The Thinking Horse: Cognition and Perception Reviewed

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Cognition and perception in horses has often been misunderstood. Not only in the past but even today, people proclaim that horses react only by instinct, that they are just conditioned-response animals, that they lack advanced cognitive ability, and that they have poor visual capabilities (e.g., acuity, color vision, depth perception). Until relatively recently, there was little scientific evidence to address such beliefs. Change, however, is underway as scientific and public interest in all aspects of equine learning and perception intensifies. A review of the scientific literature, as well as practical experience, shows that horses excel at simpler forms of learning such as classical and operant conditioning, which is not surprising considering their trainability when these principles and practices are applied. Furthermore, horses have shown ease in stimulus generalization and discrimination learning. Most recently and unexpected by many, horses have solved advanced cognitive challenges involving categorization learning and some degree of concept formation. A comprehensive understanding of the cognitive and perceptual abilities of horses is necessary to ensure that this species receives proper training, handling, management, and care. Author's address: Equine Research Foundation, PO Box 1900, Aptos, CA 95001; e-mail: EquiResF@aol.com; website: www.equineresearch.org.

1. Introduction

Traditionally, horses (*Equus caballus*) have rarely been classified as intelligent, and even today, gaps in knowledge, myths and misconceptions, and limited research affect how horses are understood or misunderstood by the public, the horse industry, and even the scientific community. Common beliefs maintain that horses have a brain the size of a walnut; horses do not think; horses are merely conditioned-response animals; horses cannot generalize; horses have no sense of concept; horses are colorblind, have poor acuity and depth perception, and cannot transfer information from one eye to another.

In reality, horses manage not only ordinary daily cognitive tasks but mental challenges as well. In the wild, they must cope with food and water of inconsistent quality or unpredictable distribution, predators that change locations and habits, and a social system in which identities and roles of individuals must be discovered and remembered.[1] Domesticated horses may face even more potentially bewildering conditions. In addition to dealing with similar situations encountered in nature, many domesticated horses must live in largely unsuitable environments, must suppress instincts while learning tasks that are not natural behaviors, and must co-exist with humans who sometimes behave bizarrely, at least likely from an equine standpoint. Horses, both feral and domesticated, are faced with varied conditions that require an assortment of learning and perceptual capabilities.

NOTES

Research is gradually providing insight into the complex and fascinating nature of cognition and perception in horses. This presentation will review learning theory and key scientific studies to date on these abilities. The findings are not only interesting and useful for the education of clients but also relevant to efficient veterinary interaction with horses. Moreover, this information may be drawn upon to enhance the training and behavior modification of horses.

2. Habituation and Desensitization

Habituation is a learning process whereby, after repeated exposure at the same intensity to an inconsequential stimulus, an animal becomes accustomed and its reaction to that stimulus either diminishes or disappears. A stimulus may be anything that incites a response. Although this is an extremely simple form of learning, it is, nonetheless, extremely important because it allows an animal to subconsciously filter out nonvital information in its environment and focus instead on what is significant. From birth to old age, horses learn through habituation. In a new environment, many horses tend to be much more reactive, at first paying attention to any and all stimuli perceived by any of the senses. However, when particular stimuli turn out to be insignificant, the response diminishes.

Desensitization is a process used to extinguish a response to a stimulus in a sensitized or hypersensitized animal. For instance, a horse may become unusually fearful or sensitive to being bridled because of rough handling of its ears or the bit banging against its teeth. This leads to head shyness and the need for retraining. Such training will be more problematic because the horse will attempt to avoid the bridle; therefore, the handler will need to approach the horse's head in increments and retreat when necessary until the horse willingly accepts normal, gentle bridling. This is an example of desensitizing a horse that had become sensitized through experience, but this process also works with horses that are by nature overly sensitive.

Good trainers take advantage of these learning abilities by exposing horses in a positive manner to all sorts of sights, sounds, and contacts (Fig. 1). When done correctly, horses become habituated and desensitized, even to potentially overwhelming stressors, and are much more capable of handling novel events calmly. It is imperative, however, for trainers to understand the principles behind the practice before attempting to desensitize horses. Done incorrectly, for example, removing an alarming stimulus too soon, can have the reverse effect—the horse becomes sensitized and more fearful. Sensitization, nonetheless, cannot be overlooked, because it is the means of achieving responsiveness and lightness to riding and handling aids.

Fig. 1. This horse is being positively exposed, without restraint, to a variety of visual, auditory, olfactory, and tactile stimuli. Stimuli include a bouncing beach ball, multicolored shiny mylar balloons, a bobbling umbrella, a plastic tarp, pylons, a barrel filled with rocks dragged rapidly around the horse, and strangely behaving humans. Photo credit: Evelyn B. Hanggi.

3. Classical and Operant Conditioning and Reinforcement

Horses, like most organisms, learn effortlessly through classical or Pavlovian conditioning, which occurs when initially unimportant stimuli or events are regularly paired with stimuli that initiate some type of response. As a result, a new stimulus–response association forms in which an animal gives a response upon presentation of the original inconsequential stimulus (now the conditioned stimulus), even though the unconditioned stimulus is no longer available. Under this condition, the animal's behavior does not affect the occurrence of later events.

Horse trainers use classical conditioning regularly when they place a word onto a behavior, such as pairing the initially meaningless word "trot" with the flick of a whip (previously associated with invoking a flight response or pain) immediately before the horse changes gait during an upward transition. Done consistently, it does not take long before the horse responds with the appropriate action when given only the verbal cue.

Researchers, likewise, employ classical conditioning to facilitate their experimental methodology. Hanggi[2] uses the verbal conditioned stimulus "good" to indicate correct responding during cognition testing, thus informing the horse that a food reinforcer is forthcoming.

To many a veterinarian's dismay, horses quickly learn that the sight of a syringe is associated with pain or discomfort. The unconditioned response (escape) then occurs whenever a horse that has not been trained to accept such handling catches sight of a syringe.[3]

Stabled horses learn sounds associated with feeding, such as the opening of hay room doors or grain poured into a bucket, or recognize visual cues, such as the arrival of a feed person or vehicle. Within a short time and to the frustration of owners, they display anticipatory behaviors, e.g., vocalizing, pawing, or kicking stall doors, which, when reinforced, become conditioned behaviors.

Unlike classical conditioning, during operant conditioning, an animal manipulates its environment to obtain reinforcement—either positive (receiving something desired) or negative (removing something unpleasant). Both types strengthen the relationship between a stimulus and the sought after response, so that when the same stimulus is given again, there is an increased chance that the animal will repeat the response.[4]

When a horse begins to learn the meaning of a new stimulus, it will respond randomly, and through trial and error chance on the desired response. Reinforcement of the response at the correct moment will cause the animal to repeat the behavior, albeit imperfectly at first. Horses excel at this type of learning, especially when positive reinforcement is available. For example, when presented with an environmental enrichment device called a foodball—which dispenses pelleted feed as it rolls around on the ground—horses will approach and investigate.[5] Because of olfactory cues, they push the foodball with their noses or legs, causing it to roll and drop pellets. Most horses rapidly learn to manipulate the foodball in this manner, thereby receiving reinforcement and gaining control over this element of their environment. It is believed that such control is important with regard to animal welfare, and more attempts should be made to allow stabled horses some degree of instrumental control over their surroundings.[1]

A good understanding of positive reinforcement is very useful in working with equids. For instance, on hearing grain hitting a bucket, a horse may inadvertently kick the stall door, perhaps out of impatience. If a person then hurriedly feeds the horse (in a misguided hope of quieting it down), the kicking behavior will have been positively reinforced, and the person can quickly become a prompt for kicking the stall door. Reinforced this way, it does not take long before the horse becomes an avid ruckus raiser capable of training humans effectively.

Operant conditioning is a horse training standard, and negative reinforcement has been the primary means of shaping behaviors. Horses typically are trained to perform actions in order to avoid something aversive. For example, under saddle, they move forward when leg pressure from the rider is applied to both sides; on the ground, they yield their hindquarters when pressure is applied to a flank; they back up when pressure is applied to the bridge of the nose; and they enter a trailer to avoid pressure from ropes or whips. The judicious trainer works on refinement: taking advantage of the principles of shaping and extinction by reinforcing the correct and ignoring the incorrect, so that, over time, only the slightest pressure produces the desired action, which makes the human/horse partnership appear effortless.

As popular as negative reinforcement is within the industry, research employing avoidance conditioning in horses is limited. In one study, ponies that learned better in a positive reinforcement single-choice point maze also learned better in a shock avoidance test. This indicates that some learning abilities are similar under positive and negative reinforcement conditions.[6] In another study, some horses performed better through positive reinforcement, whereas others performed better when they were required to avoid an aversive stimulus.[7] Two other studies used sound or visual cues as signals to avoid electric shocks for the purpose of determining optimum number of conditioning sessions[8] and optimum number of trials per session.[9] In these tests, horses reached criterion in fewer trials when given only one avoidance session per week instead of two to seven, but varying the number of trials per session did not affect their learning performance. In other words, in these negative reinforcement studies, length of session was not critical, but frequency was. This may not be true for all types of training, as can be seen from anecdotal reports citing greater success with shorter sessions, especially with young horses.

Training for research purposes is predominantly based on positive reinforcement. Horses learn to respond to a wide variety of stimuli in tests ranging from simple discrimination to concept learning, and training of basic experimental procedures flows easily. The use of positive reinforcement may be restricted to rewarding correct test choices, or it may be made the most of by chaining behaviors so that the horse, in effect, works completely on its own, thereby minimizing inadvertent cueing by a handler. In many experiments, a handler leads a horse into the testing area and turns it loose so that it may make a selection[10,11]; in others, a handler leads the horse all the way up to the test apparatus where it makes a choice.[12–14] The latter runs the risk of the horse picking up unintentional signals from the handler[15] and is, therefore, open to criticism. To avoid such pitfalls, Hanggi[2,16–18] incorporates chaining (linking a number of behaviors into a series) into experiments ranging from vision testing to categorization and concept learning (Fig. 2). Horses learn to stand quietly in a "station" (a waiting area consisting of pylons with a bar spanning the front) during intertrial (Fig. 2A) and stimulus exposure (Fig. 2B) intervals, to walk forward after the bar is lowered and select a stimulus presented in one of two or more windows by touching it with its nose (Fig. 2C), to find a food reinforcer in a feeder located on the bottom of the test apparatus, to walk away from the apparatus (Fig. 2D) then halfway down the

Fig. 2. Chaining of behaviors for research purposes at the Equine Research Foundation. Horses are trained to work independently of a handler to minimize inadvertent cueing. (B and C) The relative size concept study: for this horse, "larger than" was the correct response. Photo credit: Evelyn B. Hanggi.

length of the stable breezeway where they turn around (Fig. 2E), and walk back into the station to await the next trial (Fig. 2F). Horses learn this chain within two or three training sessions and retain it indefinitely.

Practical applications of positive reinforcement have been researched with respect to the use of these principles to facilitate trailer loading behavior in horses.[19] Trailer loading the reluctant horse is a common problem and can take hours to accomplish, with hazard to both horse and human. Resistant or frightened horses rear, pull back, kick, paw, and even fall over during the ordeal: these behaviors are reinforced when owners fail to load them and give up. Traditional loading methods are based on negative reinforcement (often with a measure of punishment thrown in). Ferguson and Rosales-Ruiz[19] found that, with positive reinforcement and target training, horses learned to load willingly, improper behaviors disappeared, and these effects generalized to novel situations. Although those of us who regularly use positive reinforcement and target training—for trailer loading (Fig. 3) and unloading, lifting feet for hoof care, groundwork, standing quietly for grooming and veterinary handling, overcoming fear or resistance, and research procedures—advocate this approach, more research and public demonstrations are needed to educate horse handlers on the techniques and efficacy of these methods. Ideally, trainers and handlers should incorporate intelligent use of both positive and negative reinforcement into a well-balanced program.

4. Discrimination Learning

Discrimination learning in horses has been reported since the 1930s and is still regularly used today in an array of tests. In discrimination tasks, horses

Fig. 3. The author loading a horse into a trailer after positive reinforcement training. Traditional methods use whips, ropes, negative reinforcement, and sometimes punishment, until the reluctant horse relinquishes. Horses do learn to load under negative conditions but some can become dangerous when stressed. Horses that have learned to load through positive reinforcement do so eagerly, even with only a visual or verbal signal and even when unrestrained. Photo credit: Jerry Ingersoll.

must learn that one stimulus, and not another, will result in reinforcement. That stimulus then begins to control behavior, such that the horse acts in a specific manner in the presence of one stimulus but not the other.[20] Gardner[21] found that horses could discriminate between a feed box covered with a black cloth and boxes that were not. This simple discrimination was retained for over 1 yr. Horses showed a standard learning curve—errors decreased as number of trials increased. However, these horses did not appear to generalize when the cloth was located above or below the box. Another study showed that one horse was able to learn 20 pairs of discriminations. This horse displayed the ability of "learning to learn" by using a general solution (one pattern in each pair was always rewarded) to more easily solve subsequent tests and was able to retain 77.5% of the discriminations after 6 mo.[22] The learning to learn phenomenon has been noted in numerous other studies[2,23–25] and is a worthwhile tool in training. Too often, horses, especially show horses, are limited to performing only within a particular discipline. Thus, western pleasure horses do not jump, and dressage horses rarely set foot on a trail. This is unfortunate because such restriction keeps the horse from learning about a great variety of stimuli, which creates an animal that cannot deal with novel situations as comfortably as one involved in a broad range of activities in many different surroundings. Researchers, equine welfare advocates, and good horse trainers agree that the more positive stimulation a horse experiences the more easily it learns in new situations and the better adjusted it is in a variety of environments.

Based on speed of acquisition and the extent to which discriminations can be reversed, spatial cues (those relating to area) seem to be more discriminable than other stimulus features to horses.[26] Vigilant horse owners who have remarked on how well horses find their way around in areas that they have only visited infrequently support this claim. Horses also react noticeably when objects in their surroundings have been moved, indicating that they recognize that something has changed spatially. Nonetheless, horses are quite adept at discriminating visual stimuli: real life objects that have been tested include buckets,[11] doors,[27] toys and photographs of toys,[17] objects for everyday human use,[18] abstract stimuli include striped patterns and colors,[28] and two-dimensional black figures.[2,16,29]

5. Discrimination and Visual Perception

The ease with which horses discriminate stimuli facilitates not only cognition testing but also the measuring of perceptual abilities, which in turn aids researchers in studying equine vision. For example, in a study of depth perception, horses learned to discriminate between two patterns using random-dot stereograms—one with no form visible and another containing a square visible to individuals with stereopsis.[30] Along with other depth perception studies,[28] this experiment provided evidence that horses possessed true stereopsis. Visual acuity was also tested in this manner. Horses were trained to choose between stimuli made up of vertical black on white stripes of different widths.[12] Discrimination testing continued until the horses could no longer differentiate the stimuli: results showed that a horse's acuity is ~20/30 on the Snellen scale. This is not quite as good as that of a "standard" human (20/20) but better than dogs (20/50 or higher), cats (20/75 to 20/100), or even what the Department of Motor Vehicles requires for driving.

Color vision in horses has also been tested through the use of discrimination learning.[14,31–33] This topic of great interest has yet to be satisfactorily resolved. Some studies showed that horses could discriminate red and blue from gray, whereas others showed that they could discriminate not only these colors but green and yellow as well. However, confounding factors, such as brightness, may have played a role to the degree that horses learned to discriminate based not on color but on another stimulus characteristic. Research recently completed by Hanggi and Waggoner[a] confirmed that horses are color-deficient compared to humans with trichromatic vision. Using discrimination tests, they showed that horses respond to color vision testing in the same manner as some red/green color-deficient humans.

A myth that has surfaced repeatedly is that horses cannot recognize with one eye what they have seen only with the other eye. This notion is used to explain why horses startle at the same object when viewed from different directions (such as when riding out and then coming back on a trail or reversing directions in an arena). Anatomical examina-

Fig. 4. This Equine Research Foundation horse, while blindfolded on the right eye, learned that the plus stimulus was correct. Evidence of interocular transfer (IOT) was shown when, after the blindfold was switched to the other eye, it again correctly chose the plus. IOT was maintained regardless of stimulus shapes, their location, or which eye was blindfolded first. Photo credit: Evelyn B. Hanggi.

tion has confirmed that the horse's cerebral hemispheres do have a functional pathway for the conveyance of information (belief contrary to this was another misconception), and a behavioral study showed that they do indeed have sufficient interocular transfer.[16] This study once again used multiple two-choice discrimination tests in which horses were trained to respond to one stimulus and not another while blindfolded over one eye (Fig. 4). Once the discrimination was learned, the blindfold was switched to the other eye. Horses immediately responded to the same stimulus, clearly indicating interocular transfer.

Discrimination learning was also used to further study why horses startle at objects they had apparently already seen. One intriguing hypothesis holds that it is not a matter of recognizing the same object during a return trip but more a matter of the object appearing different from another perspective. As mentioned earlier, horses perform very well on spatial discrimination tasks, and anecdotal evidence is vast with reference to horses noticing when objects in their surroundings have been relocated. Therefore, it is possible that horses do not always realize that an object is the same one when viewed from alternate angles. Using children's toys and a two-choice discrimination paradigm, Hanggi[b] initially trained horses to choose one of two objects, with the front of both always positioned to the left. Once the discrimination was learned, the objects were rotated front to right, front forward, front backward, upside down, etc. The horses accurately chose objects presented in certain rotations but failed with others, indicating that recognition of rotated stimuli is good under some but not all conditions.

6. Generalization

Under stimulus generalization, a behavior previously conditioned to one stimulus transfers to other similar stimuli. This adaptive trait permits an animal to form associations with a wide range of stimulus features rather than with only one element. Under generalization testing, gradients (a series of measured changes) are acquired that show how directly behavior is controlled by a given stimulus. Responding is highest to the training stimulus (which predicts reinforcement) yet still occurs, but to a lesser degree, in the presence of stimuli possessing certain features of the original stimulus.

Horses tested for stimulus generalization using circles showed symmetrical gradients: this is contrary to gradients found in pigeons where generalization tended toward the larger stimuli.[34] Generalization in horses was also examined using tactile stimuli—repetitive tapping by solenoids along the horse's back—with results showing that behavior was effectively controlled by the training stimulus.[35] Horses responded most often to the training stimulus with behavior decreasing as the stimuli were moved farther away from the original location.

Lesson horses draw on generalization regularly, understanding the assorted and inexact hand, leg, and seat cues from numerous riders of unequal skill and ability. On the other hand, generalization is discouraged in dressage horses, which must discriminate highly precise cues from their riders.

Many horses could benefit from opportunities for generalization. As mentioned earlier, horses in specific riding disciplines are frequently not allowed to participate in activities other than what interests their riders. As a result, they go through mechanical motions that rarely enhance any cognitive skill. Evidence of this can be seen in a recent study that showed that, compared with horses involved in other disciplines, high-level dressage horses displayed the lowest level of learning performance in simple tests.[36] It was hypothesized that because these horses are trained to perform highly sophisticated, precise behaviors, riders give them minimal freedom; therefore, they are inhibited from learning to learn or generalizing.

Horse trainers, from backyard to professional, can enhance their horses' generalization abilities by incorporating variety into their programs, both from the ground and in the saddle. This type of training helps keep interest up, aids the horse when it comes across something new, and also gives human and horse an alternative to riding, especially during inclement weather when horses are otherwise left to their own devices in stalls (Fig. 5).

7. Observational Learning

Horses are social animals most comfortable in the company of other horses (Fig. 6). For many animals, social interactions can facilitate the learning of new behaviors. Thus, it would not be unusual for horses to learn by observing others, and in

Fig. 5. Nonriding activities can include generalization training, which teaches the horse to accept unusual and sometimes alarming, stimuli in a relaxed manner. Photo credit: Jerry Ingersoll.

fact, many horse owners believe this to be true. McGreevy et al.[37] reported that 72% of >1000 owners thought that abnormal behaviors were learned by observation. Abnormal or stereotypic behaviors, including cribbing, weaving, head bobbing, pacing, and self-mutilation, are most often exhibited by stabled horses. Unfortunately, owners mistakenly assume that when groups of horses display the same stereotypies it is because they have learned by observing one another. This leads to the detrimental act of removing a horse from any social contact. In reality, the appearance of stereotypies in horses living near each other is more likely caused by genetic relatedness or to the stress of existing in the same, inappropriate environment.

To date, there is no research supporting observational learning in horses. Horses that observed demonstrator conspecifics solve discrimination tasks between buckets showed no sign of superior learning over controls.[25,38] Discrimination learning tests under more rigorous conditions showed similar negative findings, but observer horses did approach goal areas more rapidly—leading to the assumption that some learning had occurred.[39] Observational learning also did not seem to assist acquisition of a foot-press response.[40] Nevertheless, it is difficult to accept that horses cannot learn by observation in any situation. More likely, the proper experimental procedure has yet to be developed. Perhaps a design more suited to the nature of the horse might better reveal the extent of observational learning in horses.

Fig. 6. Being social animals, horses depend on conspecifics for safety and companionship. This is true for domesticated horses as well as these free-roaming Mustangs in Nevada. Photo credit: Evelyn B. Hanggi.

8. Categorization and Concept Learning

Many horse people believe, some even vehemently argue, that the learning abilities of horses do not go beyond the scope of associative learning and memory. Although a large amount of cognitive behavior can be explained by these mechanisms, it is critical for the well being of horses to study whether they possess more advanced learning abilities. If the cognitive abilities of horses are misunderstood, underrated, or overrated, their treatment may also be inappropriate. Equine welfare is dependent on not only physical comfort but mental comfort as well. Confining a thinking animal in a dark, dusty stable with little or no social interaction and no mental stimulation is as harmful as providing inadequate nutrition or using abusive training methods. Therefore, it is in the interest of both horses and humans to understand more fully the scope of equine thinking.

In comparison with the cognition work with other animals, little research into advanced equine learning has been completed, which is astounding considering the importance of horses to humans. Fortunately, this is now changing as researchers design experiments that center on more complex cognitive skills. For example, the ability to categorize provides the basis for substantial higher cognitive function.[41] Categorization through the identification of similar physical characteristics may involve stimulus generalization. Nicol[1] noted that this should be functionally valuable because it would allow animals to acquire broad categories (food, predator, surroundings) and react quickly in novel or unpredictable situations. For example, endurance racehorses are confronted with a great diversity of stimuli during their training and competition. Rather than having to learn about each object or event separately, they may make instant classifications of new stimuli and adjust their movements accordingly. Developing techniques to incorporate categorization learning into everyday training would undoubtedly be beneficial and would give trainers another practical tool to use.

Categorization learning in horses has been examined in only a handful of studies. Using two-dimensional triangles, Sappington and Goldman[29] found that horses could discriminate triangles from other shapes; however, they were not able to provide con-

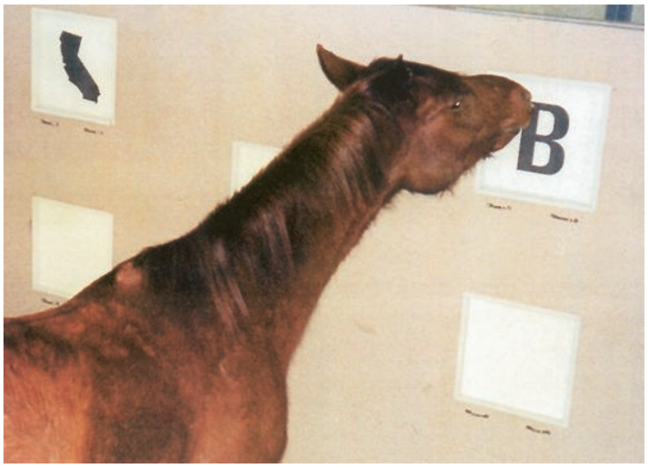

Fig. 7. This horse is making the correct choice in an Equine Research Foundation categorization study. Stimuli were either open-centered or solid two-dimensional black figures of various geometric shapes, letters, or icons of U.S. states, people, or plants. Photo credit: Evelyn B. Hanggi.

clusive evidence of categorization with novel triangles. Therefore, it is possible that the horses responded correctly because of associative learning processes.[1] The ability to categorize was more evident in a study by Hanggi,[2] in which horses were trained to discriminate between two-dimensional black figures with open centers and solid black figures (Fig. 7). Horses learned the initial discriminations by operant conditioning but then acquired subsequent discriminations with fewer errors, indicating that they had learned to learn. Evidence of the formation of a category came with the introduction of novel stimuli. Horses immediately chose the open-center stimuli in most instances, which would have been at chance levels had they been functioning only by associative learning.

Interestingly, under certain circumstances, horses have difficulty transferring learned stimuli to new tasks.[42] In one case, horses failed to use familiar stimuli (a striped board or white bucket previously used as cues for lever pressing) to solve a novel, unrelated task (maze). This may have been because of experimental design and insufficient generalization training before the start of the experiment or this specific type of transfer may indeed be difficult for horses in general. Further study is needed before conclusions can be reached regarding this detail of equine learning.

Another topic barely discussed with respect to horses, except from a negative perspective, is concept formation. Unlike categorization, where stimuli resemble one another physically, conceptualization involves responding to certain stimuli because they represent the same idea, regardless of whether they physically resemble one another.

Concept learning may involve either absolute or relational concepts, with the latter divided into (1) a complex level of conditional relations or relations between relations or (2) a more simple level of understanding relative class concepts[43] (e.g., bigger, darker). This second level, although less complicated, is still an effective measure of cognitive ability, because as Pepperberg and Brezinsky,[43] when paraphrasing Thomas,[44] state:

> Responding on a relative basis requires a subject to compare stimulus choices and then derive and use an underlying, more abstract (and thus general) concept: in contrast, learning an absolute stimulus value requires only that a subject form a single association (p. 286).

In a discussion of concept learning in horses, Nicol[1] points out that even though Sappington and Goldman[29] refer to concept formation in their horses, what they actually tested was categorization learning. Likewise, Flannery's horses,[13] in an identity match-to-sample (sample and correct response stimulus look identical) attempt, were not tested using novel, unrewarded stimuli; therefore, her findings can be explained by conventional associative learning.

Hanggi[18] studied the ability of horses to form concepts based on relative size (larger than, smaller than). After learning to respond to the larger of two stimuli for six sets of two-dimensional training exemplars, two horses were tested for size transposition that used novel larger and smaller stimuli as well as three-dimensional objects (sizes: large, medium, small, tiny; Fig. 2). Horses chose the larger of two (or more) stimuli, regardless of novelty or dimension. A second phase of this study tested "smaller than" and produced the same results, that is, the horse selected the smaller stimuli based on relative size. Moreover, the horses generalized across situations that varied from black two-dimensional shapes to three-dimensional objects of different materials and colors, including yellow foam balls, green plastic flowerpots, and red PVC connectors. All horses responded as if they had developed a concept of relative size, marking this study as the first to provide evidence of relative class concept formation in equids.

This is not to say that horses possess the same conceptualization abilities as humans, nonhuman primates, or other so-called advanced species, but it is an indication that they possess more cognitive ability than what was known. Much more focus should be placed on these types of abilities, not just to satisfy scientific curiosity but also for practical purposes. As with the application of categorization learning and generalization ability to training procedures, simple concept learning may be applied to training and handling. Equine welfare with respect to care and management may also benefit when more is discovered about abstract concept formation. It has been suggested that, if horses do not have a concept of "sameness," we cannot expect them to instantly accept new situations that are, to us, just the same as previous ones. For example, humans classify all horse trailers as the same because of their function and so might expect horses to readily enter any type after they have been trained with just one.[1] According to Nicol,[1] horses may not possess such a shared functional concept and will have to learn to enter each type individually. This idea has merit in that it should make handlers consider the environment more from the horse's point of view. However, at least in the trailer example, there is more to the issue than concept capability.

In many instances, horses refuse to enter trailers because of poor training, negative experiences, or lack of opportunity to generalize. Horses that have been properly exposed to myriad stimuli ranging from stables to loafing sheds, one-horse trailers to stock trailers, crowded places to wide-open spaces, and chaotic traffic to quiet countryside are remarkably adaptable in novel situations. On the other hand, horses cloistered in isolated stalls and only brought out for repetitive training are apt to react adversely when novelty arises, and many tend toward nervousness, flightiness, and neurotic behavior. Perhaps it is not a matter of possessing a cognitive ability or not, rather it is a function of upbringing, training, and opportunity to learn.

9. More Than the Sum of the Parts

As is generally the case in research, only particular aspects of an organism are studied. This occurrence arises from the interests of the researcher or some other entity and is not, in itself, a problem unless the item of interest overshadows everything else. Take, for example, the attention given to equine color vision and visual acuity. Substantial effort has been made to discern what and how the equine eye sees. This is admirable, that is, until assertions are made regarding equine behavior that may or may not have anything to do with vision. For example, in one case, a small group of vision researchers claimed that a racehorse crashed into a green fence because of the color, which according to their research could not be seen by horses. However, when horses were observed behaving naturally, as well as under test conditions, they easily avoided green objects even while moving at high speed.[c] This led Hanggi[c] to further test this phenomenon by placing green objects of various shapes and sizes against a similarly colored green background (a plastic tarp) set against green trees and observing whether the horses could locate them. A horse was stationed 18 feet from the background and then allowed to walk forward and make contact with the object with a nose-touch. The horse had no difficulty noticing the stimuli, regardless of their location on the background. Most notably, it could still find an object that was only $1 \times 2 \times 5/8$ in and covered with the same material as the background. This simple test showed that, even though horses may not pass certain color vision tests, they still have the capability of seeing colored objects in their environment, even when those objects are nearly camouflaged and even under conditions when their reported visual acuity would not suffice. Rather than considering the whole horse, the vision researchers made judgments based on only a few features and consequently came to the wrong conclusion. When all details of the accident were examined, it seemed much more likely that the horse crashed into the fence because of a combination of equine behavior and rider error.

10. Conclusion

In the not too distant past, little consideration was given as to why horses behaved as they did or what possibilities existed to ensure adequate care and welfare. However, during the past decade, an explosion of sorts has occurred within the horse industry. Scientific conferences, research articles, horse expositions, clinics, the Internet, television, magazines, books, videos, and worldwide tours have served the public by making available educational prospects never before seen on such a large scale. From skilled horse handlers to wide-eyed novices, everyone has the opportunity to advance their knowledge about equine cognition, behavior, training, and care. Unfortunately, as is human nature, some equine authorities take advantage of those eager for information, creating a persona of near thaumaturgy. It is up to the individual to differentiate between the sincere and the artificial, to search for truth among unsubstantiated declaration, and to become an eclectic in the world of horses.

Research into equine cognition and perception has made noteworthy advances, and greater interest is now being paid to the improvement of training methodology and management. Nonetheless, much more still needs to be learned before scientists and laypersons alike can make unequivocal claims as to what it is to be a horse. Studies combining equine learning, perception, and behavior are the next step in understanding this remarkable animal.

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