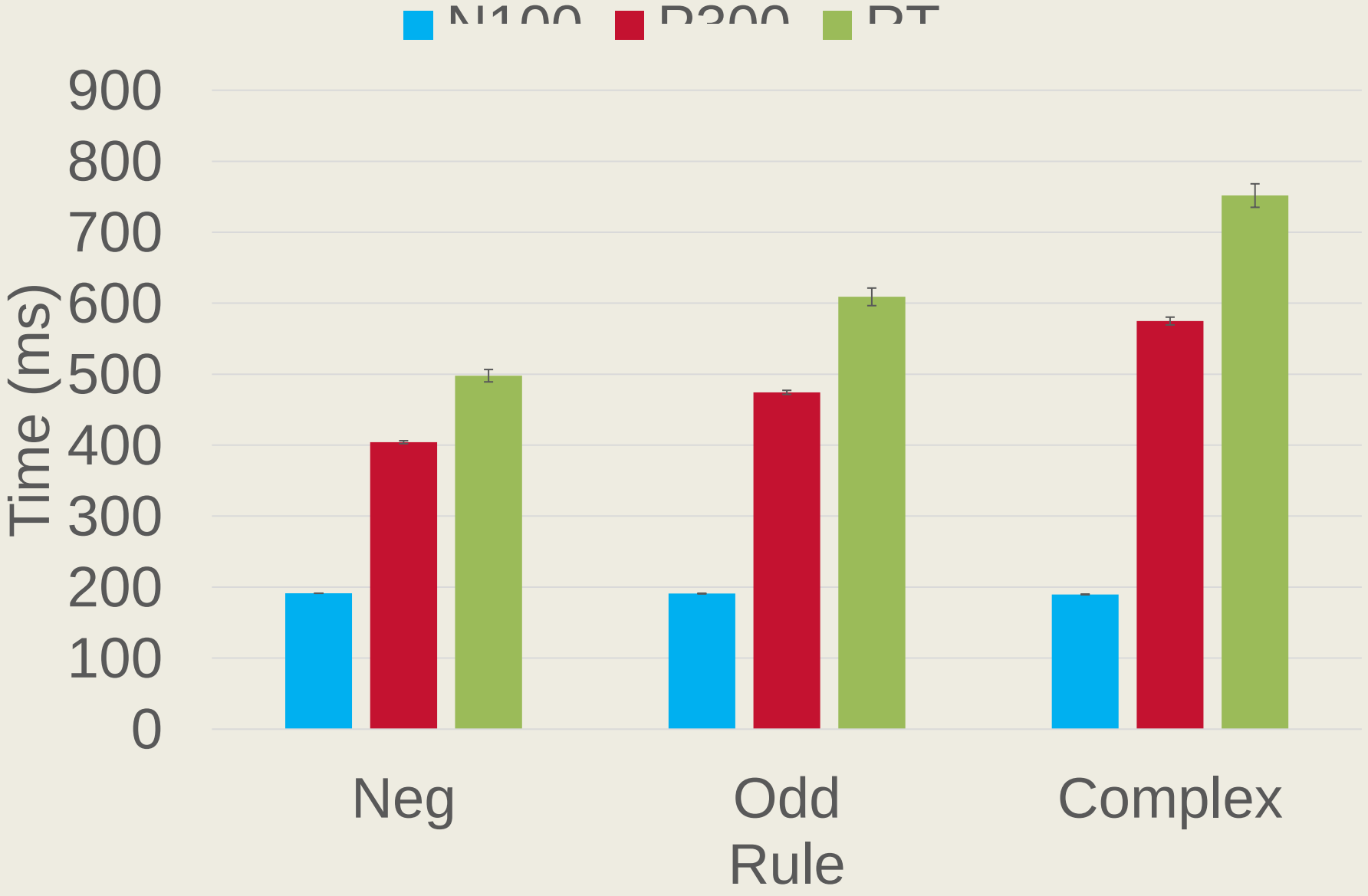
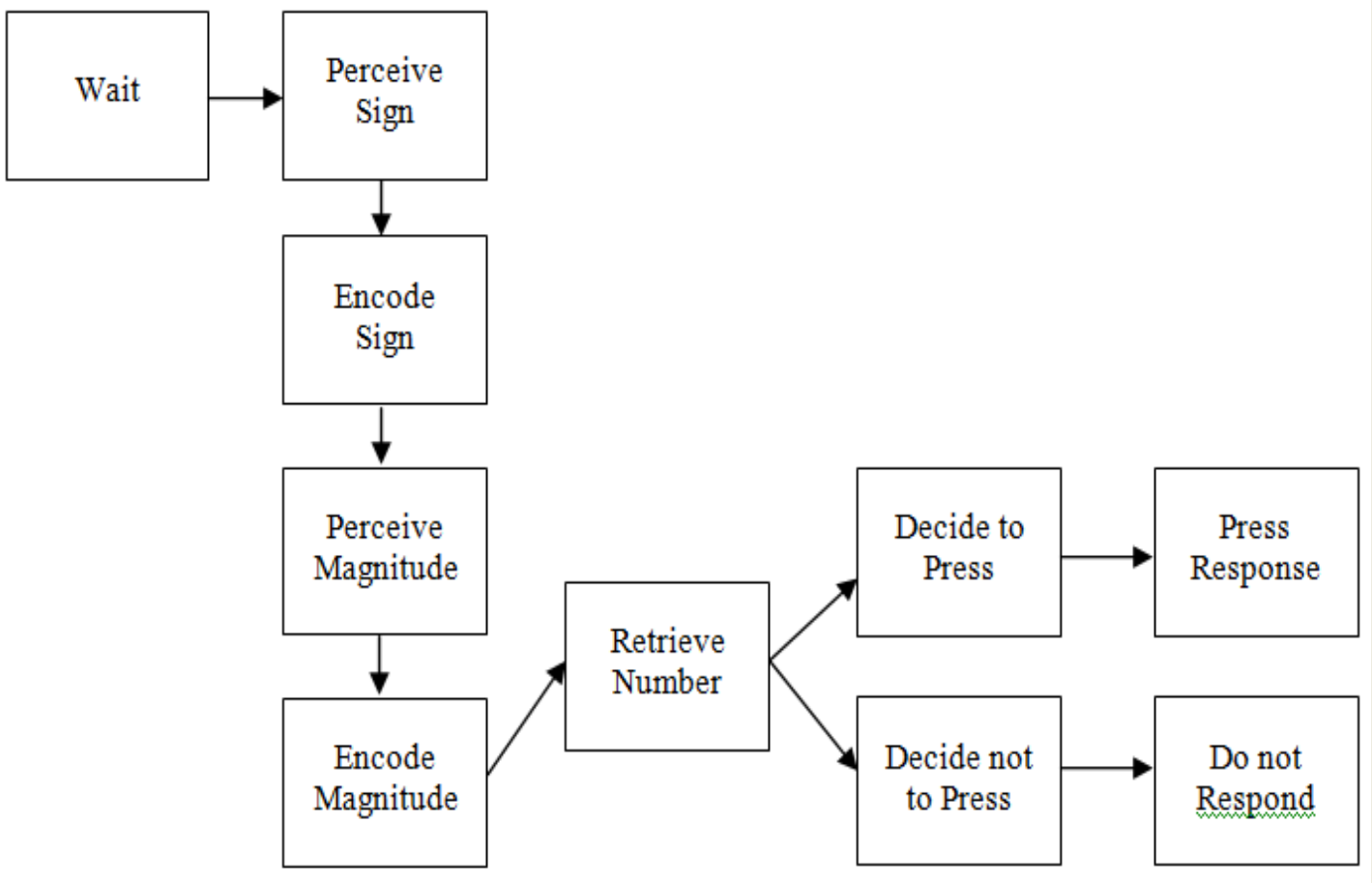
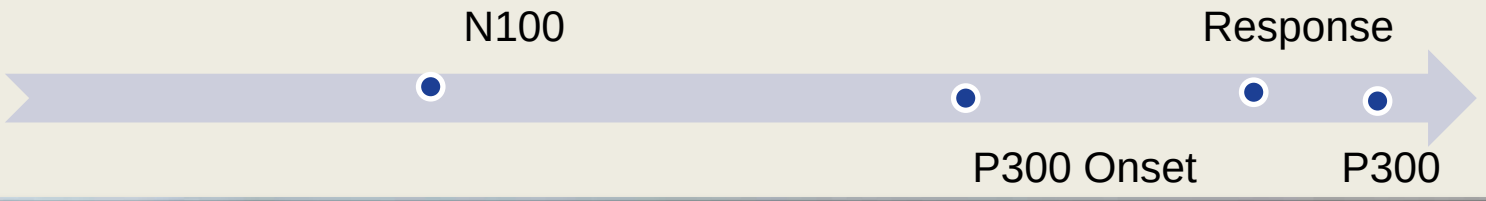
D-M Test Results

ARL

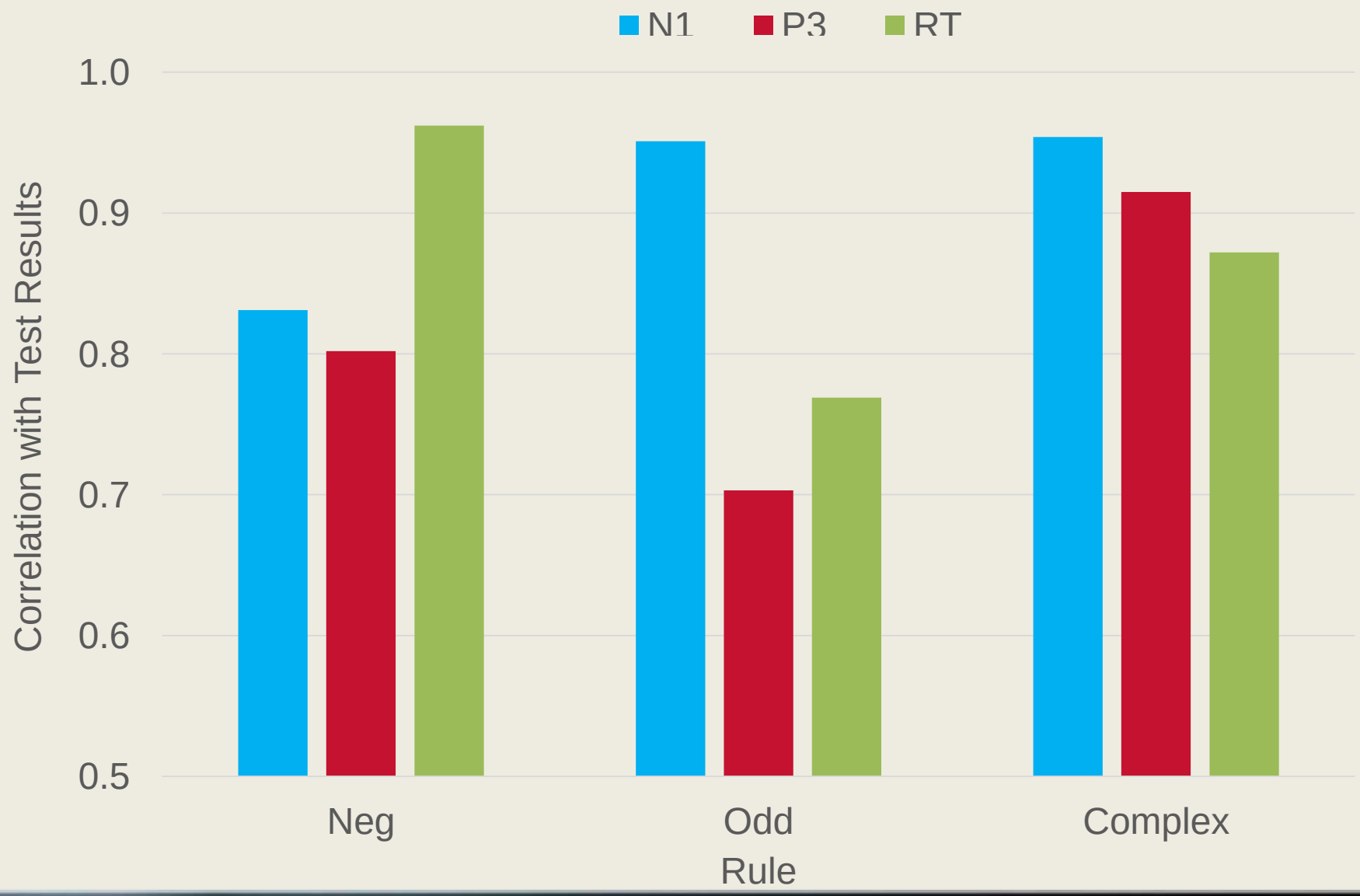


D-M Model


Wait
Perceive Sign
Encode Sign
Perceive Magnitude
Encode Magnitude
Retrieve Number
Decide to Press
Press Response
Decide not to Press
Do not Respond


N100
Response
P300 Onset
P300

DM Model Results



Production Duration

- No longer restricted to response time
- N1 – Perceptual encoding completed
- P3 – Context updating completed
- RT – Response made
- Now segmenting is possible and production times are less guesswork
- More?
  - P2 (Anderson et al, in press) – lexical access?
  - P600 (Osterhaut & Holcomb, 1992) – grammatical errors

Applied Aspects

- ERP latency → Length of time to complete stage
- Long N1 – Improve visual saliency?
- Long P3 – Disambiguate stimuli?
- Long RT – Improve response requirements?

A Program of Research

- Potential for future studies is vast
- Existing databases with ERP latencies
- New experiments with ERP latencies
- Spread over multiple cognitive phenomena
- Share results with others

Question? Comments?

- Cassenti, D.N., Kerick, S.E., & McDowell, K. (2011). Observing and modeling cognitive events through event related potentials and ACT-R. *Cognitive Systems Research, 12*, 56-65.
- Cassenti, D.N. (in press). Opening the Black Box: A Test and Computational Model of the Relationship between ERPs and Cognition. In *Event-Related Potential (ERP): Methods, Outcomes and Research Insights*