How Smart are Horses, Really? (Higher Level Equine Cognition)

Review of Literature

Dr Laurie McDuffee
Department of Health Management
Atlantic Veterinary College

Cognition

- A term referring to the mental processes involved in gaining knowledge and comprehension
  - processes involved in acquiring, storing, and using information from the environment
    - from perception to decision making
  - may include thinking, knowing, remembering, judging, and problem solving
  - many of theses involve higher-level functions of the brain
    - Indicate a higher level of intelligence

Cognition, Learning, and Memory in Everyday Life of Wild and Domesticated Horses (Equus caballus)

Equine Cognition: Basic Processes

- Perception, memory, learning
- Building blocks for more complex processes
  - Learning categories and concepts (discrimination)
  - Finding one's way around in space (spatial cognition)
  - Navigating complex social networks (social cognition)

Equine Cognition: Basic Processes

- Perception, memory, learning
- Building blocks for more complex processes
  - Learning categories and concepts (discrimination)
  - Finding one's way around in space (spatial cognition)
  - Navigating complex social networks (social cognition)

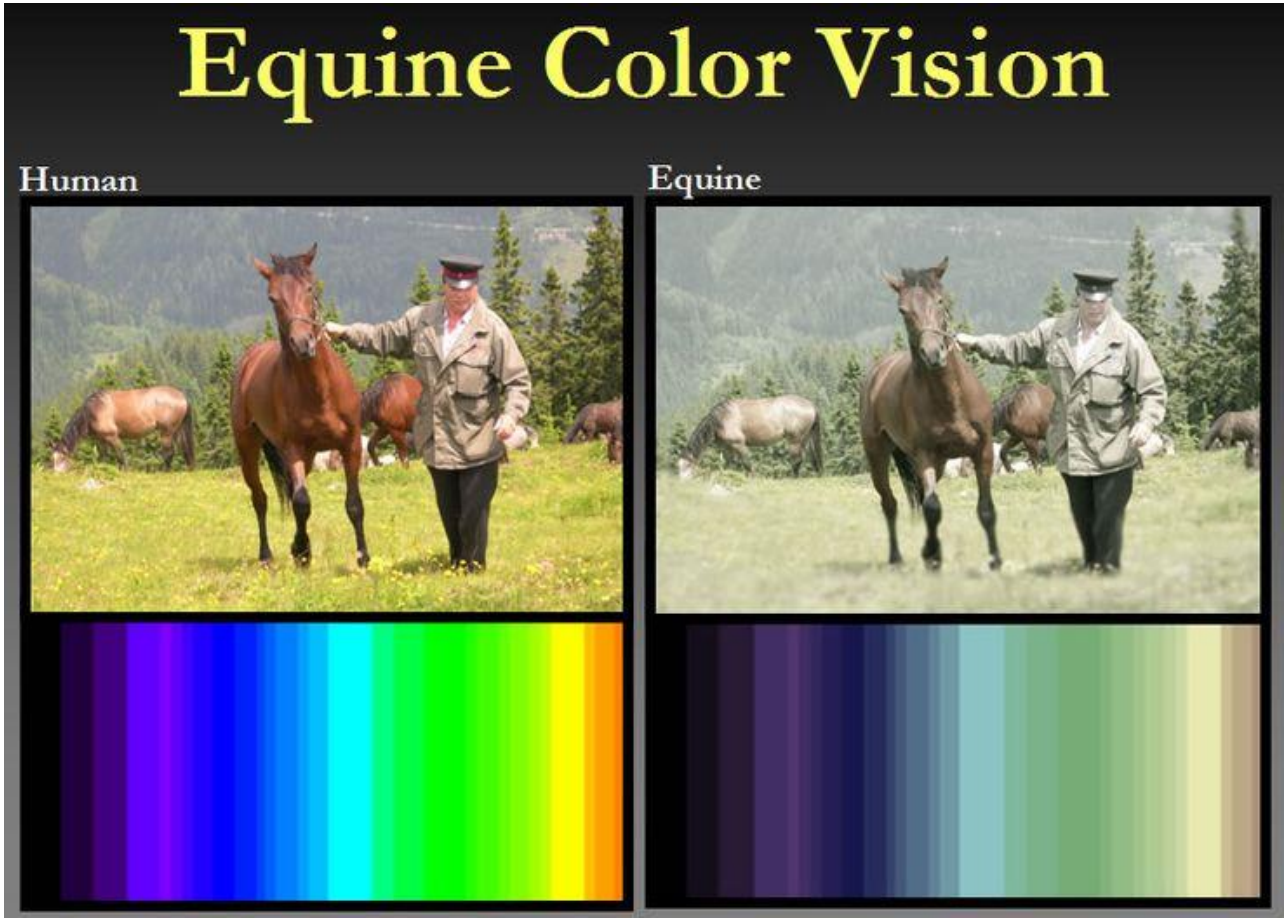
Perception

- Perceptual world of the horse (horses' umwelt)
  - different animals in the same ecosystem pick up on different environmental signals
  - help us understand the animal
  - must understand how an animal perceives in order to design appropriate studies of cognition

Visual Perception

- Horses have visual acuity of ~ 20/30
  - Horse can only discern at 20 m what a human sees at 30 m
  - Dogs (20/50) and cats (20/75-20/100)
- Horses are dichromats in well lit conditions (photopic vision)
- Horses see well under poorly lit conditions (good scotopic vision)
- Horses have a wide range of lateral & caudolateral vision

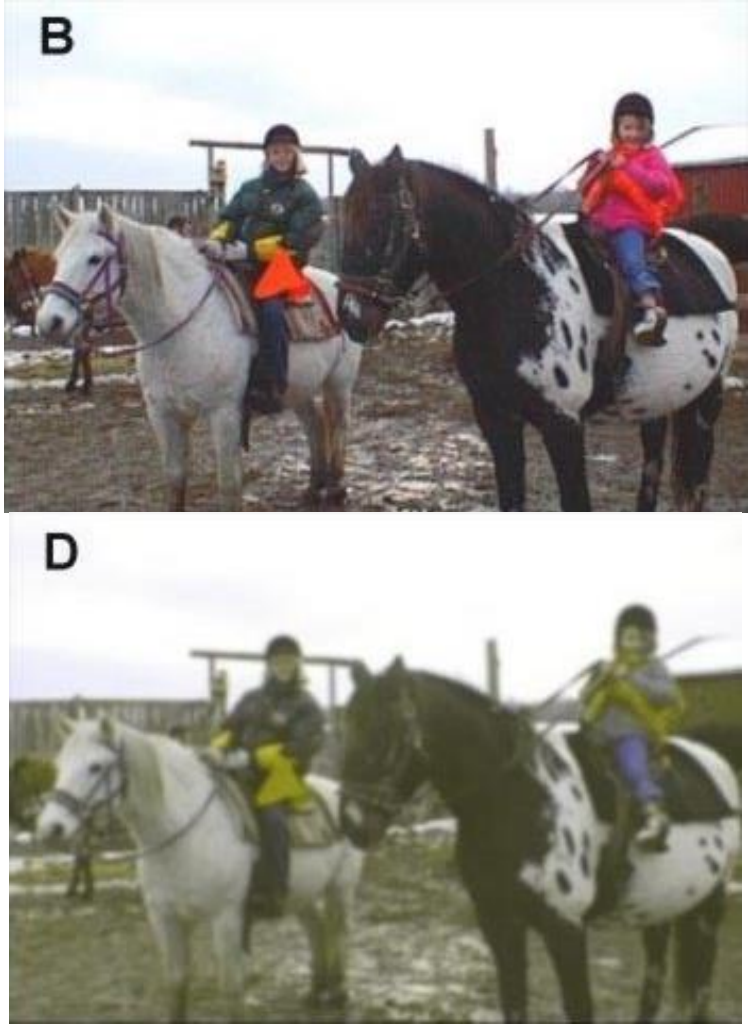
Trichromat vs Dichromat



Normal humans can see four basic color hues–red, green, blue, and yellow

Photo: courtesy of Dr. Andy Matthews

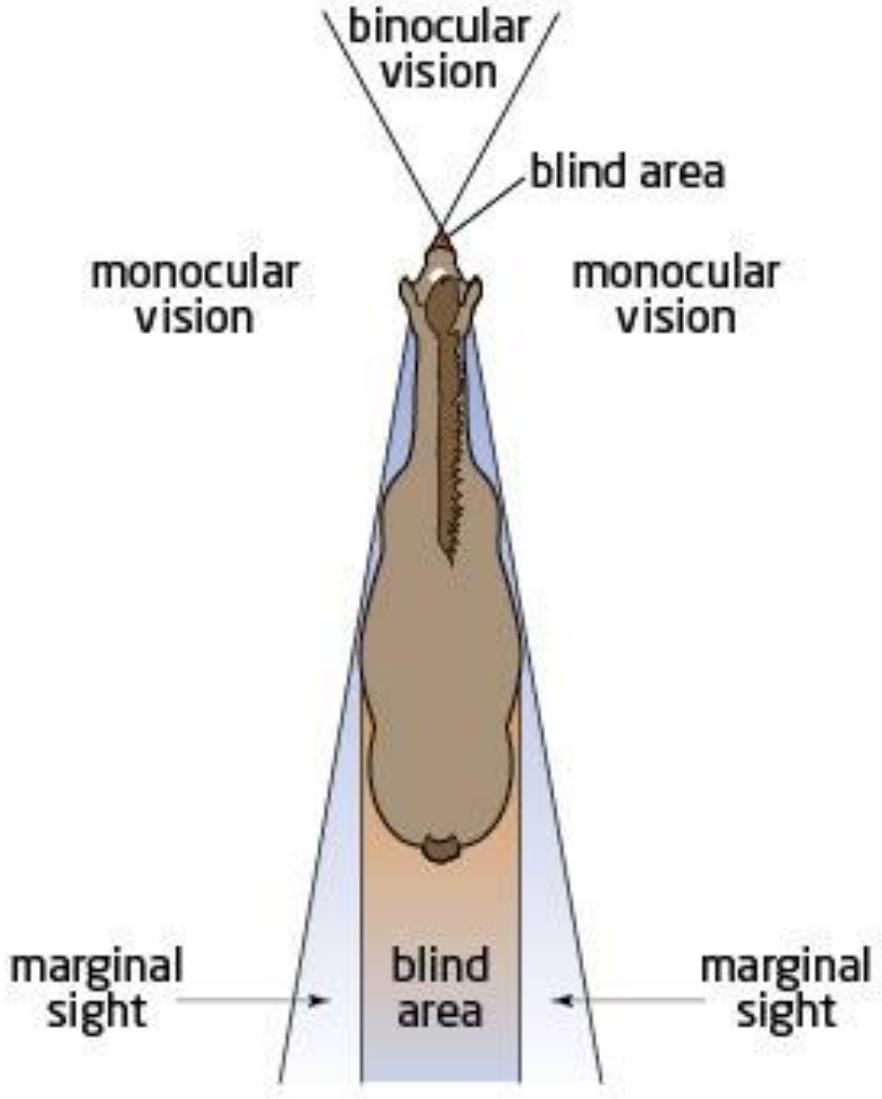
Red - Green Colour Deficiencies



Horses can only see blues and yellows

Carroll, J et al. *Journal of Vision* (2001) 1, 80-87

Lateral and Caudolateral Vision



http://blog.classic-equine.com/2012/10/how-horses-see/

Behavioural Studies Investigating Vision

- Use of Operant Conditioning and Discrimination Learning
  - Horses trained to discriminate between stimuli (objects)
  - Discrimination tasks conducted under varying conditions
    - Normal light
    - Dim light
    - Lateral and caudal placement

Discrimination Training/Learning

- Reinforcement follows one stimulus or action and not another
  - The simplest discrimination training requires a rewarded stimulus (S+) and an unrewarded one (S-)
  - When presented simultaneously, the animal chooses between them

From Shettleworth: Fundamentals of Comparative Cognition

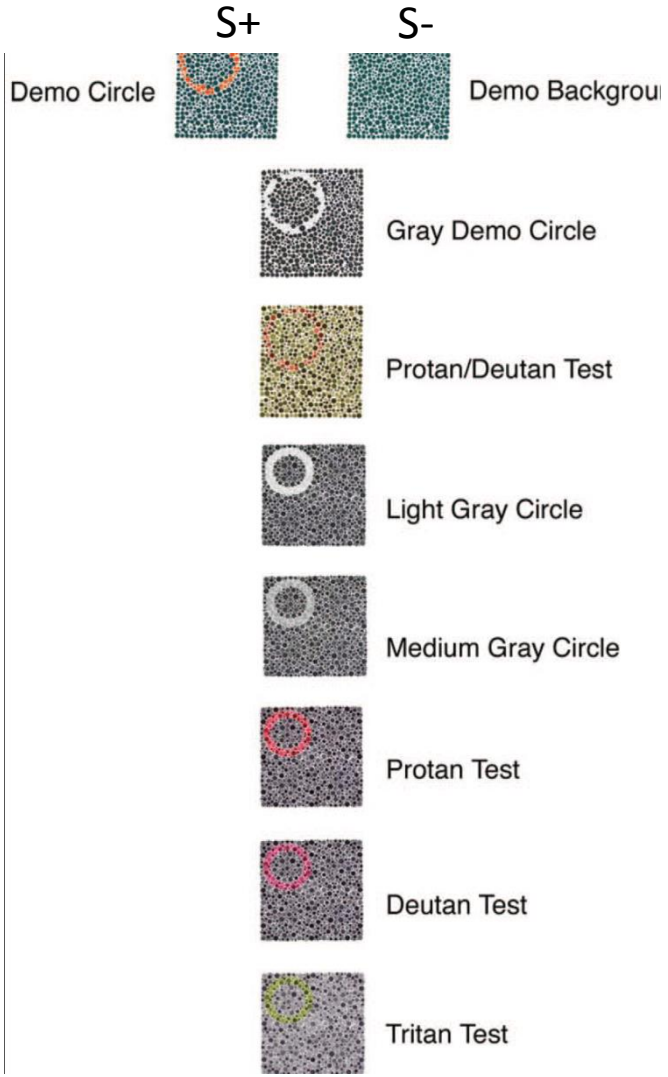
Horse Trained in Discrimination Tasks

A

Hanggi, et al. Journal of Comparative Psychology 2007, Vol. 121, No. 1, 65–72

Pseudoisochromatic Plate Test

http://www.equineresearch.org/



Training Apparatus

D

http://www.equineresearch.org/

Scotopic Vision Testing

Hanggi,et al. Behavioural Processes 82 (2009) 45–50

Making a “Choice” with the Nose

Circle = S+ Triangle S-

http://www.equineresearch.org/

Color Plates Used as Stimuli

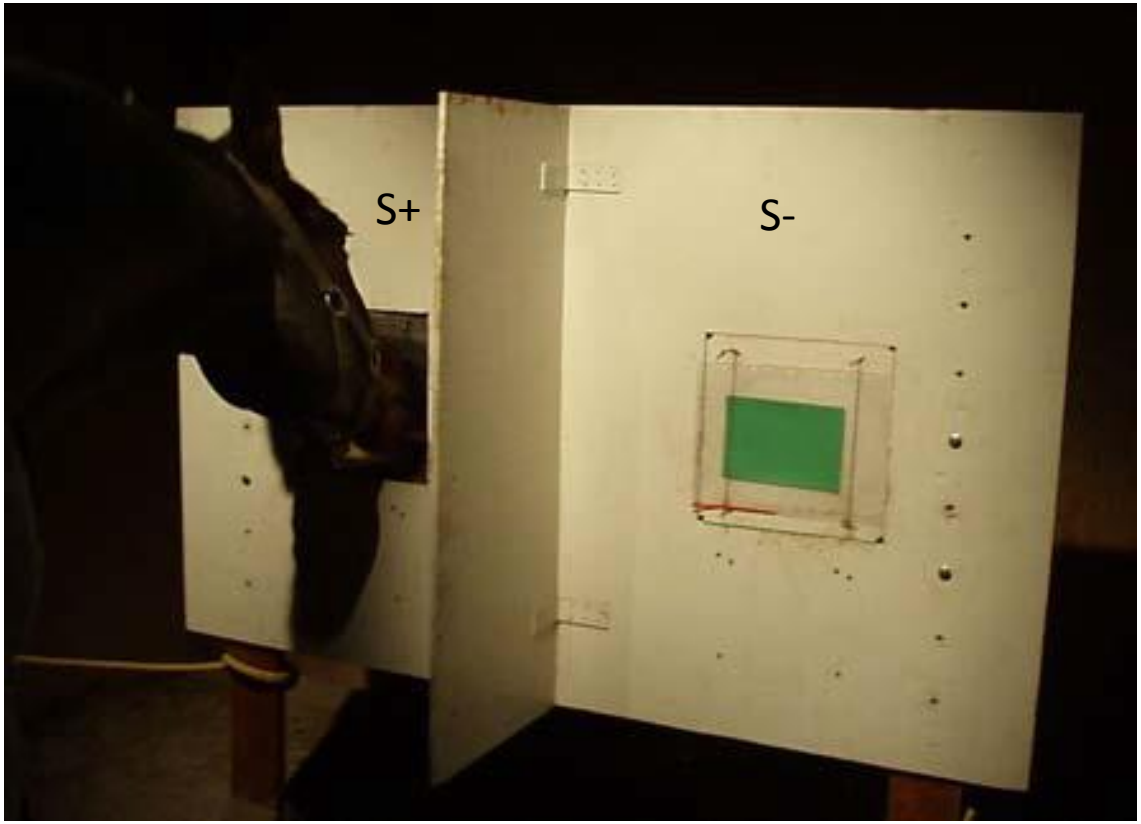


Figure 2. The dual choice apparatus wall. The door presenting the rewarding stimuli is unlocked and enables the horse to reach the pieces of carrots behind the door. Brightness controlled.

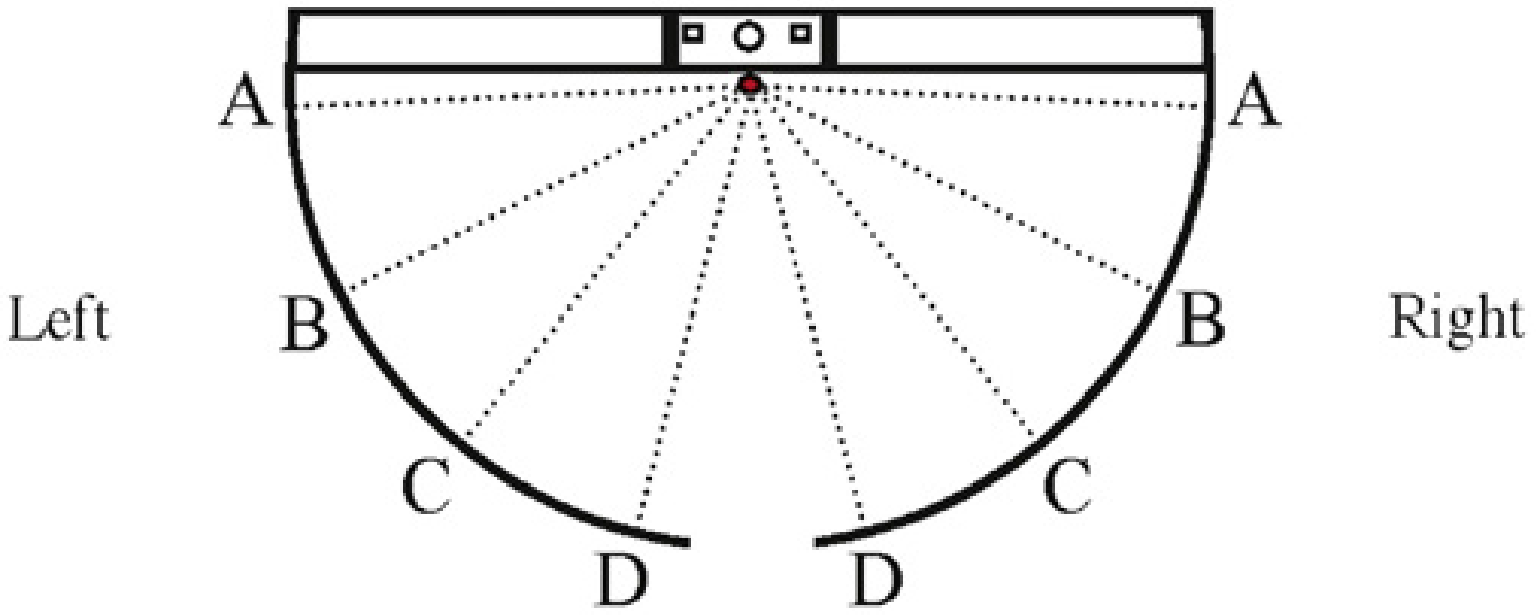
doi:10.1371/journal.pone.0003711.g002

Testing Apparatus

Positive stimulus (S+) placed in various lateral and caudolateral positions

Hanggi, et al. Behavioural Processes 91 (2012) 70– 76

Lateral & Caudolateral Vision Testing



Horses accurately discriminated between stimuli when objects appeared in positions A, B, and C for the top or bottom locations; however, they failed to discriminate these stimuli at position D. Horses were able to identify objects within most but not all of their panoramic view.

Hanggi, et al. Behavioural Processes 91 (2012) 70– 76

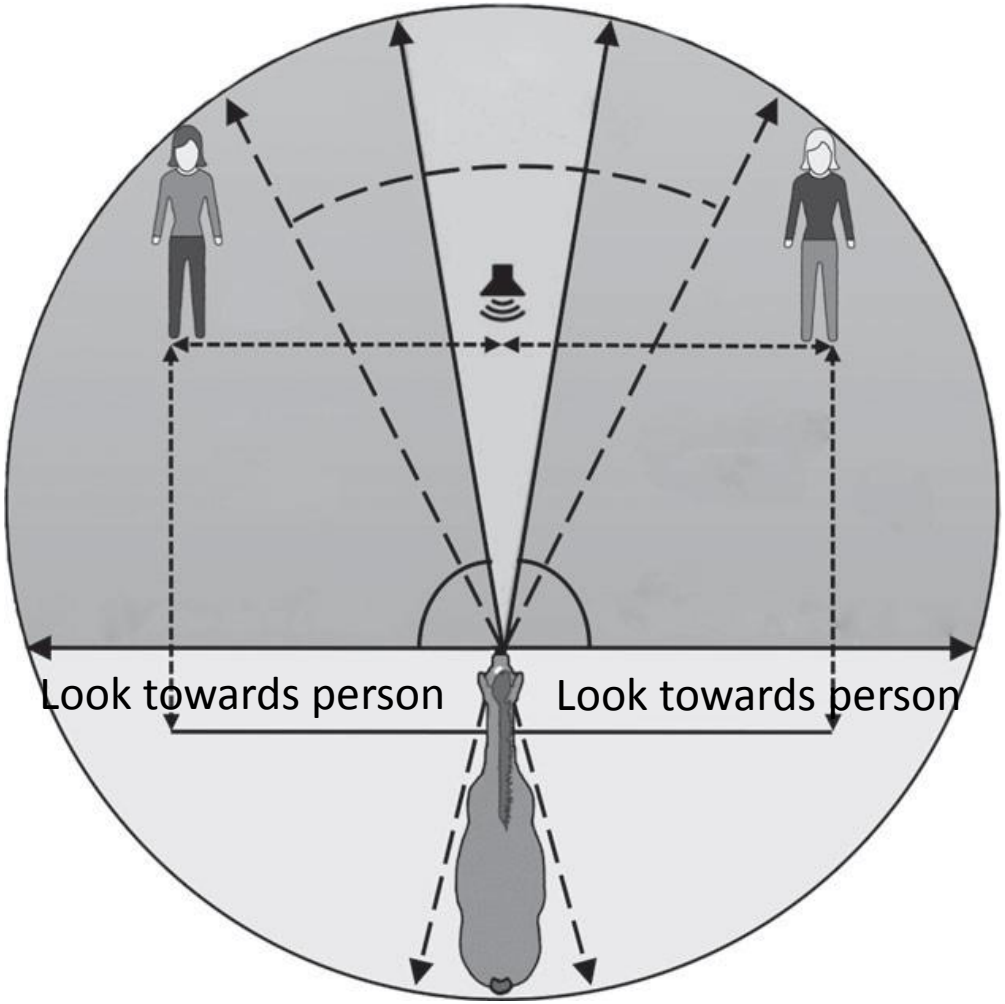
Perception (cont)

- Olfaction
- Touch
- Hearing

Hearing, Chemoreception, Tactile Sensitivity

- High frequency hearing much greater than humans
- Capacity for Chemoreception and chemical information more similar to dogs than humans
- Tactile sensitivity is high
  - In thoracic region sensitivity is greater than that of human fingertip

Cross Modal Recognition of Familiar Humans



Proops, L et al. Proc. R. Soc. B (2012) 279, 3131–3138

Recognition based on olfactory, auditory, and visual exposure

Discrimination of Human Faces

Sherril M. Stone, Anim Cogn (2010) 13:51–61

Fig. 2 a Photographs of Ahna/No Ahna, Ahna/Hay, and Ahna/Bench stimuli cards used in Experiment 1. **b** Photographs of the fraternal twins stimuli cards used in Experiment 2. Brooke on *left* and Brittany on *right*. **c** Photographs of the identical twins stimuli cards used in Experiment 2. Christi on *left* and Laura on *right*

Facial Discrimination

- Horses
  - learned to discriminate photographs of the unrelated individuals, fraternal twins, and identical twins
  - Demonstrated transfer of facial recognition by spending more time with their S+ woman in the field test

Equine Cognition: Basic Processes

- Perception, memory, learning
- Building blocks for more complex processes
  - *Learning categories and concepts (discrimination)
  - Finding one's way around in space (spatial cognition)
  - Navigating complex social networks (social cognition)

Memory

- Essential for basic learning and higher level problem solving
  - Horses have Good Short term Memory
    - Well documented in literature
  - Evidence for Long term Memory
    - 2-10 years
    - Operant conditioning and higher level learning
  - Spatial Memory
  - Prospective Memory ? (remembering to remember)

Equine Cognition: Basic Processes

- Perception, memory, learning
- Building blocks for more complex processes
  - *Learning categories and concepts (discrimination)
  - Finding one's way around in space (spatial cognition)
  - Navigating complex social networks (social cognition)

Hierarchy of learning abilities (cognition)

(Murphy J: adapted from Thomas, 1986)

Level	Description
• (1) Habituation	• (1)Learning not to respond to a repeated stimulus that has no consequences
• (2) Classical conditioning	• (2) Making reflex responses to a new stimulus that has been repeatedly paired with the original innate stimulus
• (3) Simple operant conditioning	• (3) Learning to repeat a voluntary response to obtain reinforcement
• (4) Chaining operant responses	• (4) Learning a connected sequence of operant responses to obtain reinforcement

Horses Excel Operant Conditioning

Negative Reinforcement

- Trainer or rider applies an aide or cue (leg pressure)
- Horse responds (starts to canter)
- Trainer or rider removes the aversive stimulus (removes leg pressure)

Equine Cognition: Basic Processes

- Perception, memory, learning
- Building blocks for more complex processes
  - Learning categories and concepts
  - Finding one's way around in space (spatial cognition)
  - Navigating complex social networks (social cognition)

Hierarchy of learning abilities (cont)

Level Description (cont)

- (5) Concurrent discriminations
  - (5) Learning to make an operant response to only one set of stimuli for more than one set of stimuli concurrently applied
- (6) Concept learning
  - (6) Discrimination learning based on some common characteristic shared by a number of stimuli
- (7) Conjunctive, disjunctive and conditional concepts
  - (7) Learning of concept involving a relationship between stimuli of the forms ‘A and B’, ‘A or B’, and ‘If A then B’, respectively
- (8) Biconditional concepts
  - (8) Learning of concept involving complex logical reasoning, such as ‘A if and only if B’

Discrimination Learning in Horses

- Simple discrimination tasks
- Category discrimination
  - Objects with open center or solid
- Concept Learning
  - Bigger or smaller
- Transfer of knowledge
  - Novel exemplars (objects)
  - From 2D to 3D objects

Horses Perform Simple Discrimination Tasks

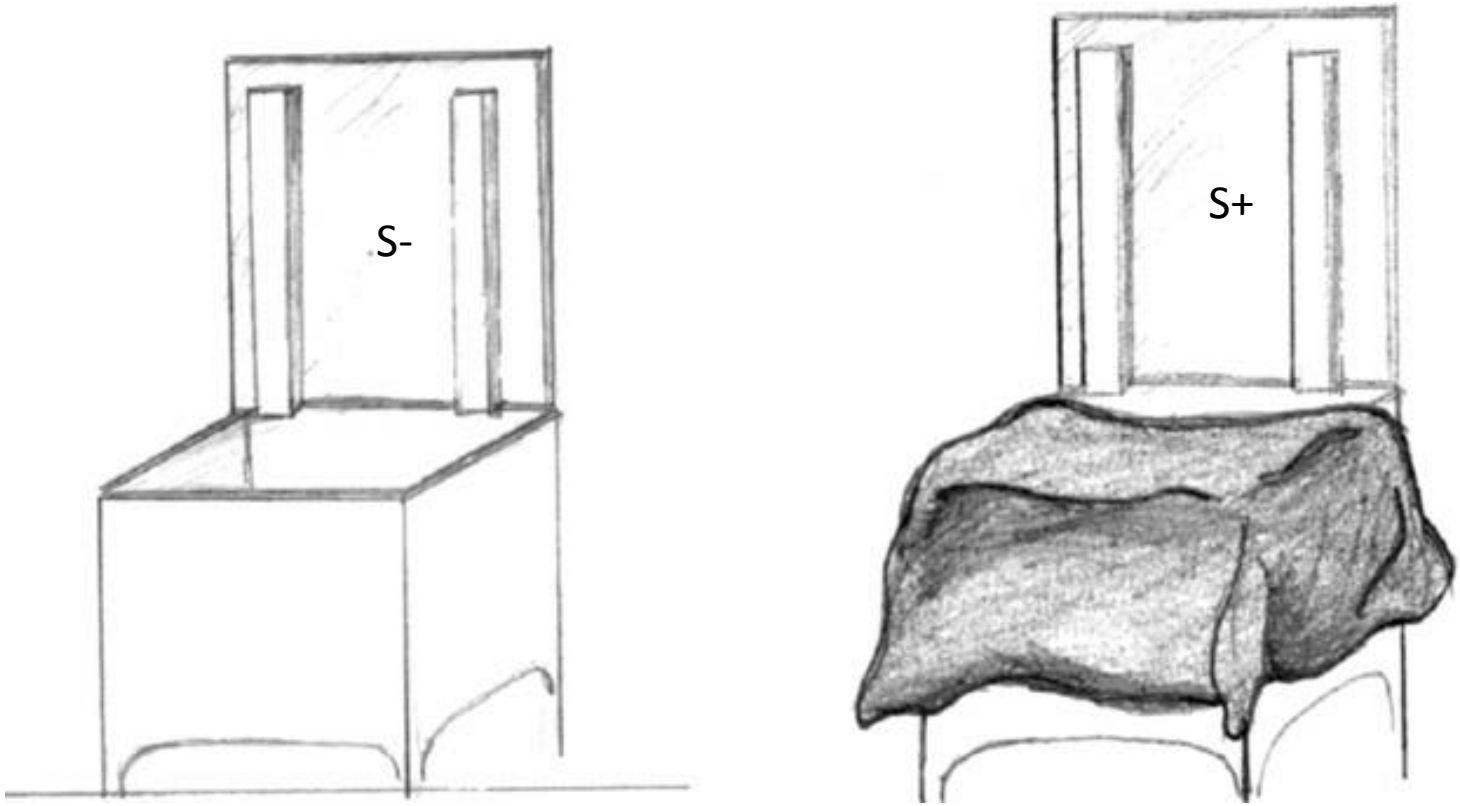


Fig. 1. An artist's impression of the Gardner feed box. From one of the earliest experimental trials for horses (from Gardner, 1937a,b).

Simple Discrimination: triangles vs circles

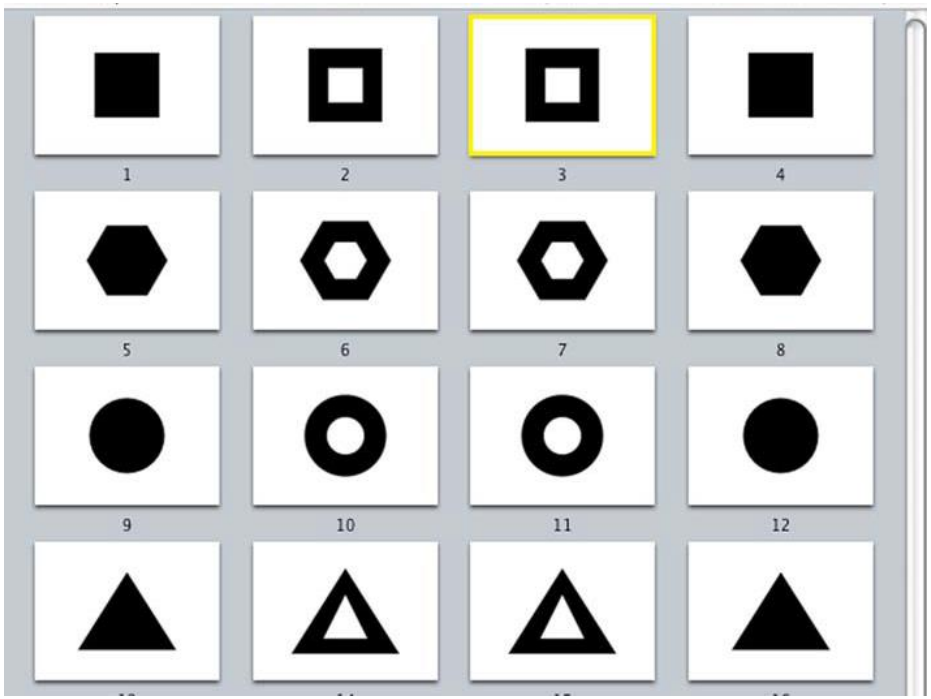
http://www.equineresearch.org/

Larger Set of Stimuli

http://www.equineresearch.org/

Category Discrimination
Higher in Complexity

- Correct category: various shapes with an open center
- Incorrect category: all solid shapes



http://www.equineresearch.org/

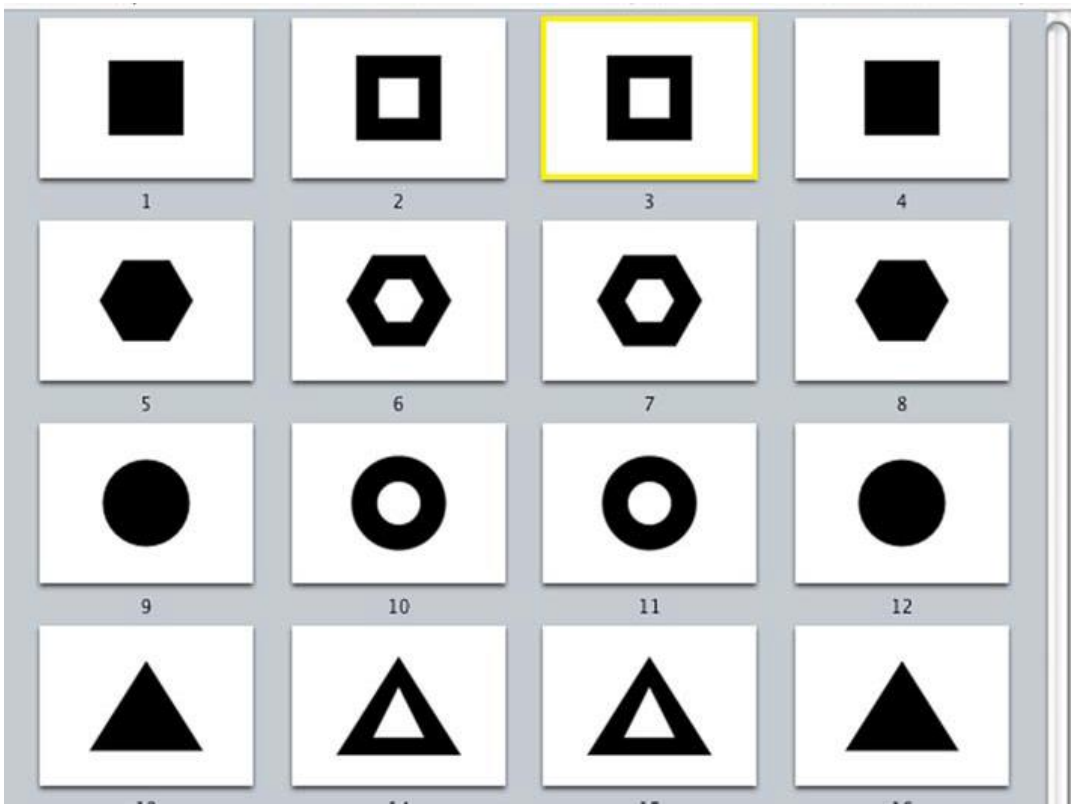
Correct Selection of Open-Center Stimulus

http://www.equineresearch.org/

Larger Set of Stimuli

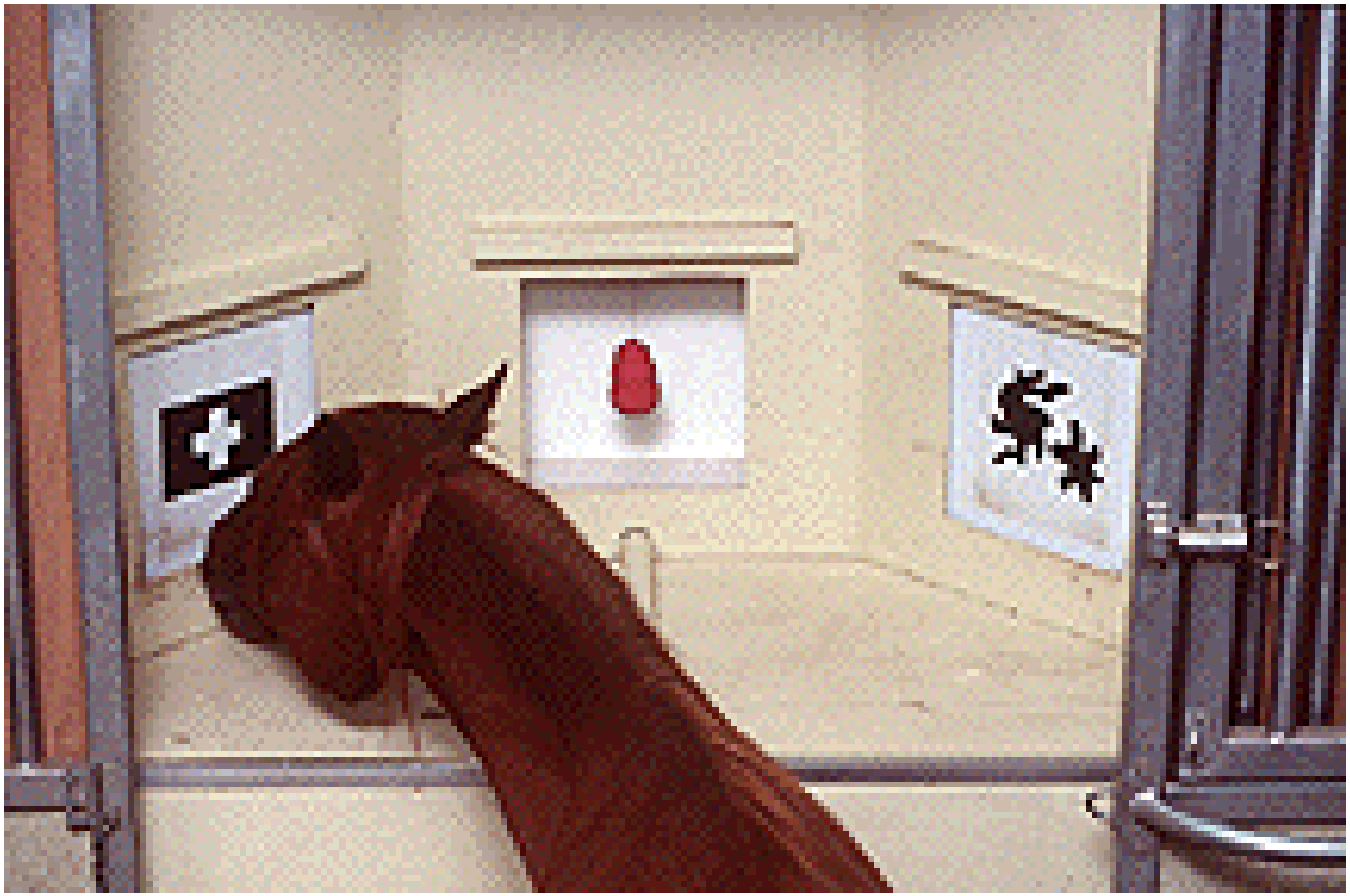
http://www.equineresearch.org/

Open Centered and Solid Stimuli



http://www.equineresearch.org/

Transfer of Learning to Novel Stimuli



http://www.equineresearch.org/

Results

- Horses are able to sort stimuli categorically
- Transfer category discrimination to novel stimuli

Concept Learning

- To determine whether horses could solve discrimination problems using relative size concepts
- To determine if the horses could generalize across dimensions
  - The study used a range of items that differed from the training stimuli (items) in dimension, material, and color in order to test the generality of the learned concept

Relative Size Concept

http://www.equineresearch.org/

Results of Concept Learning

- Horses learned to respond to the larger of 2 stimuli
- Tested for size transposition
- Transfer to novel larger and smaller stimuli
  - 3 dimensional objects

Correct Choice for relative size concept

Successful at Transposition

http://www.equineresearch.org/

Equine Cognition: Basic Processes

- Perception, memory, learning
- Building blocks for more complex processes
  - *Learning categories and concepts (discrimination)
  - Finding one's way around in space (spatial cognition)
  - Navigating complex social networks (social cognition)

Memory

- Essential for basic learning and higher level problem solving
  - Horses have Good Short term Memory
  - Evidence for Long term Memory
    - 2-10 years
    - Operant conditioning and higher level learning
  - Spatial Memory
  - Prospective Memory

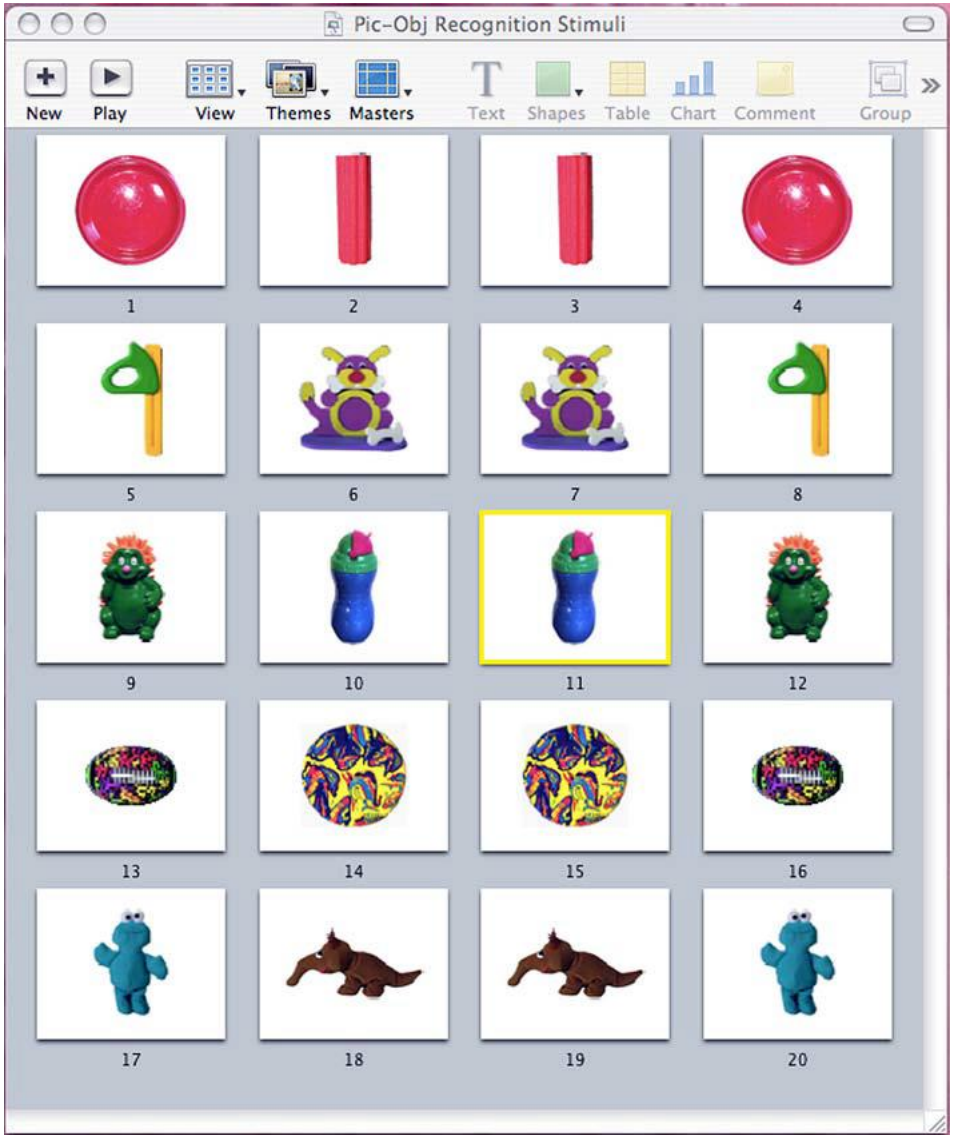
Long Term Memory (LTM)

- Purpose: to determine horses' long term memory (LTM) capabilities
  - Stimulus discrimination
  - Categorization
  - Concept usage

Experiment 1 (LTM 6 years)

- LTM for Discrimination Learning
  - derived from individual two-choice discrimination tasks
  - 5 sets of stimuli that had been learned during a picture/object recognition experiment more than 6 years earlier
  - no subsequent exposure to stimuli
- Result: no decrement in learning for 4 of 5 sets of stimuli

LTM for Discrimination Picture/Object Recognition



http://www.equineresearch.org/

Experiment 2 (LTM 10 years)

- LTM for Categorization Recall
  - correct category: various shapes with an open center
  - incorrect category: all solid shapes
  - original experiment in 1997: horses are able to sort stimuli categorically
  - no subsequent exposure to stimuli
- Results: horses immediately and consistently applied the previously learned categorization rule to familiar and novel objects after 10 years

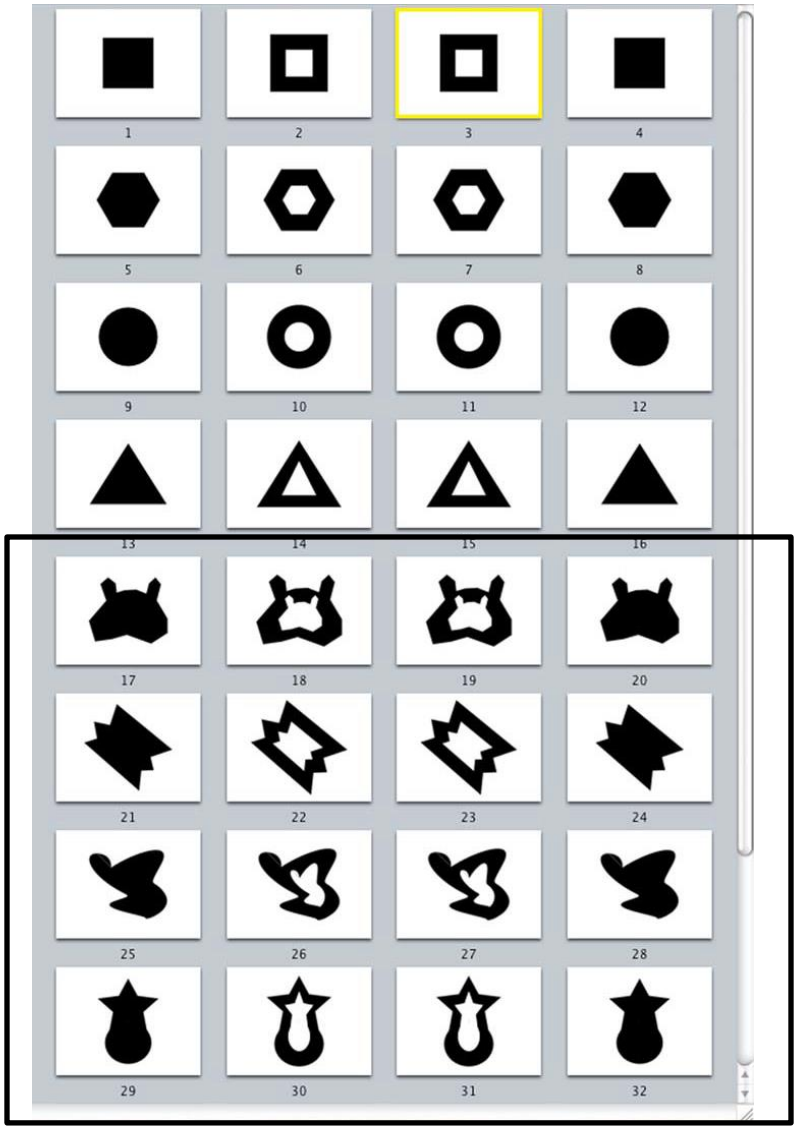
Correct Selection of Open-center Stimulus: Categorization

http://www.equineresearch.org

Open Centered and Solid Stimuli

Familiar Stimuli

Novel Stimuli



http://www.equineresearch.org/

Experiment 3 (LTM 6 years)

- LTM for Relative Size Concept
  - established size concept
  - 6 years earlier
  - No subsequent exposure to stimuli
  - Results: one horse reliably applied the size concept
    - Familiar and novel sets of stimuli

Correct Choice for relative size concept

http://www.equineresearch.org/

Conclusion: LTM

- The 6- to 10-year retention periods documented here demonstrate that memories endure for a considerable time within a horse's life span

Basic Processes

- Perception, memory, learning
- Building blocks for more complex processes
  - *Learning categories and concepts (discrimination)
  - Finding one's way around in space (spatial cognition)
  - Navigating complex social networks (social cognition)

Spatial cognition

- How do horses find their way about?
  - Elementary processes: geometric model, dead reckoning, landmark use, beacons
  - Nuerobiological studies
    - Specialized sensory information for navigation
  - Complex studies in animal way finding
  - Minimal research on Equus caballus
    - Some research on mazes and detours indicating use of spatial cues

Equine Spatial Cognition Research

- The fact that horses may be good at using spatial cues has been recognized and examined in a number of experiments examining their performance in relatively simple mazes

Social Cognition

- What do animals know about their social companions and how do they come to know it
  - Conspecifics and other species
- What and how do animals learn from each other
  - Social learning
- Social activity of communicating
  - Important in a herd environment

Equine Social Cognition

- Much research in all areas
- Much anecdotal information
- Examples
  - Observational learning of operant responses
  - Observational learning of stereotypic behavior
  - Horses and human cues
  - Recognition of herd mates
  - Recognition of humans

Conclusion

- Behavioural research has improved our understanding of how horses perceive the world
- Research provides evidence that horses are capable of higher levels of cognition beyond associative learning
  - Horses are not just stimulus – response animals
- If cognitive abilities are overrated or underrated, horses may be treated inappropriately
- Equine welfare is dependent both on physical and mental comfort

References

- Shettleworth SJ. Fundamentals of comparative cognition. Oxford University Press, New York, 2013
- Murphy J. Equine learning behavior. Behavioural Processes 76 (2007) 1-13.
- Heitor F and Vicente L.Learning about horses: what is equine learning all about? Behavioural Processes 76 (2007) 34-36
- McCall CA. Making equine learning research applicable to training procedures. Behavioural Processes 76 (2007) 27-2
- Saslow CA. Understanding the perceptual world of horses. Applied Animal Behaviour Science 78 (2002) 209-224.
- Hanggi EB. The Thinking Horses: Cognition and Perception Reviewed. AAEP Proceedings 51, 2005 246-255
- Christiensen JW. Object habituation in horses: The effect of voluntary versus negatively reinforced approach to frightening stimuli. Equine Veterinary Journal 45 (2013)298-301.
- Hausberger M, Roche H, Henry S, et al. A review of the human-horse relationship. Applied Animal Behaiour Science 109: 1-24, 2008

References (cont)

- Lansade L Coutureau E, Marchand A, et al. Dimensions of temperament modulate cue-controlled behavior: A study on Pavlovian to instrumental transfer in horses (Equus Caballus). Plos One (www.plosone.org) 8, 2013
- Goodwin D, McGreevy P, Waran N, et al. How equitation science can elucidate and refine horsemanship techniques. The Veterinary Journal 181 (2009) 5-11.
- McGreevy PD, McLean AN. Punishment in horse-training and the concept of ethical equitation. J of Veterinary Behavior (2009) 4: 193-197.
- Proops L, McComb K. Cross-modal individual recognition in domestic horses (Equus caballus) extends to familiar humans. Proc. R. Soc. B. 279: 3131-3138, 2012
- Sankey C, Richard-Yris MA, Henry S, et al. Reinforcement as a mediator of the perception of humans by horses (Equus Caballus). Anim Cogn 2010 13: 753-764
- Fox AE, Bailey SR, Hall EG, et al. Reduction of biting and chewing of horses using differential reinforcement reinforcement of other behavior. Behavioural Processes 91: 125-128, 2012

References (cont)

- Sankey C, Richard-Yris MA, Henry S, et al. Reinforcement as a mediator of the perception of humans by horses (Equus Caballus). Anim Cogn 2010 13: 753-764
- McGreevy PD, McLean AN. Roles of learning theory and ethology in equitation. Journal of Veterinary Behavior 2: 108-118, 2007
- Lampe JF, Andre J. Cross-modal recognition of human individuals in domestic horses (Equus caballus). Anim Cogn (2012) 15:623–630
- Hanggi EB, Ingersoll JF. Lateral vision in horses: A behavioral investigation. Behavioural Processes. 91 (2012) 70– 76
- Hanggi EB, Ingersoll JF. Stimulus discrimination by horses under scotopic conditions. Behavioural Processes 82 (2009) 45–50
- Hanggi EB, Ingersoll JF. Long-term memory for categories and concepts in horses (*Equus caballus*). Anim Cogn (2009) 12:451–462
- Hanggi EB, Ingersoll JF. Color Vision in Horses (*Equus caballus*): Deficiencies Identified Using a Pseudoisochromatic Plate Test. Journal of Comparative Psychology 2007, Vol. 121, No. 1, 65–72

References (cont)

- Valenchon M, Levy F, Prunier A, et al. Stress modulates instrumental learning performances in horses (Equus caballus) in interaction with temperament. Plos One ww.plosone.org 8: 2013
- McLean AN. Training the ridden animal: an ancient hall of mirrors. The Veterinary Journal 196: 133-136 (2013)
- Slater C, Dymond S. using differential reinforcement to improve equine welfare: Shaping appropriate truck loading and feet handling. Behavioural Processes. 86: 2011 329-339
- Visser EK, VanDierendonick, Ellis AD, et al. A comparison of sympathetic and conventional traiing methods on response to initial horse training. The Veterinary Journal 181 (2009) 48-52. (habituation)
- Slater C, Dymond S. Using differential reinforcement to improve equine welfare: Shaping appropriate truck loading and feet handling. Behavioural Processes. 86: 2011, 329-339
- McGreevy PD, McLean AN. Punishment in horse-training and the concept of ethical equitation. J of Veterinary Behavior (2009) 4: 193-197
- Lesimple C, Fureix C, LeScolan, et al. Housing conditions and breed are associated with emotionality and cognitive abilities in riding school horses. Applied Animal Behaviour Science 129: 92-99, 2011
- Farm Animal Welfare Council. Five freedoms. Available at www.fawc.org.uk/freedoms.htm