

# Animal Metacognition: The Extended Mind in Self-Interaction

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# Acknowledgments

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Jared Tagliatela

David Washburn

# Acknowledgments

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National Institutes of Health (USA) HD-38051

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European Science Foundation: EuroCores Program

# ***1. Introduction to Animal Metacognition***

# Metacognition in Animals

- Paukner et al. (2006) *Anim. Cognit.* 9 (110)
- Smith et al. (2006) *J. Exp. Psych.: Gen.* 135 (282)
- Beran et al. (2006) *J. Exp. Psych.: Anim. B.* 32 (111)
- Washburn et al. (2006) *J. Exp. Psych.: Anim. B.* 32 (85)
- Smith & Washburn (2005) *Curr. Direct. Psych. Sci.* 14 (19)
- Shields et al. (2005) *J. Gen. Psych.* 132 (165)
- Smith et al. (2003) *Behav. Brain Sci.* 26 (317)
- Call et al. (2001) *Anim. Cognit.* 4 (207)
- Hampton (2001) *Proc. Nat. Acad. Sci.* 98 (5359)
- Inman et al. (1999) *J. Exp. Psych.: Anim. B.* 25 (389)
- Smith et al. (1998) *J. Exp. Psych.: Gen.* 127 (227)
- Shields et al. (1997) *J. Exp. Psych.: Gen.* 126 (147)
- Smith et al. (1997) *Cognit.* 62 (75)
- Smith et al. (1995) *J. of Exp. Psych.: Gen.* 124 (391)

# Metacognition in Animals

Smith et al. (2009) *Anim. Cognit.* in press

Fujita (2009) *Anim. Cognit.* 12 (575)

Smith (2009) *Trends Cog. Sci.* 13 (389)

Beran et al. (2009) *J. Exp. Psych.: Anim. B.* 35 (371)

Crystal/Hampton/Jozefowicz/Smith (2009) *Comp. Cog. Beh. Rev.* 34 (1)

Kornell (2009) *Curr. Dir. Cog. Sci.* 18 (11)

Roberts et al. (2009) *J. Exp. Psych.: Anim. B.* 35 (129)

Sutton et al. (2008) *J. Exp. Psych.: Anim. B.* 34 (266)

Suda-King (2008) *Anim. Cognit.* 7 (239)

Carruthers (2008) *Mind & Lang.* 23 (58)

Smith et al. (2008) *Psychon. Bull. & Rev.* 15 (679)

Basile et al. (2008) *Anim. Cognit.* 12 (169)

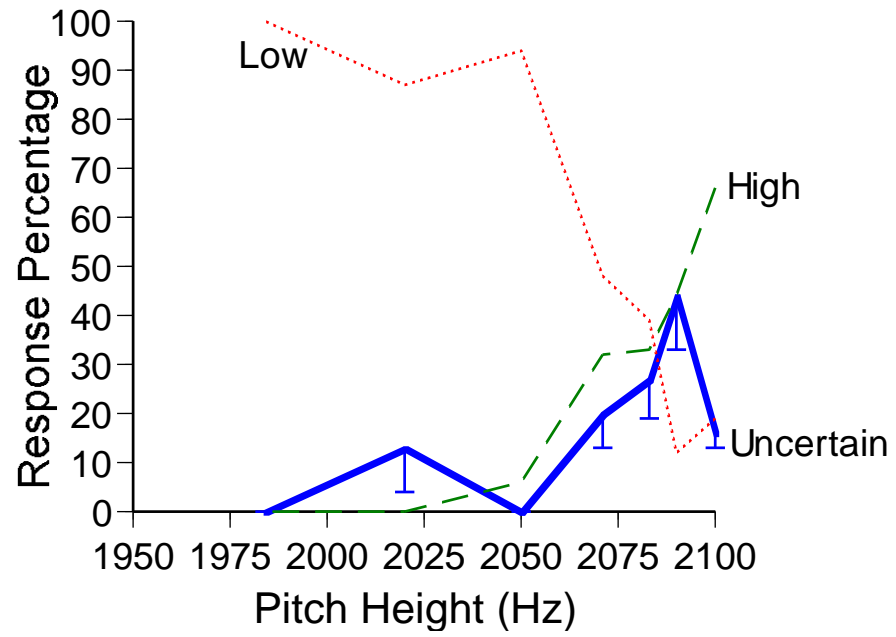
Proust (2007) *Synthese* 2 (271)

Foote & Crystal (2007) *Curr. Biol.* 17 (551)

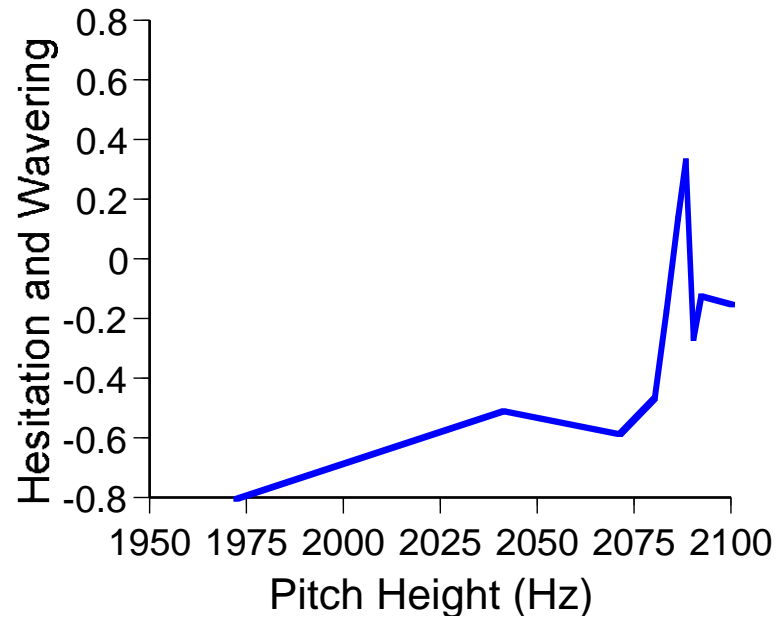
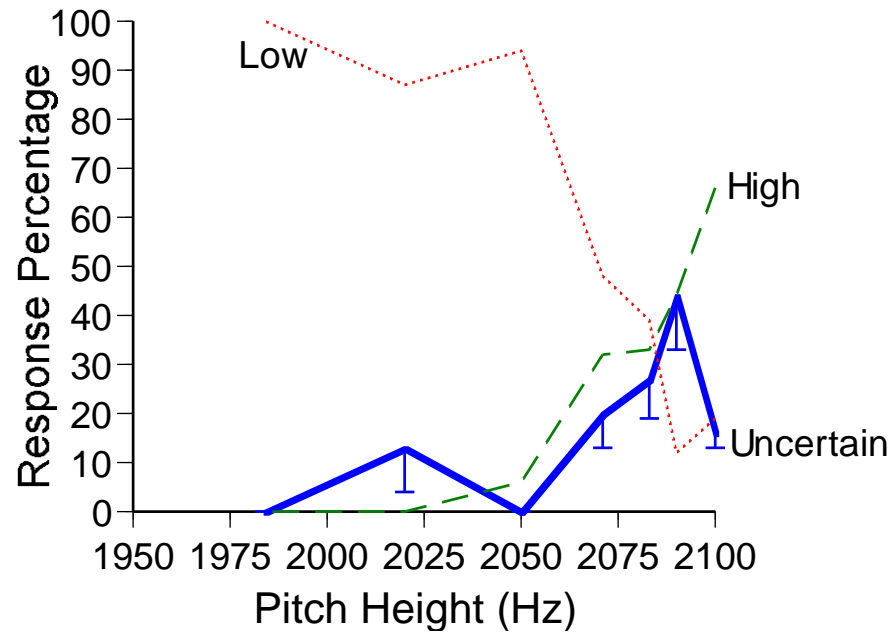
Kornell et al. (2007) *Psychol. Sci.* 18 (64)

Staddon et al. (2007) *PsyCrit* April 13 (1)









Tolman, E. C. (1927). A behaviorist's definition of consciousness. *Psychological Review*, 34, 433-439

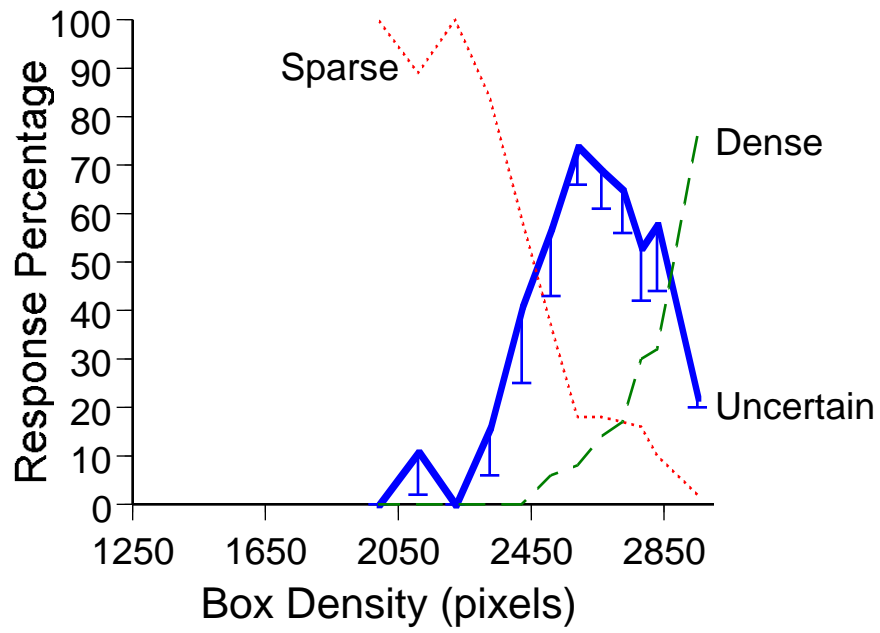


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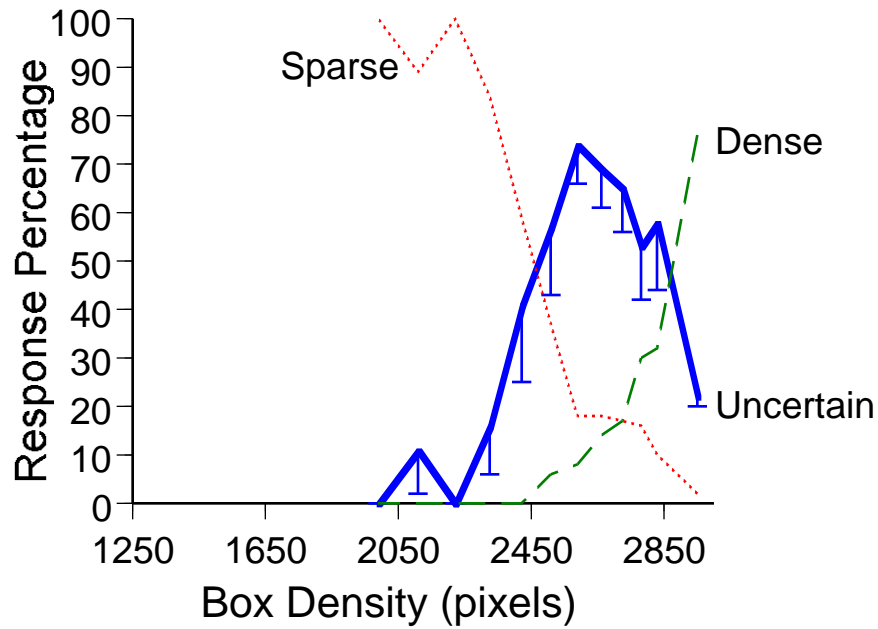




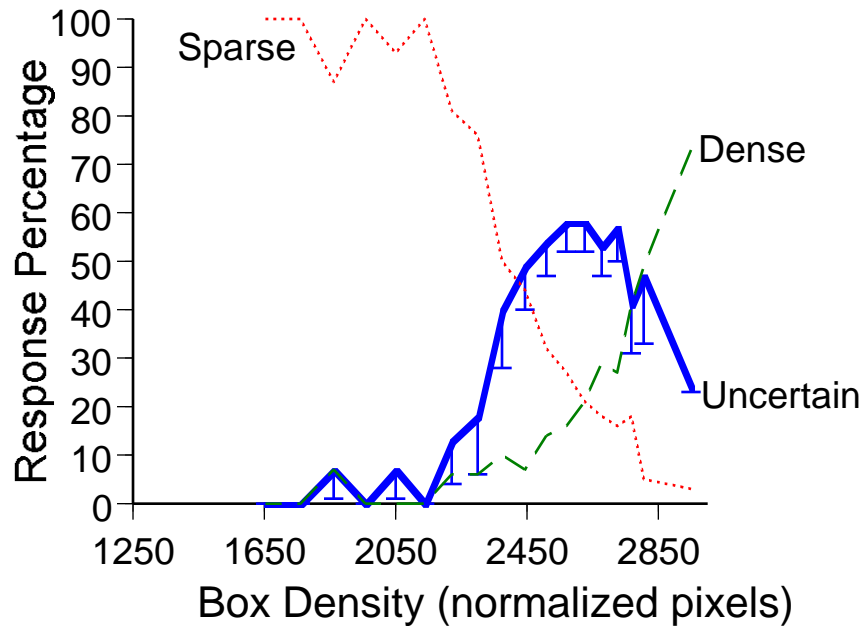
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## Monkey



## Humans



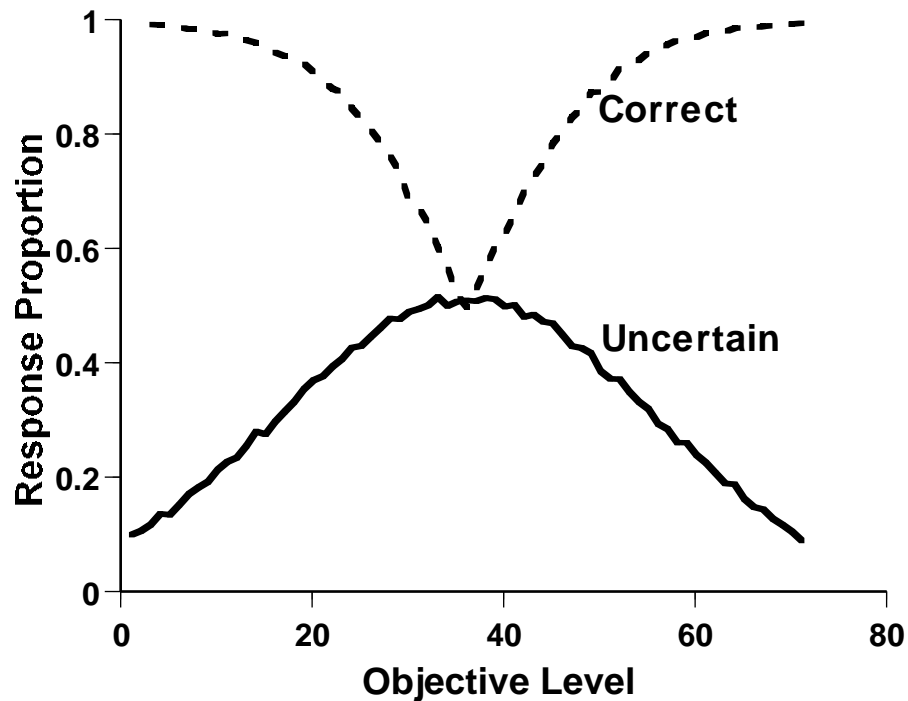
## Morgan's Canon (1906, p. 53)

“In no case may we interpret an action as the outcome of the exercise of a higher psychical faculty, if it can be interpreted as the outcome of the exercise of one which stands lower in the psychological scale.”

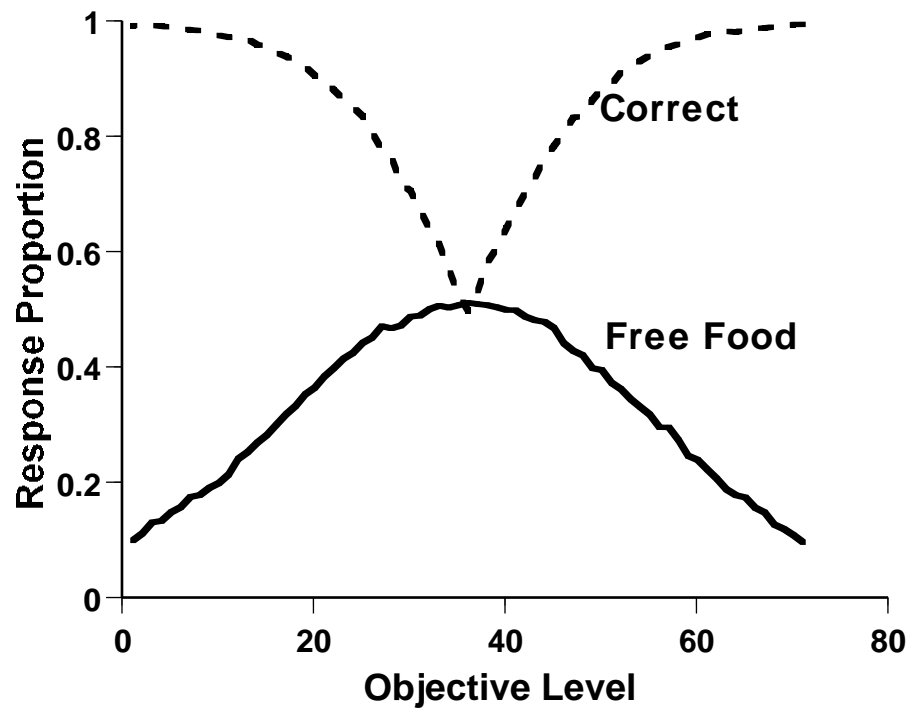
Smith, J. D., Beran, M. J., Couchman, J. J., & Coutinho, M. V. C. (2008). The comparative study of metacognition: Sharper paradigms, safer inferences. *Psychonomic Bulletin and Review*, 15, 679-691.



# Metacognition



# Reinforcement



## ***2. Sharper Paradigms, Safer Inferences***

# Rewarded Uncertainty Responses

Fujita (2009) *Anim. Cognit.* 12 (575)

Roberts et al. (2009) *J. Exp. Psych.: Anim. B.* 35 (129)

Sutton et al. (2008) *J. Exp. Psych.: Anim. B.* 34 (266)

Suda-King (2008) *Anim. Cognit.* 7 (239)

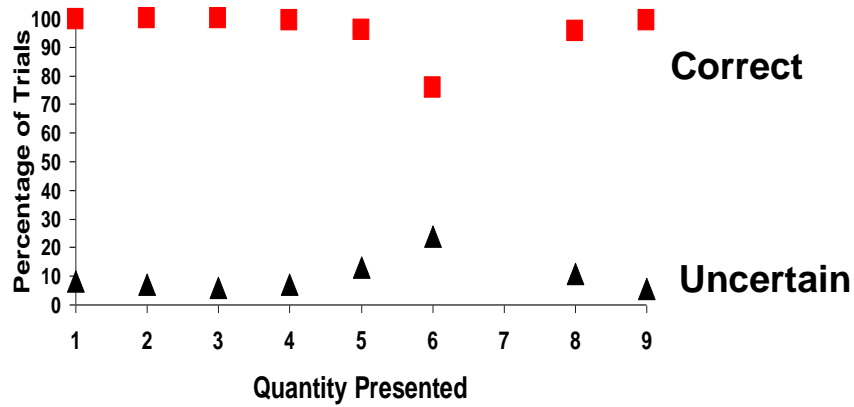
Foote & Crystal (2007) *Curr. Biol.* 17 (551)

Kornell et al. (2007) *Psychol. Sci.* 18 (64)

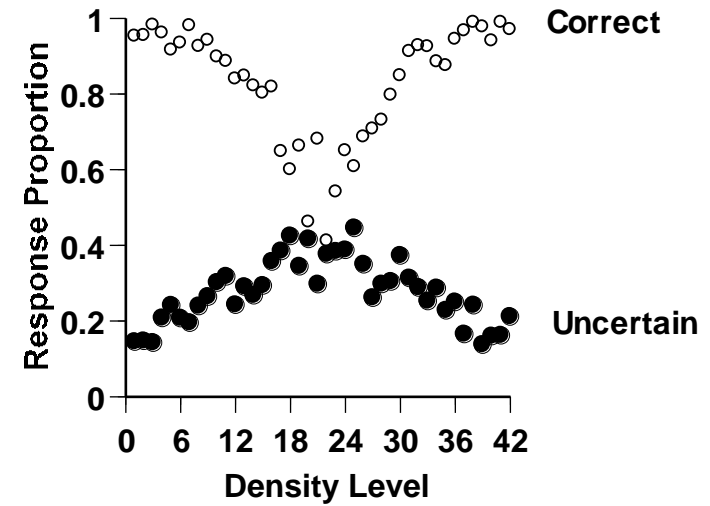
Hampton (2001) *Proc. Nat. Acad. Sci.* 98 (5359)

Inman et al. (1999) *J. Exp. Psych.: Anim. B.* 25 (389)

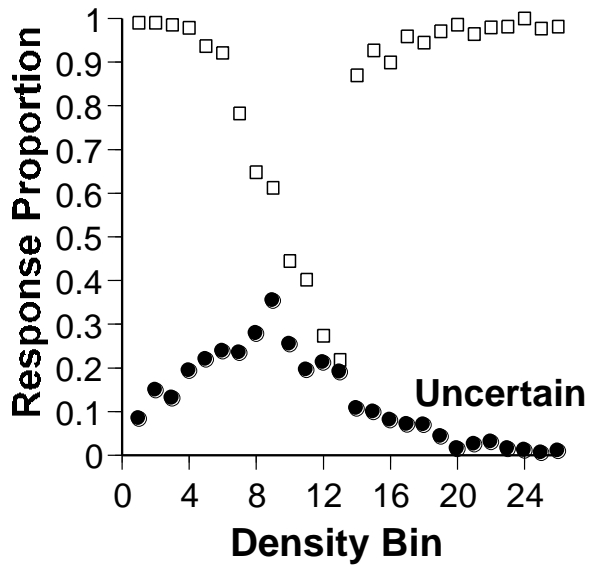
Beran et al. (2006)  
**JEP: Anim B 32 (111)**



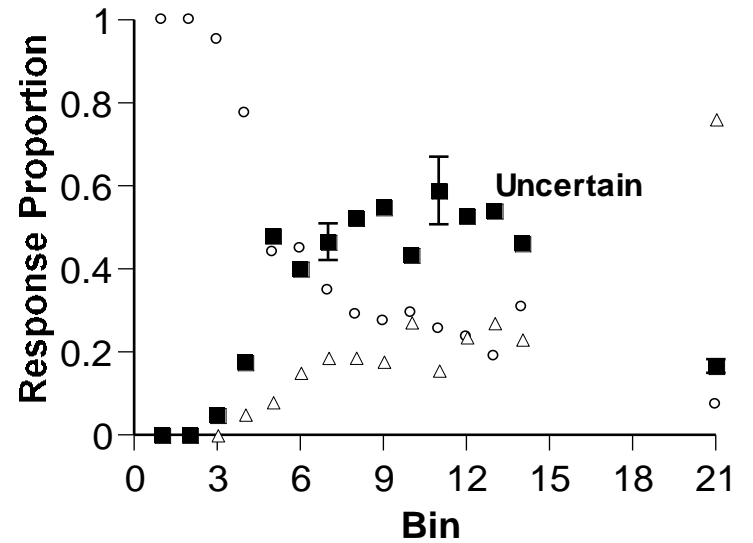
Coutinho et al.  
(in preparation)



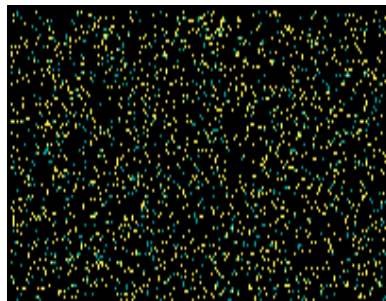
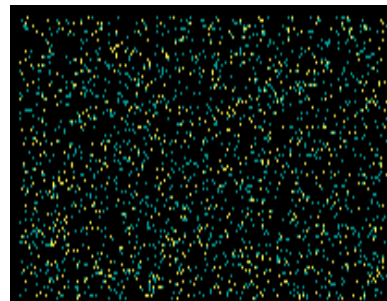
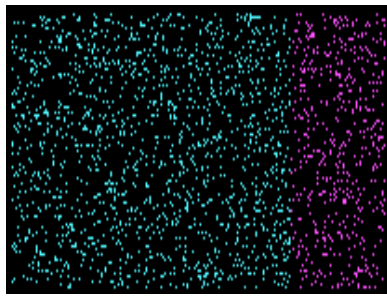
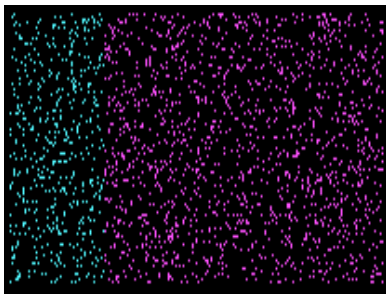
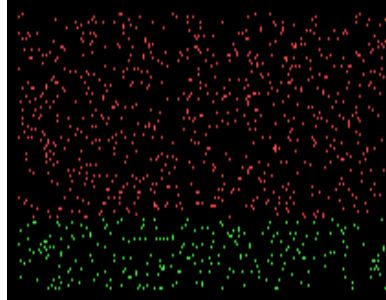
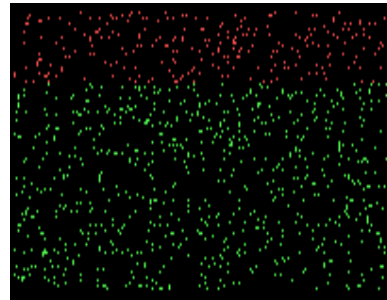
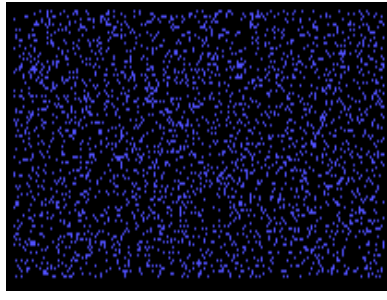
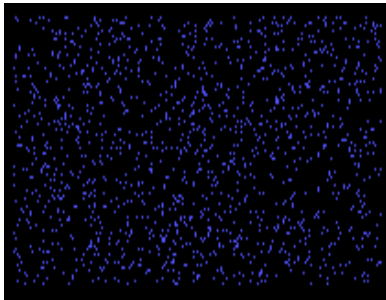
Smith et al. (2006)  
**JEP: Gen 135 (282)**

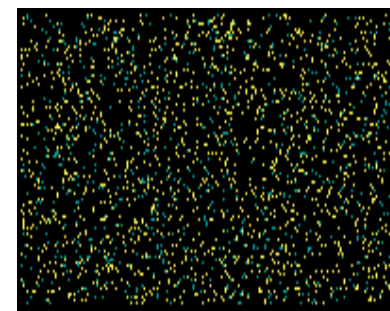
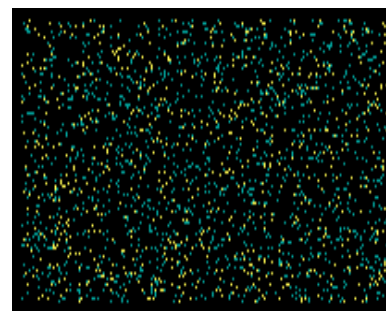
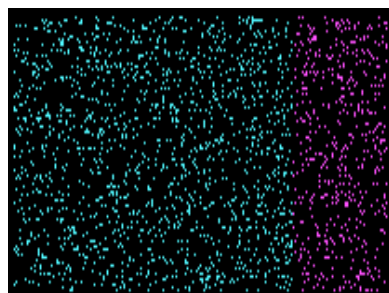
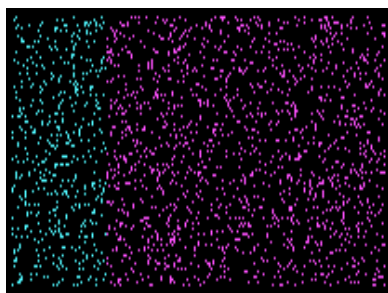
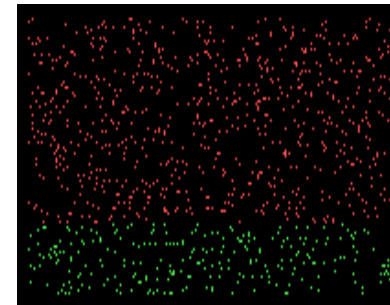
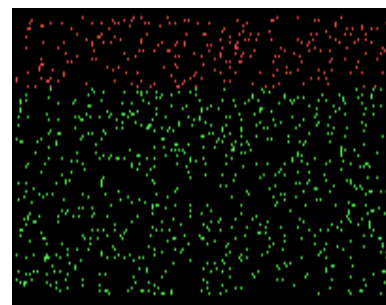
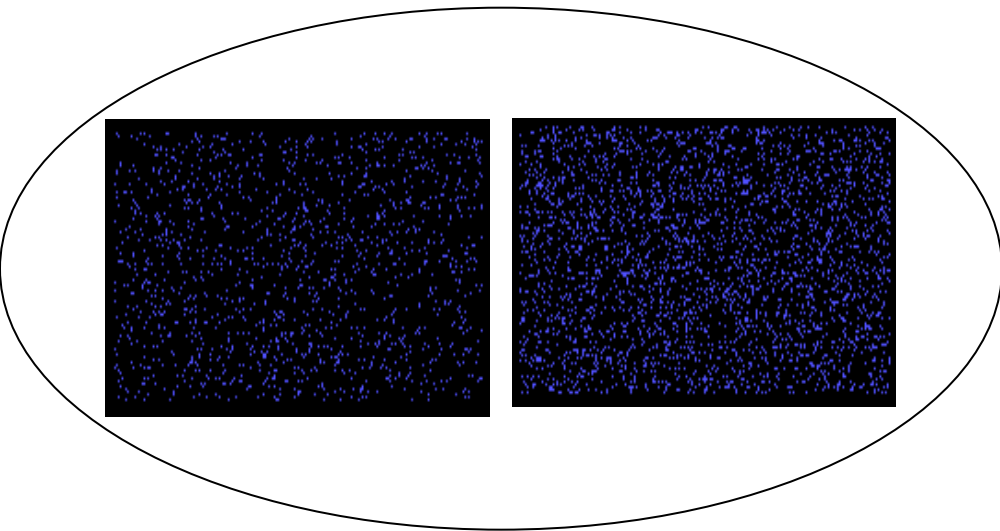


Couchman et al  
(submitted)

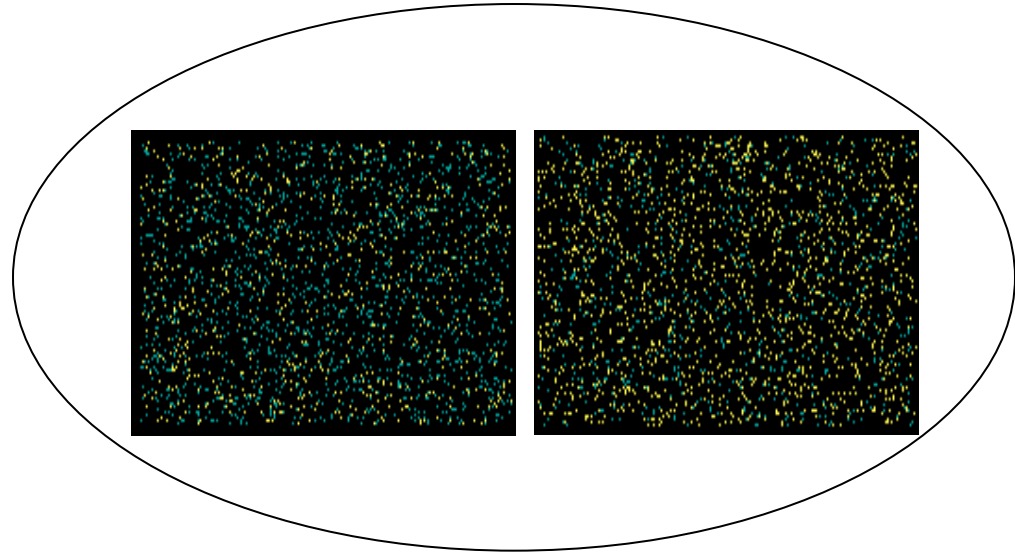
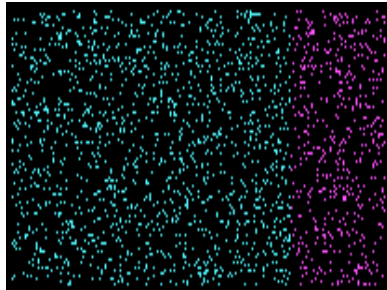
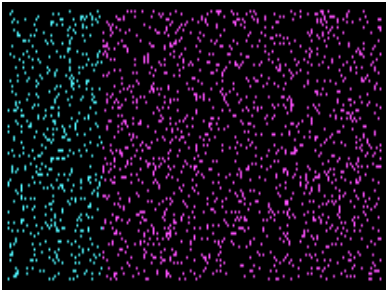
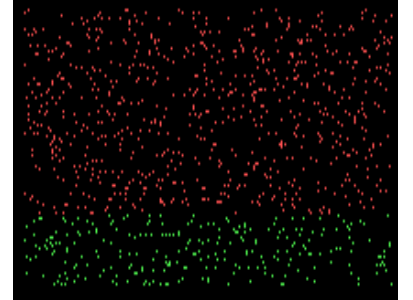
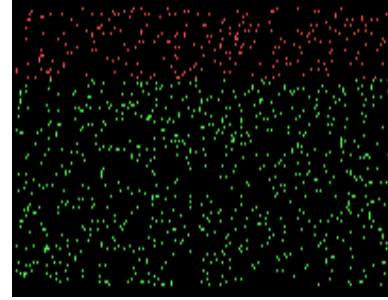
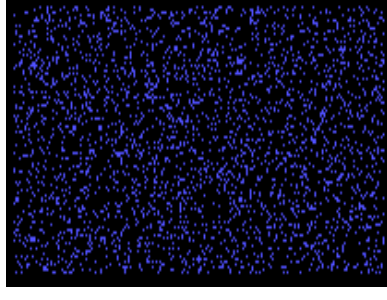
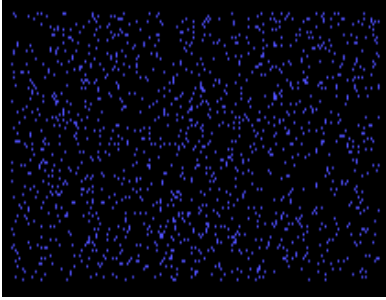


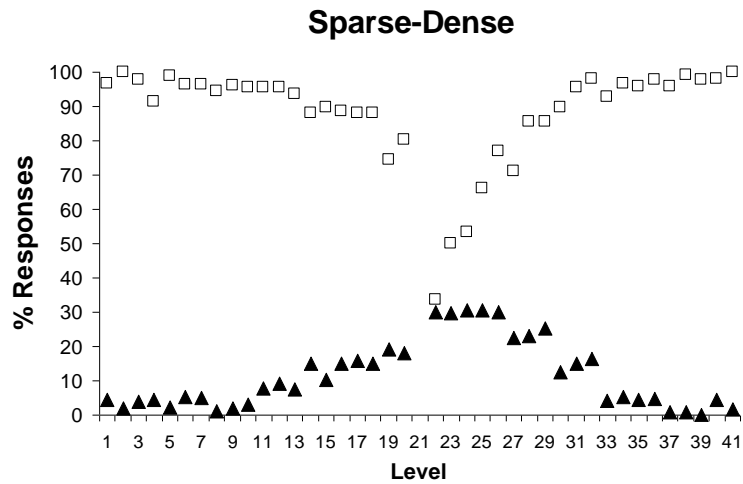
Smith, J. D., Redford, J. S., Beran, M. J., & Washburn, D. A. (in press). Monkeys adaptively monitor uncertainty while multi-tasking. *Animal Cognition*.



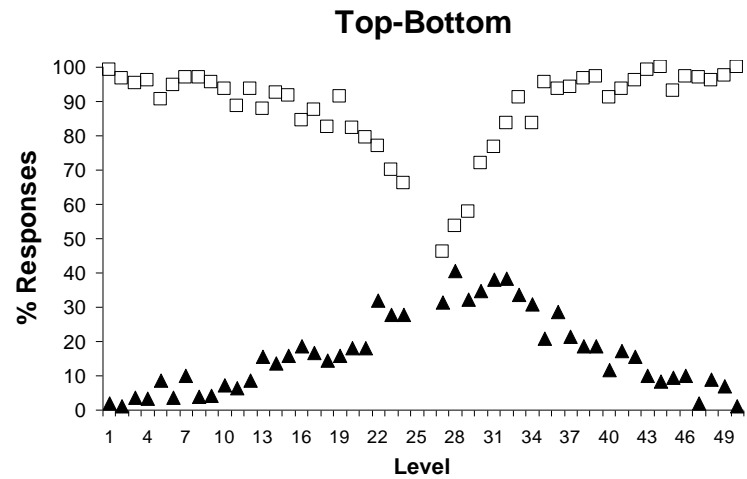




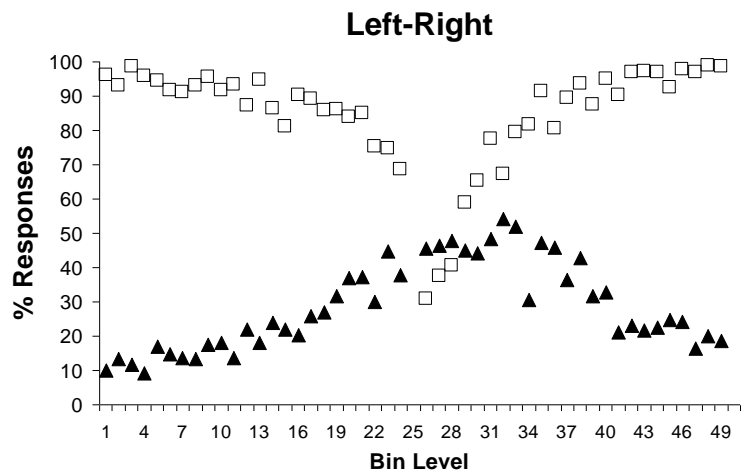




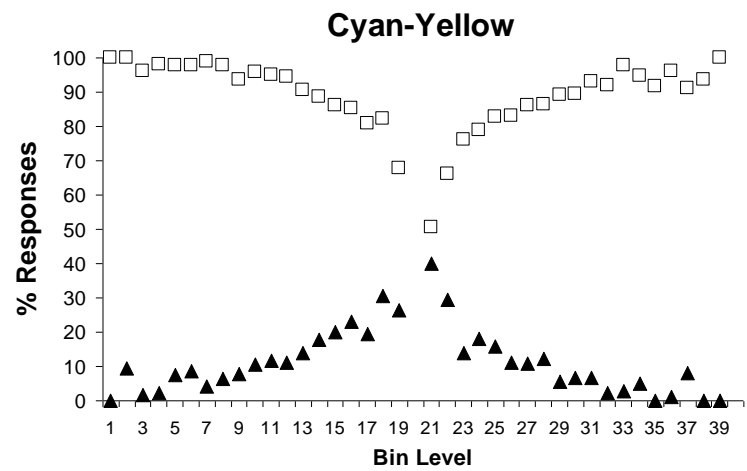
A



B



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D

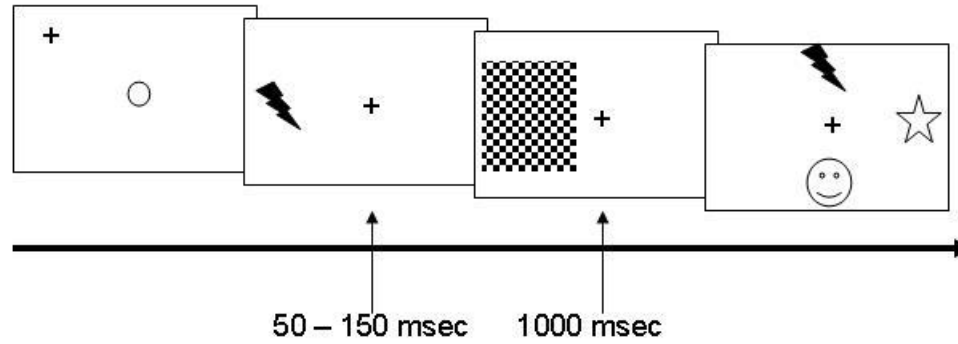
Smith, J. D. (2009). The study of animal metacognition. *Trends in Cognitive Sciences*, 13, 389-396.

Washburn, D. A., Gullledge, J. P., Beran, M. J., & Smith, J. D. (2009). With his memory magnetically erased, a monkey knows he is uncertain. In press, *Biology Letters*.

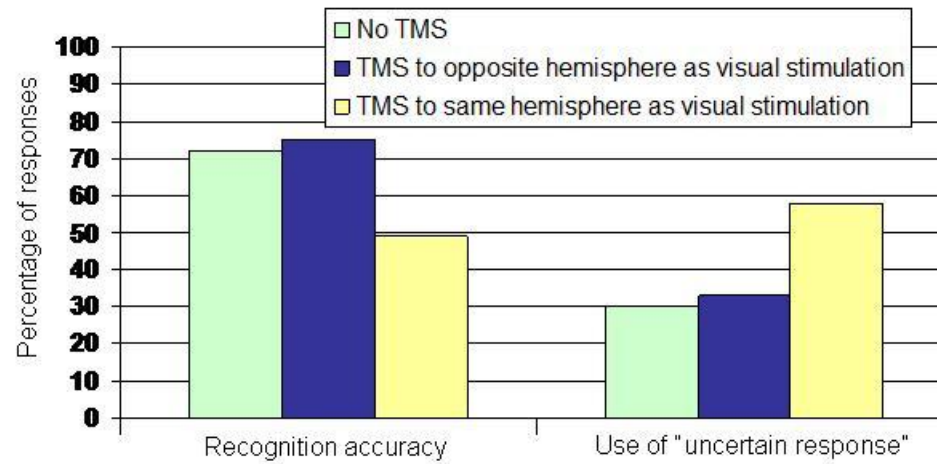
A



B

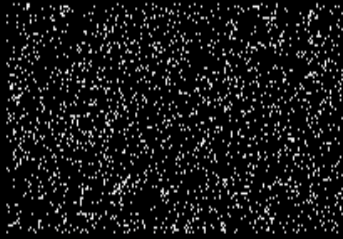


C



### ***3. Species Differences in Animal Metacognition***

Beran, M. J., Smith, J. D., Coutinho, M. V. C., Couchman, J. J., & Boomer, J. (2009). The psychological organization of “uncertainty” responses and “middle” responses: A dissociation in capuchin monkeys (*Cebus apella*). *Journal of Experimental Psychology: Animal Behavior Processes*, 35, 371-381.



S

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D

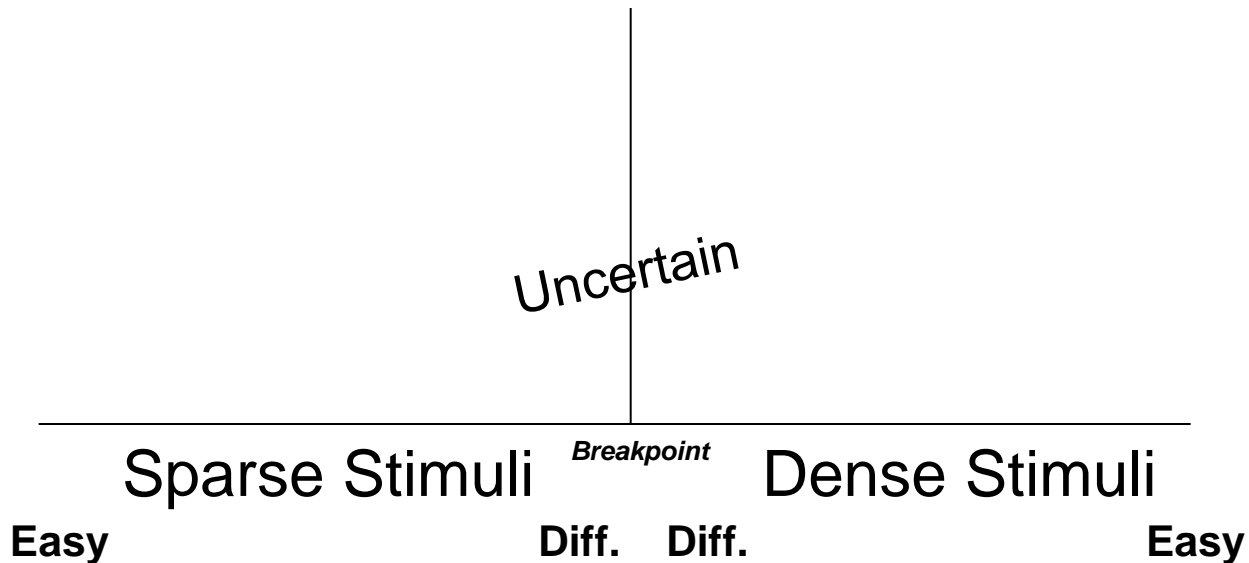
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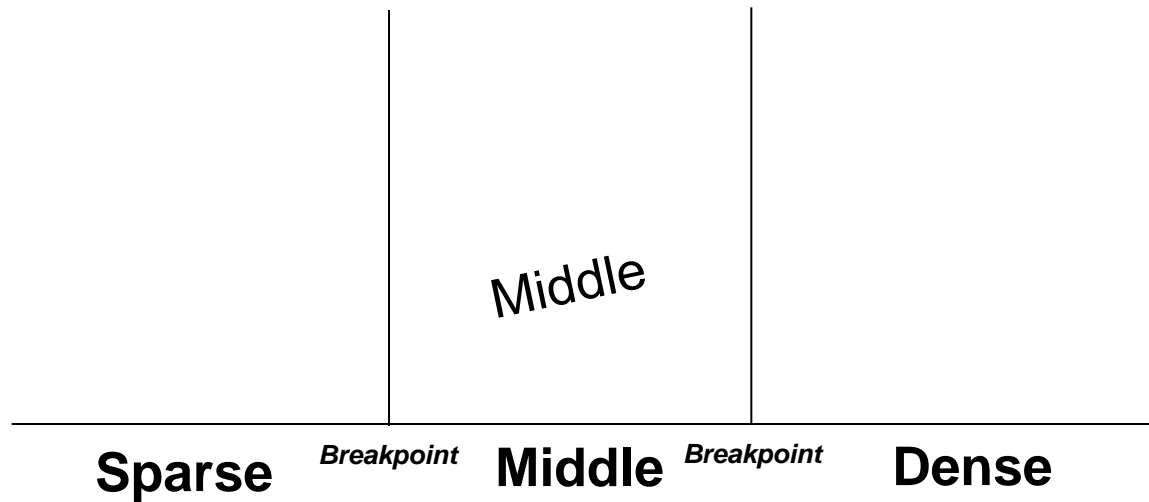
# Sparse-Uncertain-Dense Task

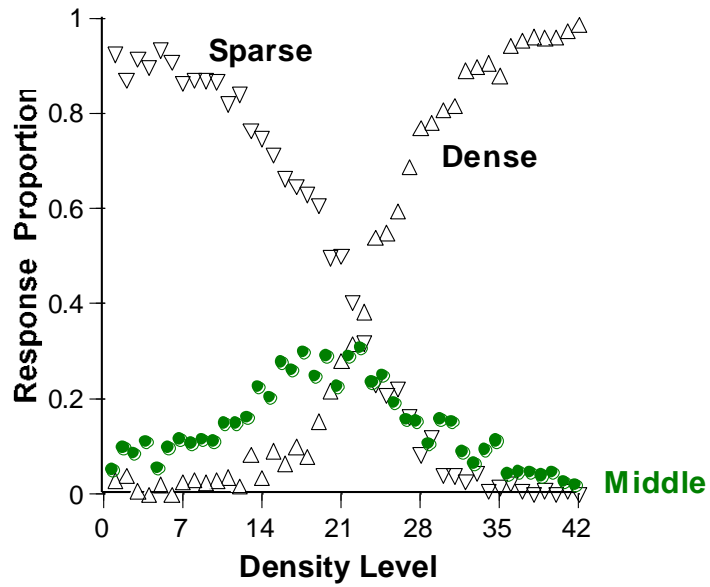
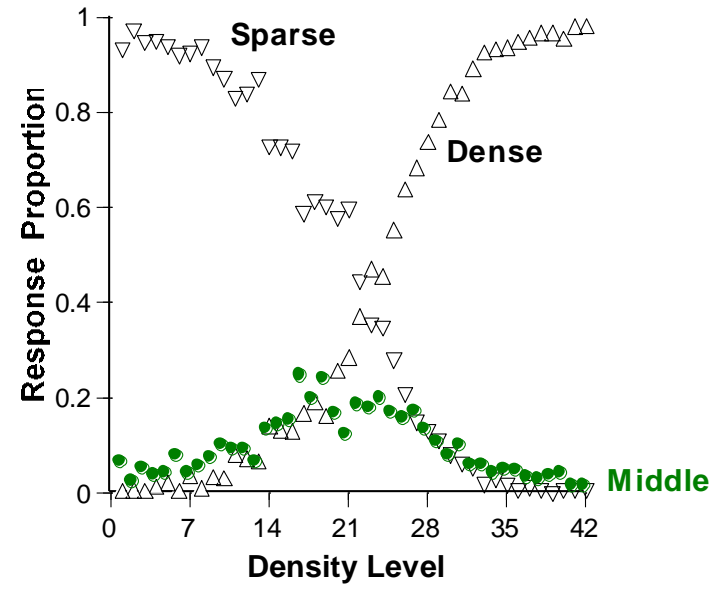
- One discrimination breakpoint
- Two stimulus classes
- Respond: Sparse-Uncertain-Dense

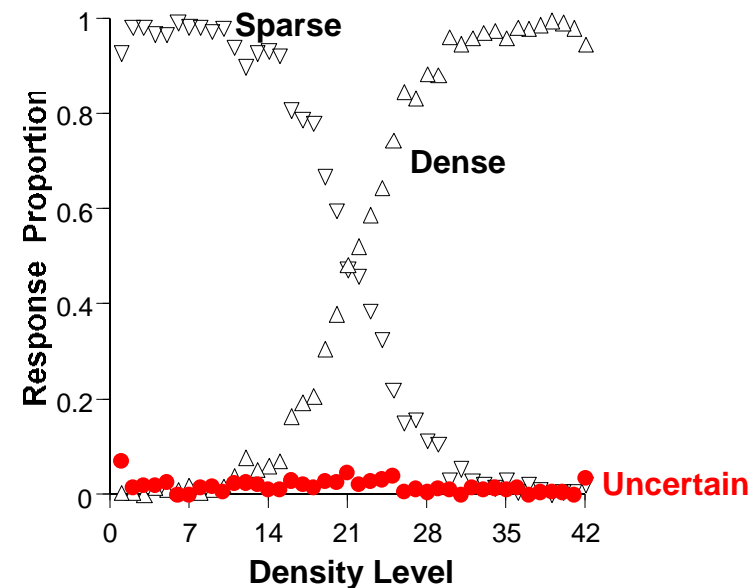
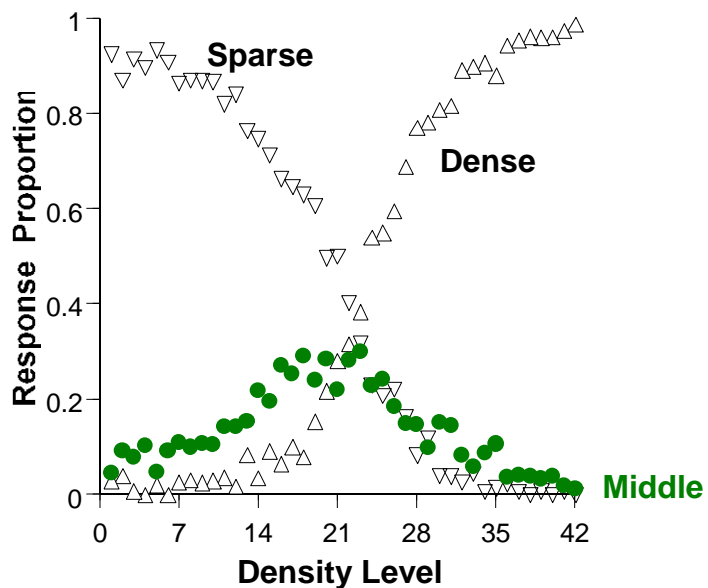
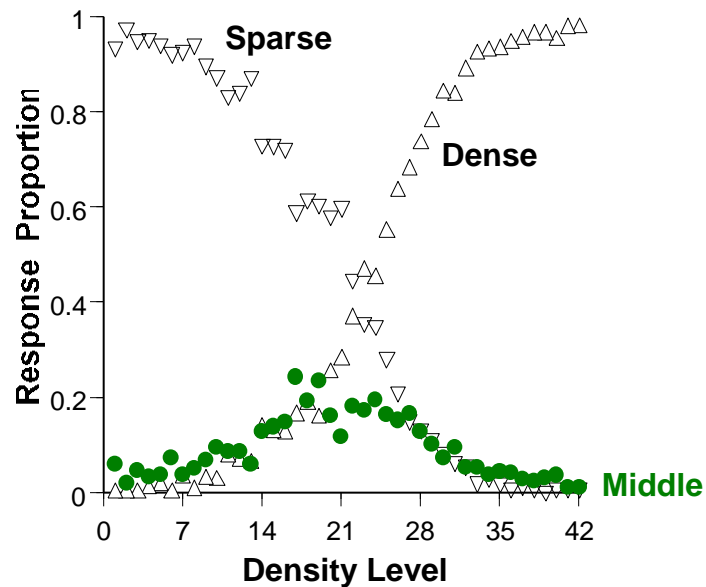
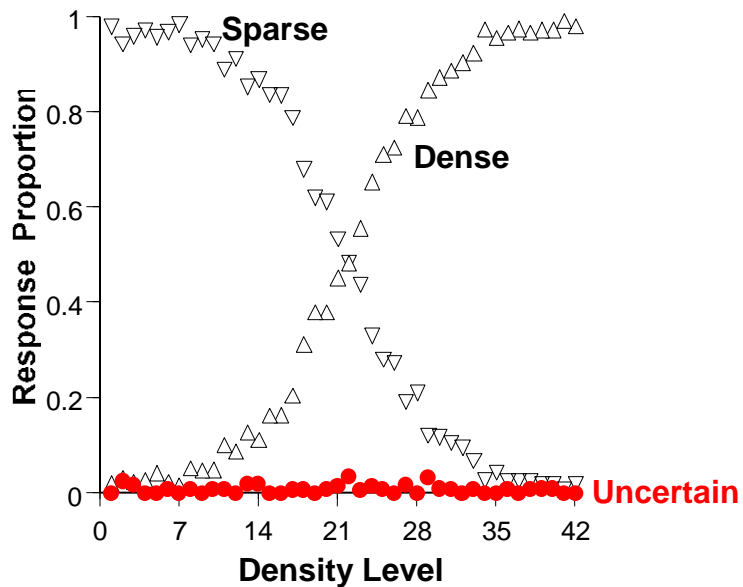


# Sparse-Middle-Dense Task

- Two discrimination breakpoints
- Three stimulus classes
- Respond: Sparse-Middle-Dense

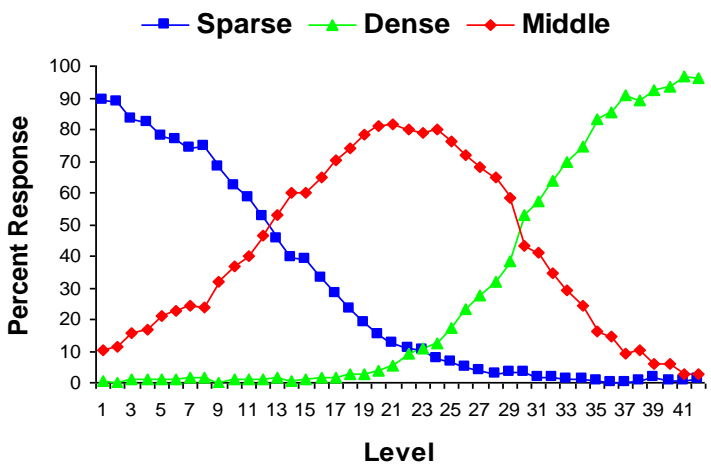
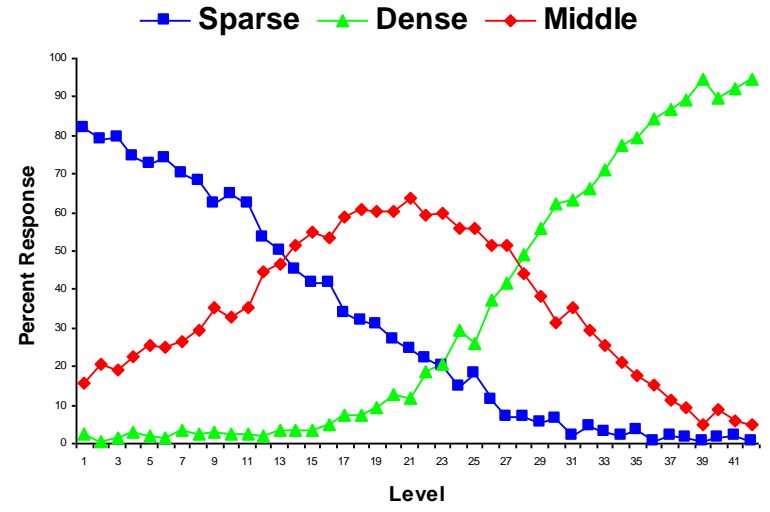


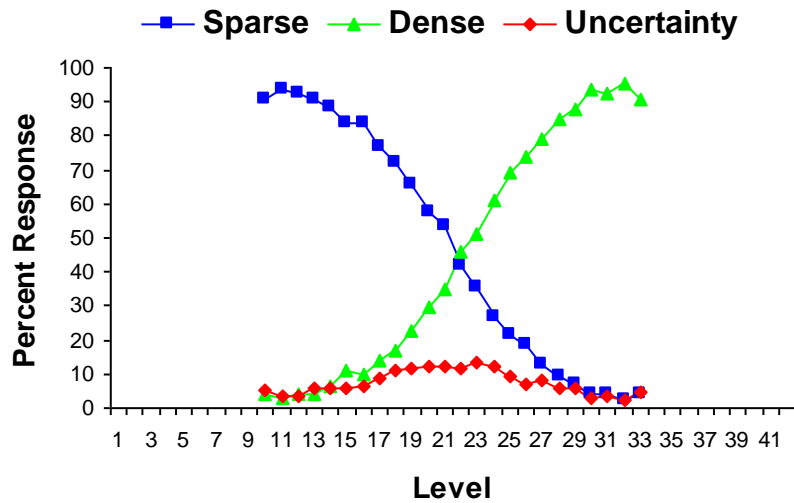
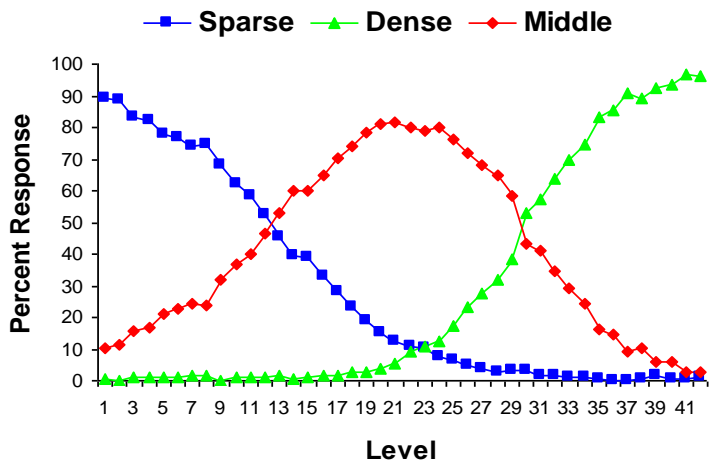
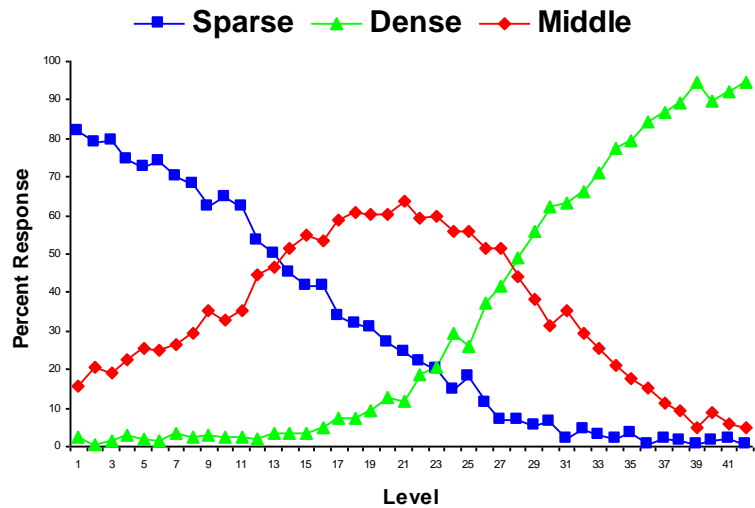
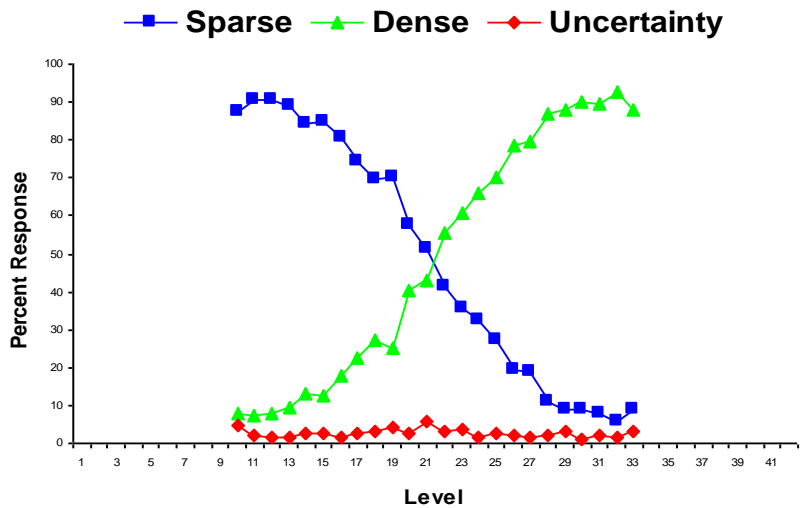




# Performance Costs

- Absence of URs meant:
  - 1651 errors in the uncertainty task
    - 20 s timeout for each error
  - 33,020 s
  - More than 9 hours of timeouts
  - More than 25% of time on task





# Metacognition in Capuchins?

Paukner et al. (2006) *Anim. Cognit.* 9 (110)

Basile et al. (2008) *Anim. Cognit.* 12 (169)

Fujita (2009) *Anim. Cognit.* 12 (575)



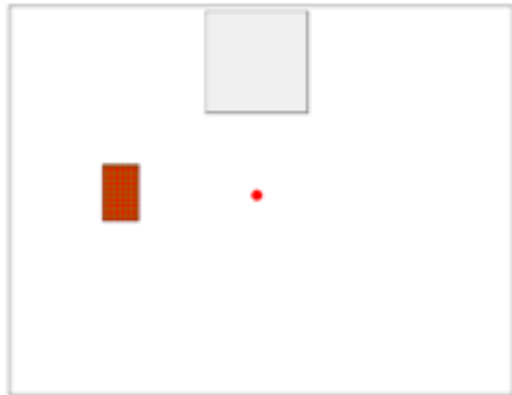
# Metacognition in Pigeons?

Inman et al. (1999) *J. Exp. Psych.: Anim. B.* 25 (389)

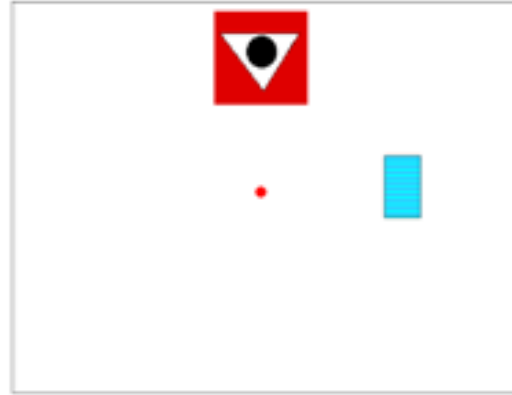
Sutton et al. (2008) *J. Exp. Psych.: Anim. B.* 34 (266)

Roberts et al. (2009) *J. Exp. Psych.: Anim. B.* 35 (129)

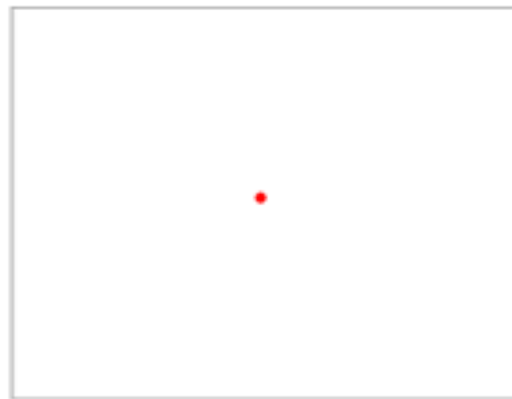
Beran, M. J., Evans, T., & Smith, J. D. (in preparation). The studious macaque.



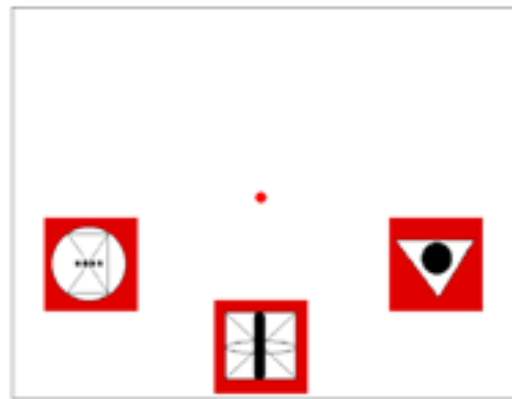
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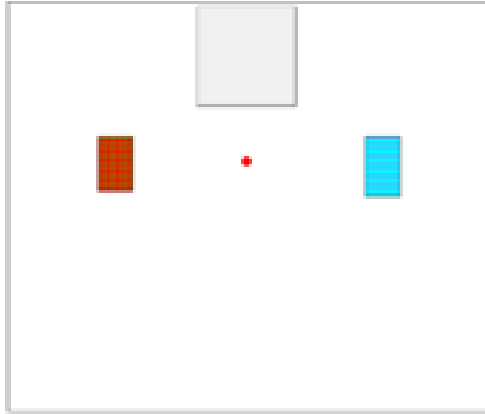
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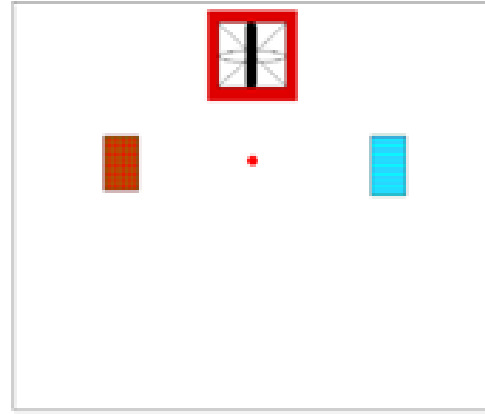
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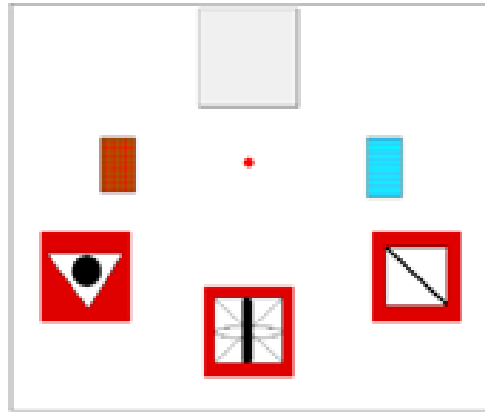
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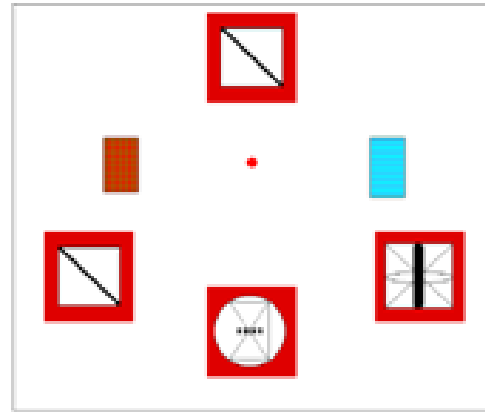
A



B

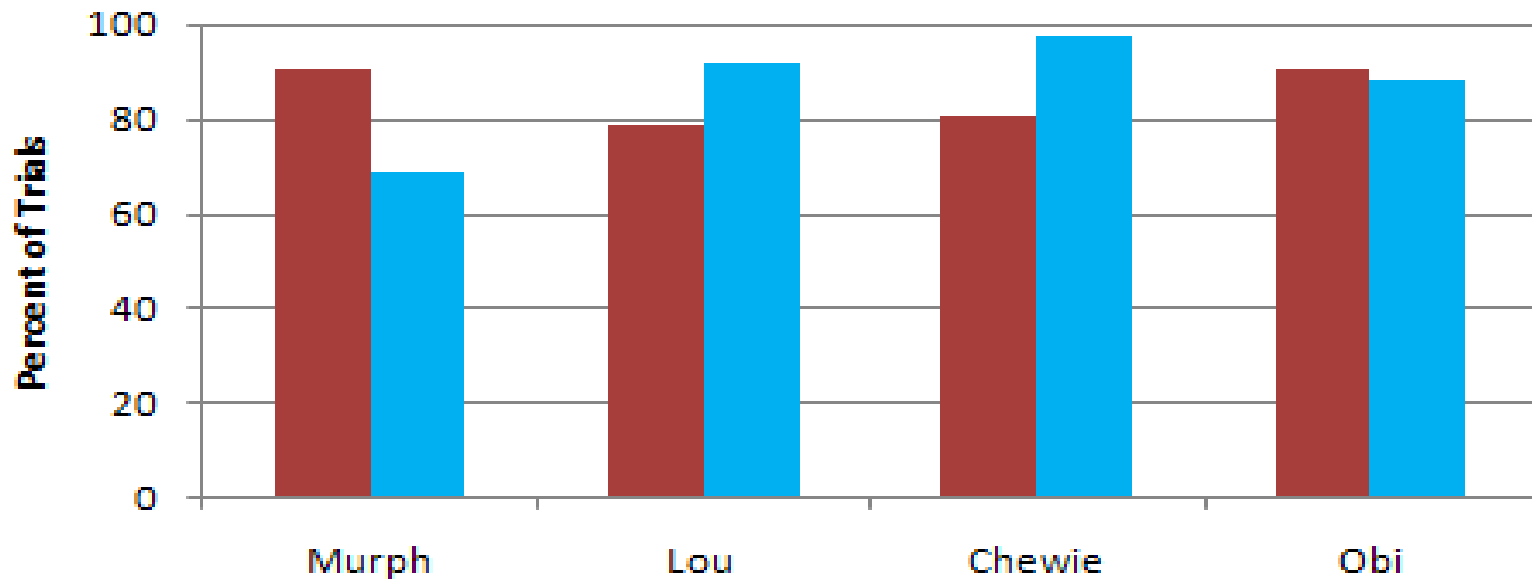


C



D

- Nothing Visible - Chose Sample-Revealing and Matches-Revealing Rectangles
- Sample Visible - Chose only Matches-Revealing Rectangle



## ***4. Executive-Attentional Uncertainty and Metacognition***

# Symptoms of Explicit Cognition

Controlled

Deliberate

Reflective

Executive

Attentional

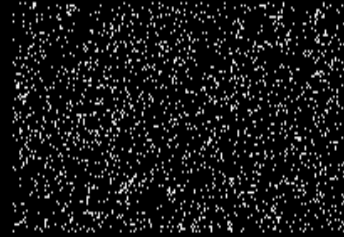
Pre-frontal

In working memory

Aware

Conscious

Declarative



S



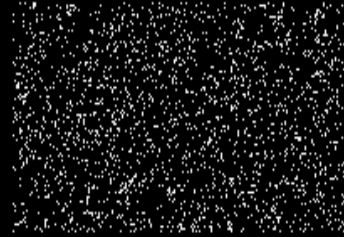
D

?



3

5



S



D

?

What number was the larger quantity?

or

What number was the larger font?

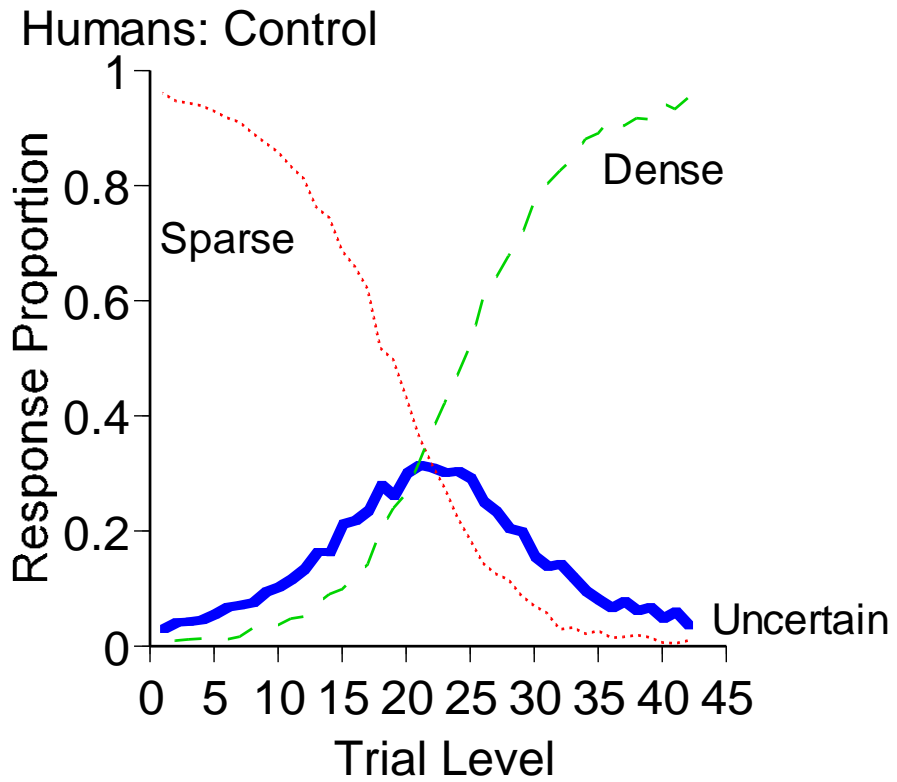
What number was the larger quantity?

5

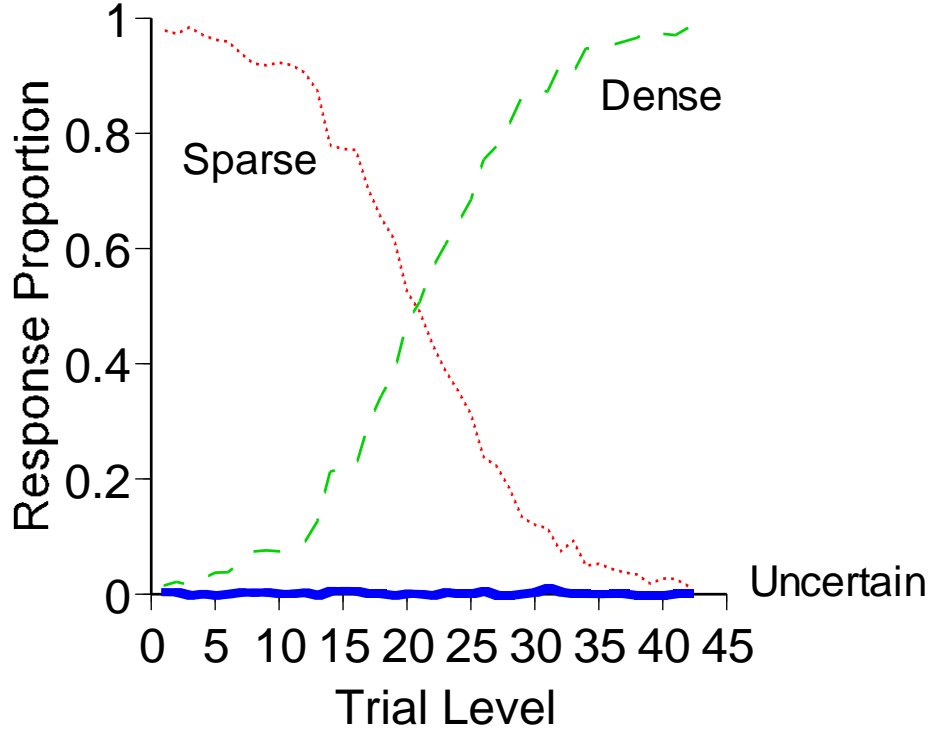
or

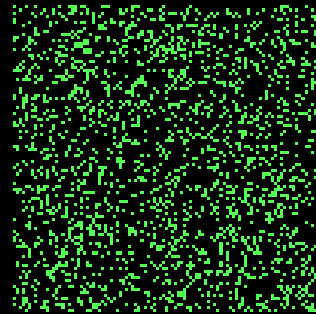
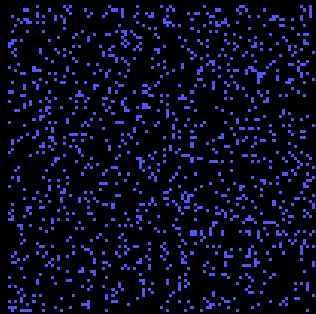
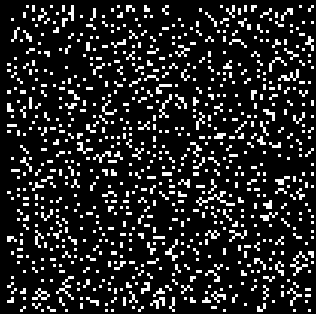
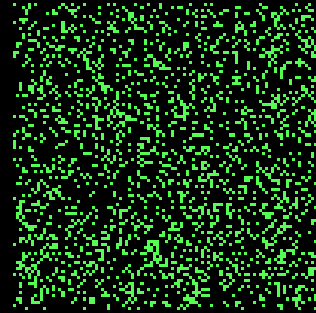
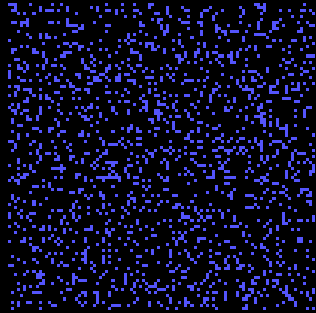
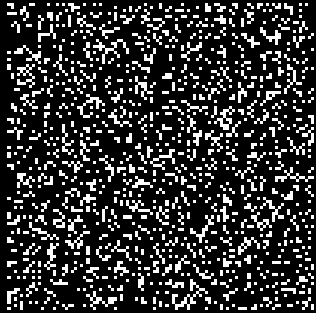
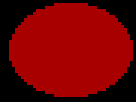
What number was the larger font?

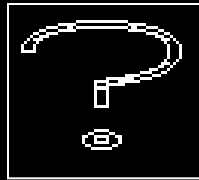
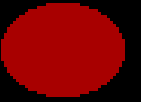
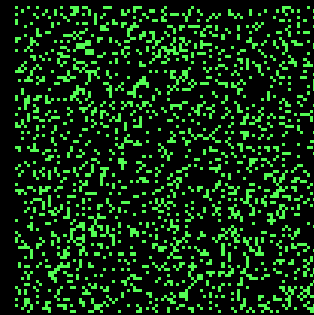
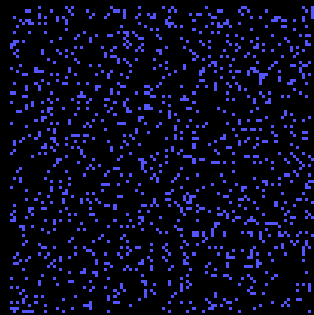
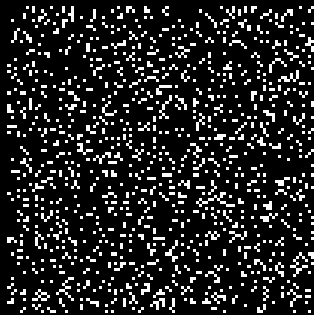
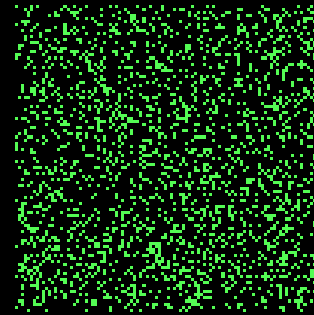
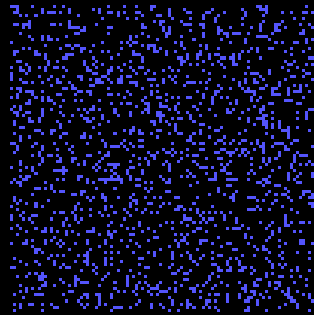
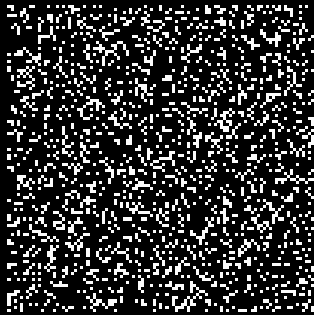
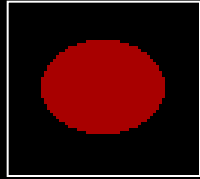
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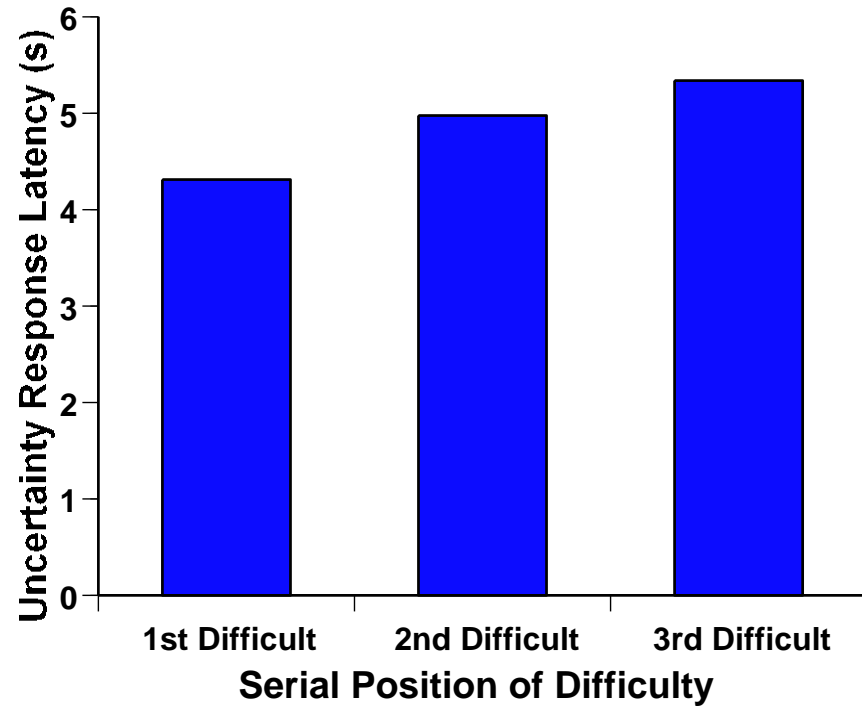
Humans: Concurrent

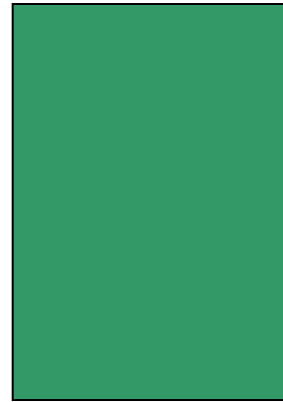
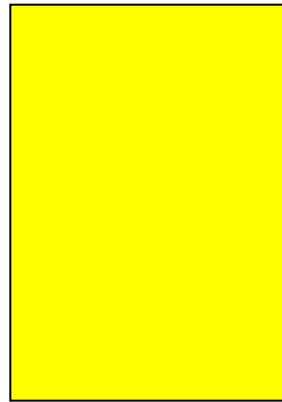
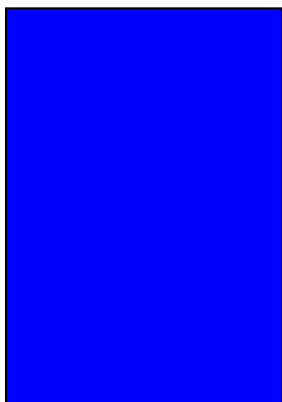
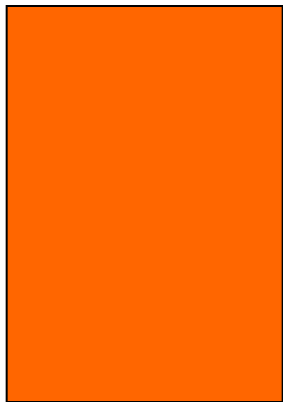












Bet  
Low

A  
-5

B  
-5

C  
+5

D  
+5

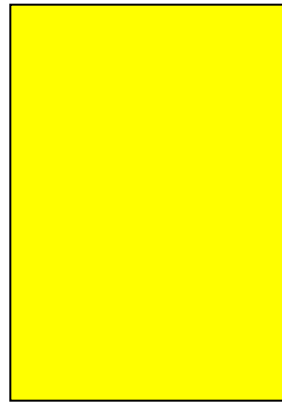
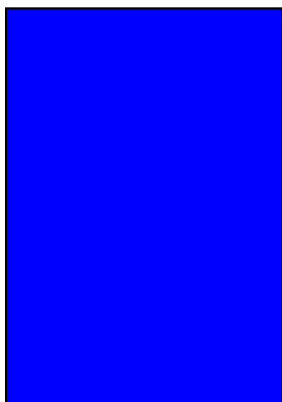
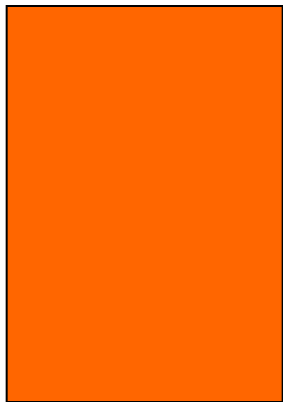
Bet  
High

A  
-10

B  
-10

C  
+10

D  
+10



Bet  
Low

A  
-5  
21.21

B  
-5  
21.21

C  
+5  
21.21

D  
+5  
21.21

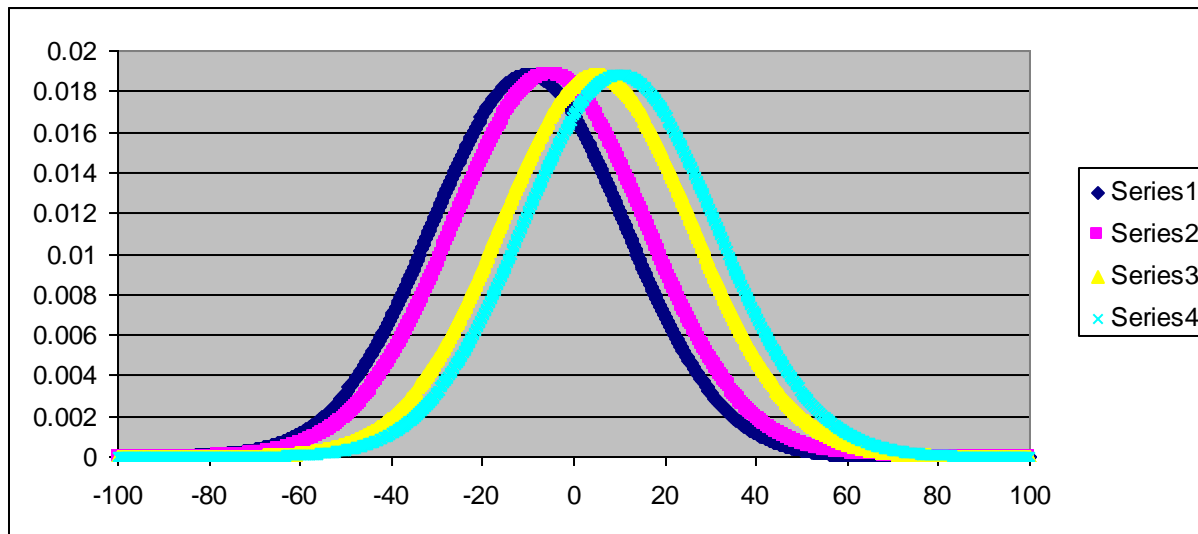
Bet  
High

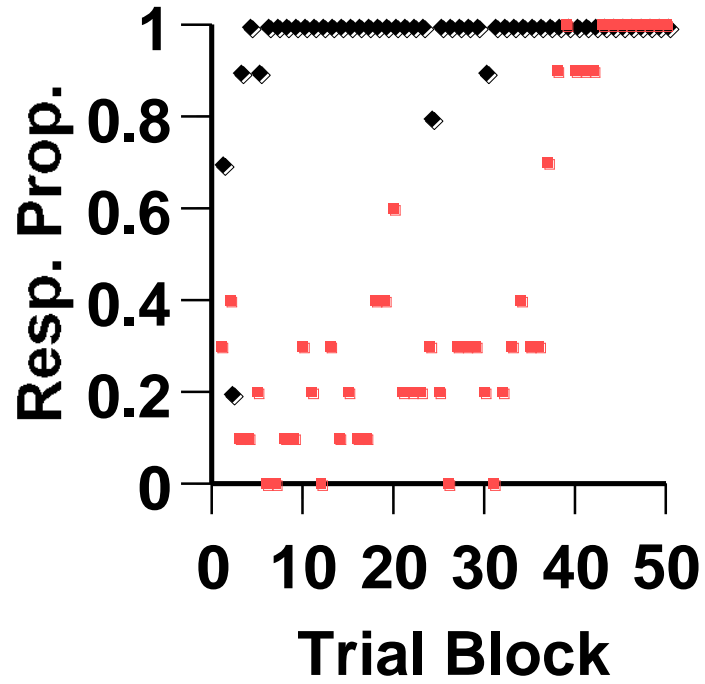
A  
-10  
21.21

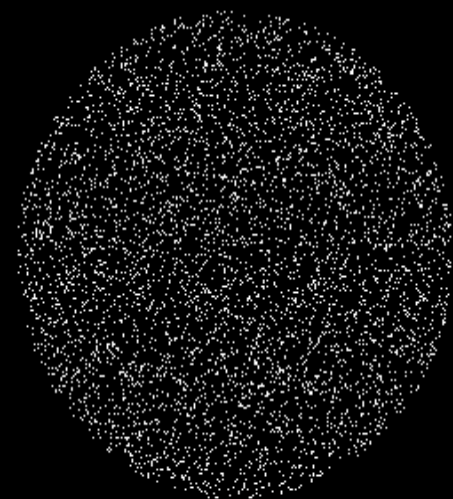
B  
-10  
21.21

C  
+10  
21.21

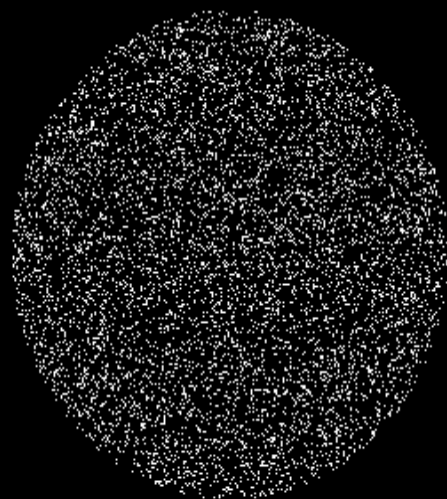
D  
+10  
21.21



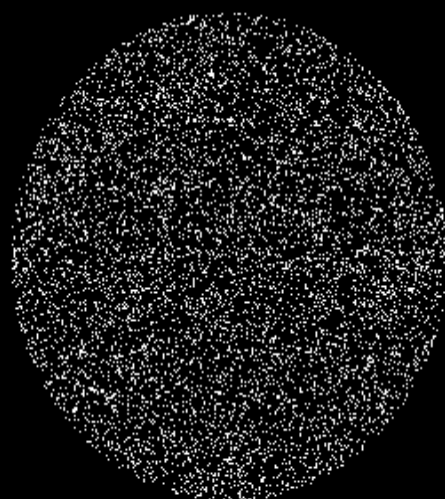




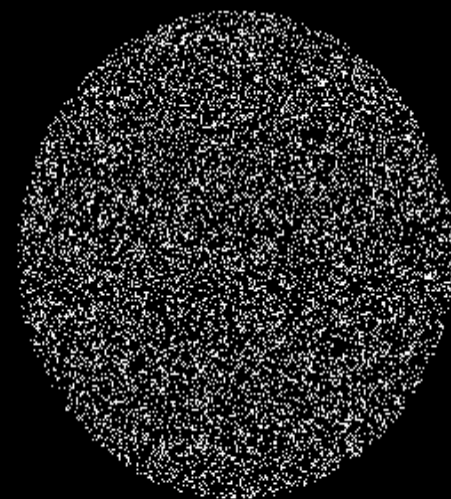
Sparse 1



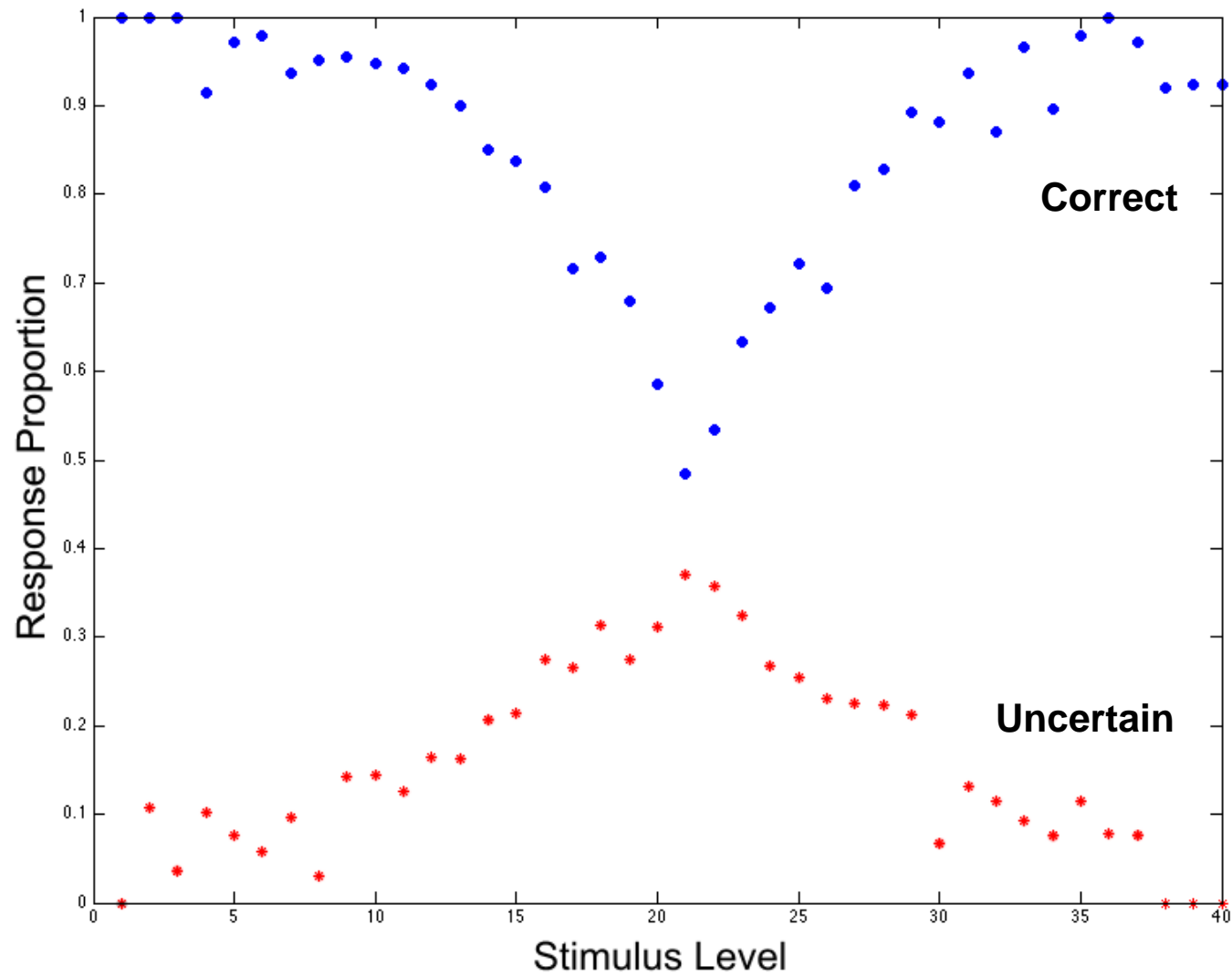
Sparse 20

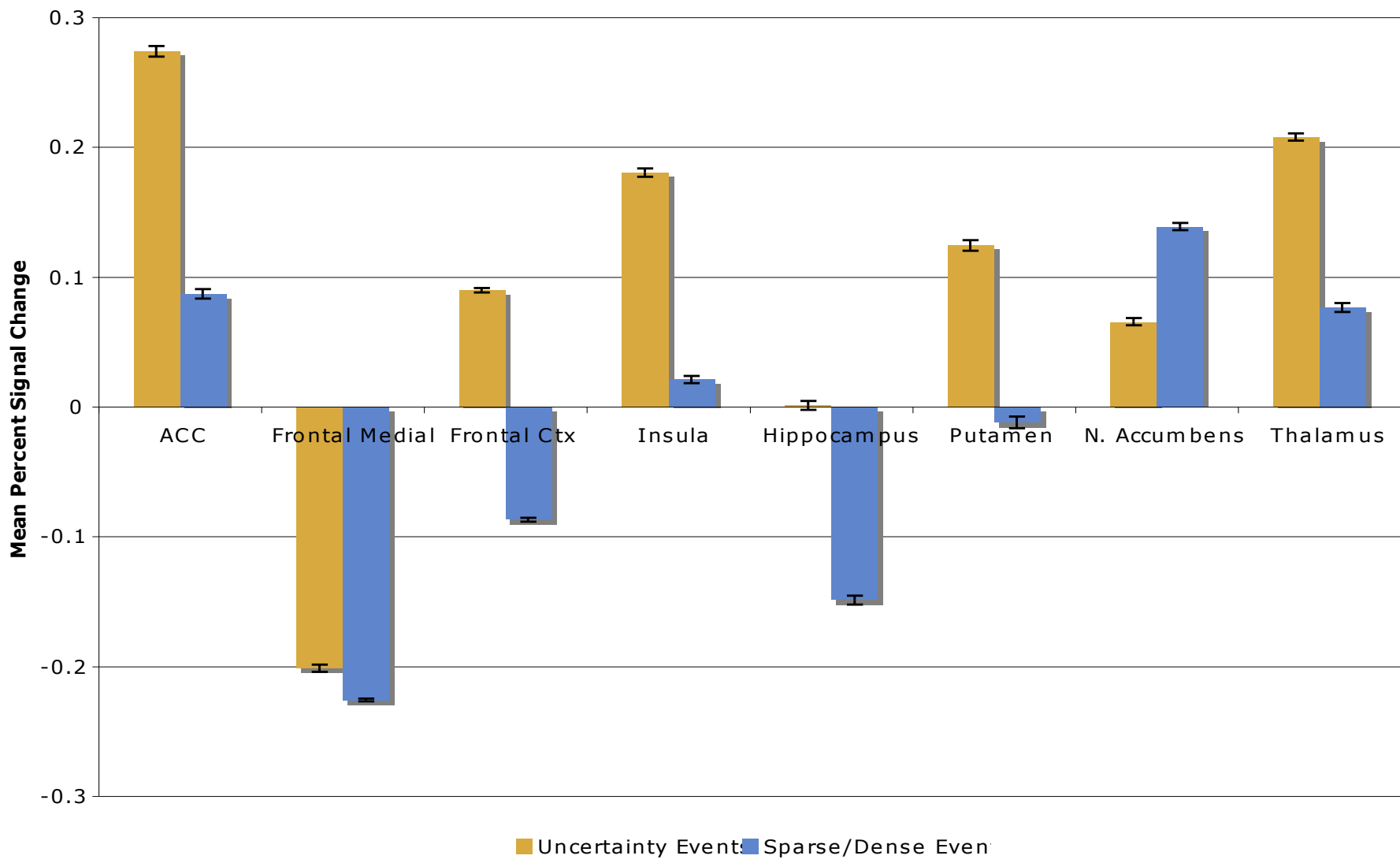


Dense 22



Dense 41









*Thanks!*

