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Preference of domestic horses for shade in a hot, sunny environment[1]

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ABSTRACT: Provision of shade is recommended by best practice guidelines for horses living in hot, sunny environments despite a lack of research focused on potential benefits. We found in a previous study that horses without access to shade showed greater rectal temperature (RT), respiration rate (RR), and skin temperature (SK) and exhibited more sweat than horses that were completely shaded. Yet not known is whether horses will choose to stand in the shade when given a choice of areas with and without this resource. Our objective was to assess horse preference for shaded and unshaded areas in the hot and arid, sunny summer weather in Davis, California. For this preference test, 12 healthy, adult horses (6 mares, 6 geldings) were randomized into 3 sequential trials using 4 horses in each trial. The trials consisted of 2 d of acclimation and either 5 d (Trial 1) or 7 d (Trials 2 and 3) of observation. Horses were housed individually in dry lot pens. Half of each pen was covered by an open-sided shade structure. The amount of the pen shaded varied slightly throughout the day with a mean of 50.1% of the pen shaded. Physiological measurements (RT, RR, SK, sweat score) were recorded at 0900, 1230, and 1800 h. Behavioral observations (horses' location relative to shade, time spent walking, foraging, and standing) were recorded at 5-min intervals from 1300 to 1800 h daily and at 10-min intervals from 1800 to 1300 h on alternate days. Insect avoidance behavior was recorded for 1 min/h for each horse. Weather factors were recorded every 5 min, 24 h/d throughout the study; mean daytime ambient temperature was 29°C ± 5°C. Data were analyzed using PROC MIXED in SAS. Horses were located in the shade in 7.1% more observations than by chance (SE = 1.3, $P < 0.001$), with greatest use before and during peak solar radiation and then again following peak black globe temperature. Horses performed more walking and foraging behavior in the shaded areas ($P < 0.01$). Our research indicates that individually housed horses prefer shade when it is available in hot, sunny environments. These results support recommendations for access to shade when developing best practice guidelines for the care of domestic horses.

Key words: environmental temperature, horses, housing, preference, shade, welfare

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INTRODUCTION

Provision of shade for domestic horses is recommended by numerous standards of care programs for horses managed by research and teaching institutions as well as those in agriculture, recreation, and sport (Houpt and Ogilvie-Graham, 2002; Federation of Animal Science Societies [**FASS**], 2010). These recommendations are based, in part, on considerable evidence that shade prevents the deleterious effects of heat stress on health and production measures in other domestic livestock (West, 2003; Tucker et al., 2008; Marcillac-Embertson et al., 2009; Schütz et al., 2010). In addition, some studies of equine social behavior reported observations of horses using shade in summer (Stebbins, 1974; Pratt et al., 1986; Crowell-Davis, 1994; Heleski and Murtazashvili, 2010), whereas using shade was believed to be secondary to avoiding biting insects by others (Keiper and Berger, 1982).

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However, until recently, there have been no studies directly evaluating the effects of shade on horses. In a previous study (Holcomb et al., 2013), individually housed horses without access to shade in a hot, sunny environment showed greater rectal and skin temperatures and respiration rates than completely shaded horses. Although this provides evidence that horses benefit from shade, a focused preference test is required to evaluate whether or not they will take advantage of this resource when use is optional. Preference tests can be used to evaluate the choices animals make between resources (Kirkden and Pajor, 2006) and have been used to assess shade use by dairy cows (Schütz et al., 2009). The specific objectives of this study were to quantify the preference for shade use by individually housed horses in a hot, sunny environment, to measure their physiological and behavioral responses, and to evaluate use of the shade structure independent from the presence of the sun. We hypothesized that horses would show a preference for shade, especially during the daily maximum perceived temperature as estimated by a black globe thermometer.

MATERIALS AND METHODS

Animals and Design

This study was performed at the Department of Animal Science beef cattle research facility located at the University of California, Davis, from August 9 to September 2, 2011. Approval was obtained from the University's Investigational Animal Care and Use Committee (protocol 16034). Twelve healthy horses (6 mares, 6 geldings) from the UC Davis School of Veterinary Medicine's Center for Equine Health were randomized into trials for this study. All horses had previous experience with shade structures in both individual pens and as small groups in dry lots. Five of the horses were Thoroughbreds, and 7 were Quarter Horses. The mean age was 11.4 yr (SD = 3.4 yr), mean BW was 573 kg (SD = 53 kg), and mean body condition score was 6.1 (SD = 1.3) on a 9-point scale (1 = extremely thin, 9 = extremely fat, Henneke, 1985). All horses were trained to be handled easily for research and teaching activities, including haltering and leading, blood sampling, and trailering.

The study was a preference test offering individually housed horses unrestricted access within pens that had approximately equally sized shaded and unshaded areas. There were 4 pens per trial with 3 consecutive trials. A 2-d acclimation period (d -1 and 0) was followed by 5 consecutive days of observation and data collection for Trial 1 (d 1–5) and 7 d for Trials 2 and 3 (d 1–7; Fig. 1). The additional days in Trials 2 and 3 were included to take advantage of predicted high ambient temperatures.

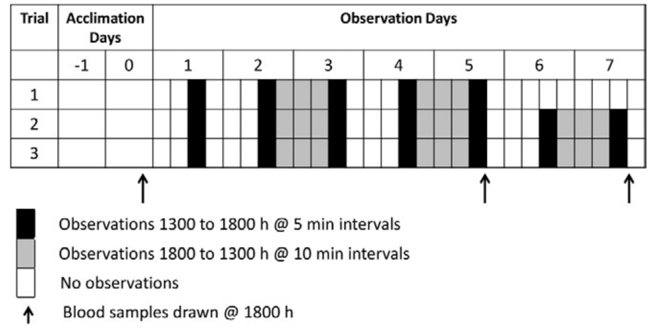

Figure 1. Study schedule showing acclimation period, observation days, observation times, and schedule of blood sampling for one 5-d and two 7-d trials

Four pens (6.1 × 12.2 m) were constructed using 6-rail pipe livestock fencing panels such that an existing open-sided shade structure covered the southern 6.1 × 6.1 m of each pen, leaving the northern 6.1 × 6.1 m exposed to the sun during daylight hours (Fig. 2). The structure consisted of a corrugated metal, shed-style roof with its long axis oriented east to west. The roof was 3.9 m above ground at the highest point (north) and 3.3 m at the lowest point (south), with a slope of 8.7%. Pens were separated from each other by a 6.1-m buffer zone to allow visual and auditory communication but no physical contact between horses. The flooring in all pens was a loose dirt surface, and no bedding was provided. Horses were randomized into pens within trials. Trials were balanced by sex, with 2 mares and 2 geldings in each trial. The 2 breeds were not available in equal numbers (5 Thoroughbreds, 7 Quarter Horses), and thus, trials were not balanced by breed. Cattle housed at the site were a minimum distance of 15.2 m from the study pens. No other horses or other livestock species were housed at the research facility.

Water and hay were provided in equal amounts in both the shaded and unshaded areas of the pen to prevent the location of water and feed from being a factor influencing where horses spent time. Water was provided from 16-L buckets on the west side of pens. Two buckets were secured to the fence in the shaded area and 2 in the unshaded area. Horses were fed alfalfa hay (dry matter 93.7%; CP 20.2%) at 1.75% of their body weight daily at 0800 and 1830 h. Hay was weighed and divided into 2 equal portions that were then simultaneously dropped into the east side of horses' pens directly opposite the water buckets, so that half was provided in the shaded area and half in the unshaded area of the pen. Daily water consumption was calculated by measuring centimeters of water remaining in each bucket at 0900, 1200, and 1830 h and converting to liters of water consumed using a regression equation. A trace-mineralized salt block was available in each pen and placed on the ground near the center of the east fence line where horses could have access whether in shade or sun. Pens were cleaned of manure and any remaining feed daily at 1130 h.

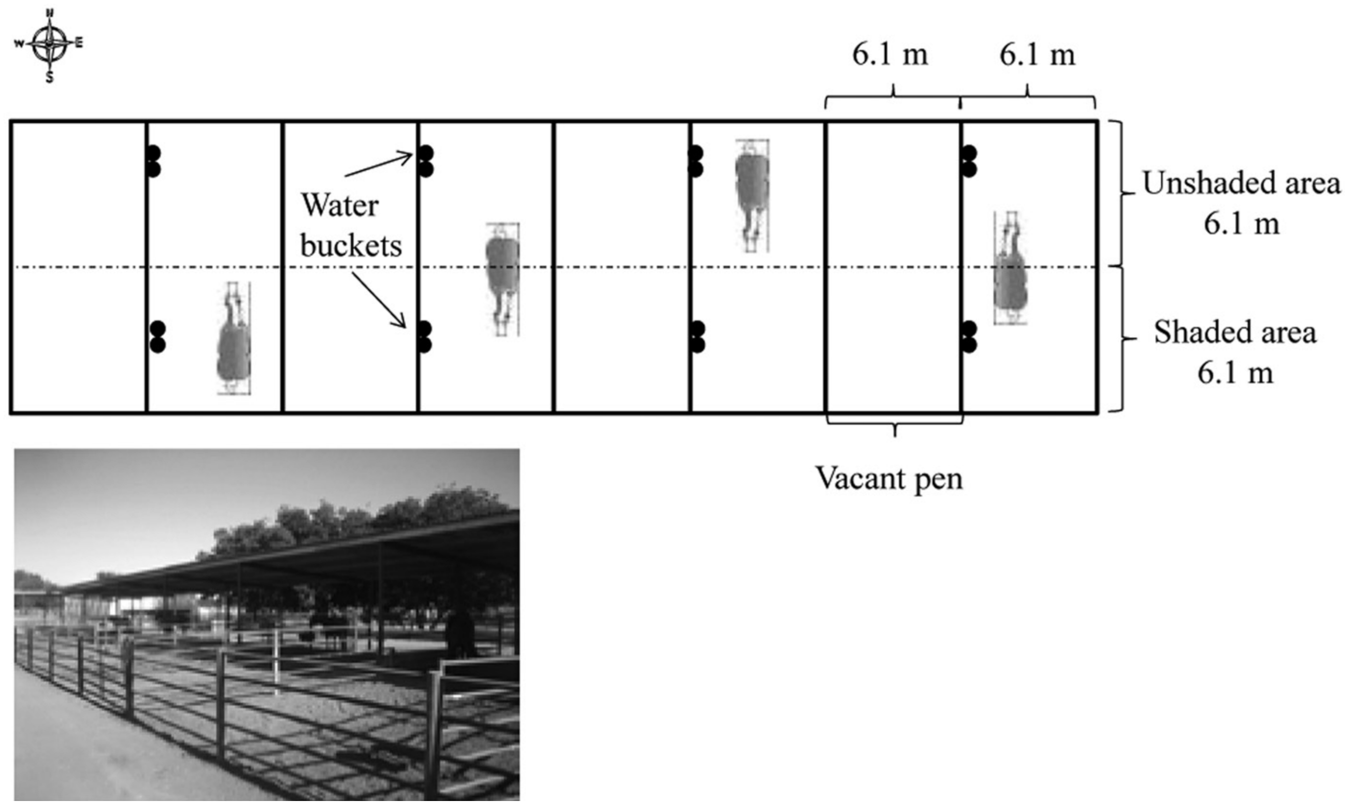

Figure 2. Layout and photograph of study site showing pens with approximate dimensions of shaded and unshaded areas, vacant pens separating horses, and location of water buckets

Data Collection

Ambient temperature (**T_{amb}**), relative humidity (**RH**), black globe temperature (**T_{BGT}**), and solar radiation were recorded at 5-min intervals for 24 h/d during all trials using sensors with automated data loggers as described previously (Holcomb et al., 2013). Surface soil temperature (**T_{soil}**) was measured hourly from 1300 to 1700 h using a handheld infrared thermometer (Raytek MT6, Raytek, Santa Cruz, CA) at 2 locations each in the shaded and unshaded areas. Wind speed was measured hourly from 1300 to 1700 h using a handheld anemometer (Speedtech Instruments SM-18 SkyMate Wind Meter, Weathershack.com, Roanoke, VA) at a standard location in front of each pen. Because of technical difficulties, wind speed was not recorded on d 1–4 of Trial 1. To supplement our data, wind speed was also obtained from the California Irrigation Management Information System (2011) for a local weather station.

The percentage of shaded and unshaded areas available to horses varied slightly throughout the day with movement of the sun. To facilitate quantification, tape was placed at 0.3 m intervals on a fence rail of 1 short and 1 long side in Pens 1 and 4. The length and width of the shaded area in these pens were recorded at 30-min intervals from 0900 to 1900 h on d 1 of the first trial. The measurements were confirmed by observation during the second and third trials. The average percentage of the pen that was shaded at each hour was used for analysis.

Behavioral measures consisted of real-time observations using 2 methods of sampling according to criteria in Table 1. Instantaneous scan samples were recorded at 5-min intervals from 1300 to 1800 h daily (Martin and Bateson, 2007). In addition, observations were recorded at 10-min intervals from 1800 to 1300 h beginning on d 2, 4 (Trials 1–3), and 6 (Trials 2 and 3; Fig. 1). These additional observations provided 24-h data to examine possible behavior patterns unrelated to solar radiation or ambient temperature (e.g., horses showing a preference for standing underneath the structure regardless of temperature or time of day). In addition to the behaviors of foraging, locomotion, standing near or away from water buckets, drinking, and recumbency, each horse's position relative to the shade and shade structure was recorded in 2 ways: the number of hooves in shade cast by the shade structure and the number of hooves directly beneath the shade structure as physically defined by the corner support posts. Data were calculated for each horse as the percentage of observations in which the behavior was recorded during each observation hour.

Insect avoidance behavior was recorded using focal sampling for 1 min/h for each horse between 1300 and 1800 h on each observation day (Martin and Bateson, 2007), using the criteria in Table 1. For analysis, these

Table 1. Description of criteria for recording behavioral data using instantaneous scan sampling for various behaviors and focal sampling for insect avoidance behaviors[1]

Behavior	Definition
Instantaneous scan sampling	
Stand away from water	Upright posture with no forward motion, at least one-half horse length away from water bucket and performing none of the other behaviors
Stand near water	Within one-half horse length of water bucket, muzzle not in bucket
Drink water	Muzzle within and below top rim of water bucket
Forage	Muzzle at ground level actively exploring matter on ground
Locomotion	Forward ambulatory motion at any speed
Recumbent or rolling	Lateral recumbency: 1 side of body in contact with ground, including neck, hip, and shoulder Sternal recumbency: body in contact with ground not including neck, hip, or shoulder Rolling: movement from standing to sternal recumbency, folding legs and rotating from sternal to dorsal position 1 or more times
Focal sampling for insect avoidance behavior	
Head movement	Using muzzle or teeth to bite at or rub any part of body Shaking whole head in side-to-side motion 3 or more times, vigorous enough that bottom of jaw and top of ears swing in opposite arcs Tossing head such that nose goes above level of top of withers or nose flexes toward chest going behind vertical
Stomp	Rapidly lifting and then lowering hoof; hoof clearly leaving the ground and returning to approximately the same place; no forward motion

[1]Modified from Holcomb et al. (2013).

data were combined as total insect avoidance in counts/h for each horse. The number of flying insects was estimated by counting the number of winged insects trapped on adhesive fly strips (4 × 60 cm, Catchmaster #9144, AP&G Co. Inc., Brooklyn, NY) that were suspended 1 m above the ground in a shaded and unshaded area adjacent to the study pens. Strips were removed and replaced at approximately 1230 h each day.

Observers maintained a minimum distance of 7.6 m from study pens during all behavior observations. The order in which horses were observed was randomized for each observation day. Nine student observers were trained and tested for reliability before the start of observations (Martin and Bateson, 2007). Students averaged 99.8% agreement with the researcher (K.E.H.) for instantaneous scan sampling, ranging from 99.0% to 100%. The correlation coefficient between observers for focal sampling averaged 0.97 with a range of 0.93 to 1.0.

Rectal temperature (**RT**), respiration rate (**RR**), skin temperature (**SK**), and a sweat score were measured as described previously (Holcomb et al., 2013) at 0900, 1230, and 1800 h daily. Blood samples were obtained on d 0 and 5 (Trials 1–3) and on d 7 (Trials 2 and 3) at approximately 1800 h. Samples were processed as described previously (Holcomb et al., 2013) to measure hematocrit (**HCT**), the neutrophil to lymphocyte ratio (**N:L**), and cortisol.

Statistical Analysis

Behavioral data were averaged by horse and hour to obtain values for statistical analysis (e.g., all data points from 1800 to 1855 h were averaged as time = 1800 h). Water consumption, serology variables, and count of insects were each analyzed by horse and day. Shade use was defined as the horse standing with at least 2 hooves in the shade cast by the structure. Structure use was defined as the horse standing with at least 2 hooves underneath the structure as bounded by the corner vertical support posts. Preference for location in shade was calculated as difference between shade use and chance, with chance equal to the percentage of the pen covered by shade for each hour from 0900 to 1800 h, which averaged 50.1% (range 40.5% to 54.5%). Preference for location beneath the shade structure was calculated as the difference between structure use and chance, which was 50%. The variables "stand near water" and "drink water" were combined into a single measure designated "standing near water."

During the 2-d acclimation period, 1 horse repeatedly displayed stereotypic weaving and was therefore excluded from data collection; thus, there were $n = 11$ horses for statistical analysis. The horse remained in the study pen to maintain consistency across trials. No analyses were performed for sweat, recumbency, or rolling because they were rarely observed (13 of 207 observations, 67 of 1,792 observations, and 5 of 1,792 observations, respectively).

Preference for shade and the structure were analyzed in PROC MIXED in SAS (SAS 9.3, SAS Inst. Inc., Cary, NC). The model included trial, day, time, and interactions with horse nested in trial as the random variable. Intercept was included in model statement options to obtain a *P*-value for the overall difference from chance for shade or structure usage.

To evaluate differences in physiological and behavioral variables by time of day, least squares means were calculated for RT, RR, and SK (0900, 1230, and 1800 h) and total insect avoidance behavior (1300, 1400, 1500, 1600, 1700 h) using PROC MIXED with a model that included trial, time, and interactions with horse nested in trial as the random variable. Comparisons of the location of behaviors performed in the shaded or unshaded area and under or not under the structure were analyzed in PROC MIXED. The model included location, trial, day and interactions, with horse nested in trial as the random variable. The same model was used to compare daily insect count and water consumption. To evaluate differences in serological variables by day in study, means for HCT, N:L, and cortisol were calculated (d 0, 5 for Trials 1, 2, and 3; d 0, 5, 7 for Trials 2

Table 2. Mean and maximum ambient temperature (T_{amb}) are shown with mean relative humidity (RH), black globe temperature (T_{BGT}), and solar radiation for 24 h and from 0900 to 1800 h, along with mean soil temperature (T_{soil}) from 1300 to 1800 h, for observations taken during all 3 trials

	24 h		0900 to 1800 h	
Weather variable	Shade, Mean (SD)	No shade, Mean (SD)	Shade, Mean (SD)	No shade, Mean (SD)
T_{amb}, °C	22.7 (7.3)	22.7 (7.5)	29.1 (5.0)	29.4 (4.9)
Maximum T_{amb}, °C	36.6	37.0	36.6	37.0
% RH	56.9 (21.9)	55.8 (22.4)	38.6 (14.2)	36.7 (13.8)
T_{BGT}, °C	24.4 (8.4)	26.5 (11.3)	32.6 (4.9)	38.3 (4.6)
Solar radiation, W/m^2	12 (12)	247 (295)	25 (7)	556 (195)
T_{soil},[1] °C	—	—	33.6 (3.7)	55.4 (8.1)

[1]Soil temperature was measured from 1300 to 1800 h.

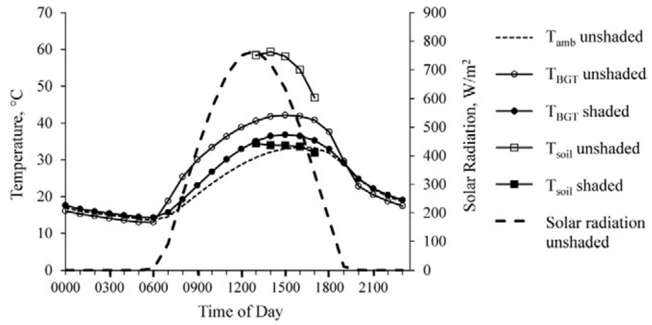

Figure 3. Hourly mean ambient temperature (T_{amb}), black globe temperature (T_{BGT}), soil temperature (T_{soil}), and solar radiation over 24 h for all observation days of the 3 trials (19 d total) in shaded and unshaded areas of the pens; the average difference between T_{amb} in shaded and unshaded areas was 0.01°C.

and 3) using PROC MIXED in a model that included trial and day, with horse nested in trial as the random term.

Homogeneity of variance was tested using the Levene test, and normal distribution of residuals was tested using the Shapiro-Wilk statistic (Pearson and Hartley, 1972; Sachs, 1984). When significant heteroscedasticity was evident, analyses were run using weighted least squares methods with the weighting factor being the reciprocal of the residual variance for the appropriate term. Cortisol data were not normally distributed; these were log transformed for analysis, and back-transformed means are reported. Least squares means were calculated using the Tukey-Kramer least squares means adjustment (Day and Quinn, 1989) and are reported with SE unless otherwise noted. Significance was considered at a level of $P < 0.05$.

RESULTS

The average 24-h T_{amb} during the study was 22.7°C with RH of 56.6% and no precipitation. Mean and maximum T_{amb} are shown with mean RH, T_{BGT}, solar radiation, and T_{soil} for all observation days in Table 2. The mean wind speed measured on site from 1300 to 1700 h was 2.1 m/s (SD = 1.0), and a mean wind speed of 2.2 m/s (SD = 0.8) from 0900 to 1700 h was calculated from the local weather station data. The T_{amb} in sun and in shade differed by < 0.6°C at all time points. Hourly mean T_{amb}, T_{BGT}, T_{soil}, and solar radiation are shown graphically in Fig. 3.

Horses were recorded in shade in 7.1% more observations than expected by chance during daylight hours (SE 1.3, $P < 0.001$). Time of day was a significant factor, with observations in the shade greater than chance during the hours of 1000, 1100, 1300, 1700, and 1800 h ($P < 0.001$, Fig. 4). Foraging and locomotor behavior took place more often in the shaded area ($P < 0.001$) than in the unshaded area from 0900 to 1800 h, but there were no differences for standing near and standing away from water (Table 3).

Horses were located beneath the shade structure greater than chance in 10.3% of daytime observations and in 12.5% of observations over a 24-h period (daytime: SE = 1.4, $P = 0.003$; 24 h: SE = 1.0, $P < 0.001$), with most observations beneath the structure at night and in the morning (Fig. 5). Foraging, locomotion, and standing away from water were observed underneath the structure more often than outside the structure over 24 h ($P < 0.05$), but there was no difference for standing near water (Table 3).

There was a trend toward more insect avoidance behavior in the shaded area than in the unshaded area (2.2/min and 1.4/min respectively, SE = 0.3, $P = 0.052$). However, there was no difference between the 2 areas in the insect count (shaded: 18.6 insects/d, unshaded: 19.4 insects/d, SE = 2.7, $P = 0.848$).

Mean RT for all trials was 37.5°C (SD = 0.4), mean RR was 16.4 breaths/min (SD = 6.2), and mean SK was 33.6°C (SD = 1.9). The RT, RR, and SK of horses did not differ by time of day ($P \geq 0.264$).

The means for both HCT and cortisol were greater on d 0 than on d 5 for all trials as well as on d 7 for the two 7-d trials ($P \leq 0.017$), as shown in Table 4, but there were no differences between d 5 and 7 for the 7-d trials ($P \geq 0.853$). The mean N:L for all trials on d 0 was not different than on d 5 ($P = 0.099$). However, for the two 7-d trials, the mean N:L on d 0 was greater than on d 5 ($P = 0.004$), whereas d 5 and 7 were not different ($P = 0.480$).

One horse splashed water from both its shaded and unshaded buckets, resulting in missing water consumption data on 2 of 5 d. Total water consumed per day during all 3 trials was 6.2 L/100 kg BW (SD ± 2.4), with no difference between areas (shaded area: 3.2 L/100 kg BW, unshaded area: 3.0 L/100 kg BW, SE = 3.4, $P = 0.758$).

DISCUSSION

When horses in this study were provided free access to pens with a choice between shaded and unshaded areas, they showed a preference for both the shade and

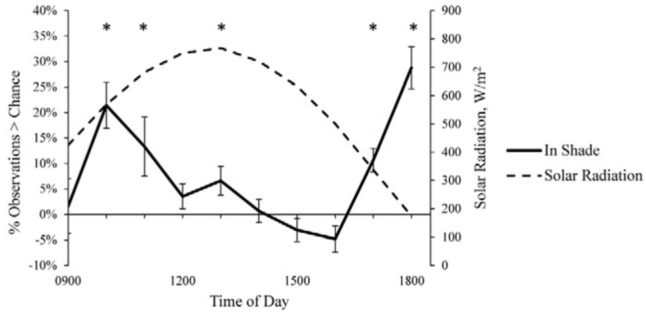

Figure 4. Hourly mean percentage of observations of horses in shade from 0900 to1800 h for all observation days of the 3 trials (total 19 d), expressed as difference from chance (mean ± SE, *$P < 0.05$), and hourly solar radiation.

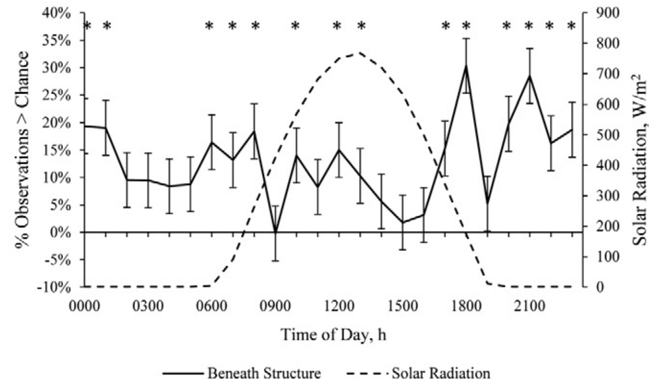

Figure 5. Percentage of observations of horses located beneath the shade structure over 24 h, expressed as difference from chance (mean ± SE, *$P < 0.05$), and hourly solar radiation.

shade structure. They were able to maintain consistent RT, RR, and SK and showed almost no sweat, in contrast to our previous study that found elevated levels of each of these variables in horses without access to shade in sunny, hot conditions (Holcomb et al., 2013). However, their use of shade did not coincide temporally with maximum mean T_{BGT} as hypothesized. The percentage of observations where horses were located in shade was equal to chance at 0900 h after they were fed in the morning, which was expected because feed was placed equally in the shaded and unshaded areas. Use of shade then increased, remained greater than chance until early afternoon, and then decreased to 5% less than but not significantly different from chance at 1600 h before increasing again. Thus, the nadir of shade use actually coincided with peak T_{amb} and T_{BGT}.

The temporal pattern of shade use displayed in the current study suggests that horses may have been responding to rapidly increasing solar radiation in the morning. Weather conditions experienced by an animal are a result of the combined effects of T_{amb}, RH, wind speed, precipitation, and solar radiation. When humidity, wind speed, and precipitation are held constant, T_{amb} is essentially equal whether in the sun or shade. Solar radiation becomes the critical factor increasing the animal's effective temperature as the sun's electromagnetic waves are absorbed by its body as heat. A black globe thermometer consists of a thermometer placed within an otherwise hollow copper sphere that is painted matte black to absorb the maximum heat from solar radiation. The thermometer measures the effect this radiant heat has on T_{amb} minus any heat removed from the sphere by convective air currents. The black globe thus measures the combined effects of T_{amb}, solar radiation, and wind, providing an estimate of the effective temperature experienced by an animal. Solar radiation peaks when the sun is at the zenith in midday. In our previous study (Holcomb et al., 2013), the RT of horses with no access to shade increased with solar radiation, peaking several hours before maximum T_{amb} and T_{BGT}. Use of shade as solar radiation was reaching peak levels may have prevented an increase in RT in this study, allowing horses to remain comfortable in the sun in the afternoon with decreasing solar radiation but increasing T_{BGT} until by 1700 h, just after maximum T_{BGT}, their heat load grew and shade use increased. Future research could focus on the possible dynamic of increased shade use around the time of peak solar radiation and T_{BGT}.

Whereas maximum solar radiation in a cloudless sky occurs consistently at midday, the time of day that T_{amb} and T_{BGT} peak varies geographically. The time gap between peak solar radiation and T_{BGT} may be shorter or longer or the peaks may coincide in some locales, and thus, horses living in other regions may show a different pattern of shade use across the day. For dairy cows, there is a linear relationship between solar radiation and the amount of time they spend in shade (Schütz et al., 2009). Dairy cows in New Zealand used shade more in the afternoon than in

Table 3. Comparison of mean percentage of observations in which foraging, locomotion, standing near water, and standing away from water were recorded for horse location in shaded or unshaded areas from 0900 to 1800 h and beneath or outside the shade structure for 24 h

Behavior,	0900 to 1800 h				24 h			
% of observations	Shaded	Unshaded	SE	*P*	Beneath structure	Outside structure	SE	*P*
Forage	14.0	10.6	0.73	0.004	14.7	12.4	0.47	0.002
Locomotion	6.0	3.3	0.94	0.002	5.6	2.8	0.66	<0.001
Stand near water	11.1	4.7	2.73	0.099	8.9	3.0	2.18	0.093
Stand away from water	25.7	24.1	3.35	0.744	29.9	19.6	1.92	<0.001

Table 4. Means for hematocrit (HCT), neutrophil to lymphocyte ratio (N:L), and cortisol by day of study

	d 0	d 5	d 7	SE	*P*
Hematocrit, %					
Trials 1 to 3	34.7[a]	31.6[b]	—	0.74	0.017
Trials 2 to 3	35.8[a]	31.7[b]	31.1[b]	0.85	0.004
Cortisol, μg/dL[1]					
Trials 1 to 3	4.2[a]	2.9[b]	—	—	0.008
Trials 2 to 3	4.6[a]	2.9[b]	2.9[b]	—	0.001
N:L					
Trials 1 to 3	2.1[a]	1.9[a]	—	0.14	0.099
Trials 2 to 3	2.1[a]	1.6[b]	1.7[b]	0.08	<0.001

[a,b]Means within rows without a common letter are different ($P < 0.05$).

[1]Values are back-transformed, thus SE are not provided.

late morning (Schütz et al., 2010), but the time of day that T_{BGT} peaked was not reported. Evaluation of shade use by horses in geographical regions where peak T_{amb} and T_{BGT} differ markedly from the present study would contribute to a more complete understanding of the conditions under which horses utilize available shade.

It is important to note that even at the time of least shade use, the total percentage of observations that horses were in shade was well above zero, at 45%, and thus, horses were not actively avoiding the shade structure. Although this percentage is less than shade use reported for feedlot cattle (Brown-Brandl et al., 2005), caution is required when making direct comparisons between horses and cattle because cattle have a very different physiology, body type, and behavior. The relatively longer legs and neck of horses give them a larger body surface-to-volume ratio than cattle. Horses also spend less time lying down than cattle (8% to 20% of 24 h period in horses vs. almost 50% in cattle; Houpt, 2005), and horses sweat, whereas cattle pant for most evaporative cooling (Morgan, 1997). Each of these factors influences the ability of horses to dissipate heat, and each is likely to affect shade-seeking behavior.

Horses showed a preference for being in the shade, and thus, it follows that more behaviors would occur there. Of note, however, is that differences were seen only for the active behaviors. Horses foraged and showed locomotor activity more often in the shade, but their proximity to water buckets did not differ between sun and shade. Foraging behavior included exploring matter on the ground with the muzzle whether or not feed was still present, yet horses foraged more in the shade even though feed had been provided equally in shaded and unshaded areas. In our previous study, horses without shade spent more time near their sources of water than horses with shade under hot, sunny weather conditions (Holcomb et al., 2013), in agreement with observations of cattle (Widowski, 2001; Schütz et al., 2008). Given the choice of water availability in the shaded or unshaded area, horses in this study showed no preference for the location of this resource.

Horses in this study demonstrated a consistent overall preference for standing beneath the shade structure at all hours of the day except after being fed. As expected, horses spent equivalent amounts of time beneath and outside of the shade structure at feeding time because hay was provided simultaneously in both. Horses in this study clearly also preferred to be beneath the structure in the dark as well as in daytime. The few studies of equine time budgets that documented use of shelters were focused largely on cold, winter weather. Groups of horses in pastures with partially enclosed shelters across all seasons showed a range of shelter use with greatest use at night and during inclement weather (Michanek and Bentorp, 1996; Mejdell and Bøe, 2005; Heleski and Murtazashvili, 2010). Mejdell and Bøe (2005) reported that horses used the shelter least between 1600 and 1800 h. A similar pattern was observed in the present study, with greater use of the structure overall during the night and least use (not associated with feeding) at 1600 h. It is possible that the study horses found some feature of the structure appealing in addition to shade itself, potentially including an increased sense of security.

Location of the horse relative to the structure was recorded to account for the fact that horses could be shaded by the structure without being directly beneath it and vice versa because of the path of the sun casting shade at an angle. The criterion for an observation being counted as "in shade" or "under structure" was the presence of at least 2 of the horse's hooves in that location, equivalent to at least half of the horse's body. Shade use may have been underestimated because part of a horse's body, especially its head, could have been shaded by the structure even when all 4 hooves were unshaded. The hypothalamus plays a central role in thermoregulation (Clark et al., 1939), and targeted warming of specific brain regions elicits thermoregulatory responses from rats (Kanosue et al., 1998; Bratincsak and Palkovits, 2004). Observing the frequency with which horses keep their heads shaded in hot, sunny weather would be an interesting topic for future research.

We recognize that a complete quantification of insect avoidance behavior in horses would include skin twitches and tail swishing (McDonnell, 2003; Cozzie and Irby, 2010). However, in the present study, only head movements and hoof stomping could be accurately quantified from a distance without affecting other behaviors. Our previous study of horses that were either completely shaded or completely unshaded showed no difference in number of insect avoidance behaviors but a greater count of flying insects in the sun (Holcomb et al., 2013). Although in the present study there was no difference in the number of insects counted in the shaded and unshaded areas, horses in the shaded area showed a strong trend toward more insect avoidance behavior. There has been speculation that insects might seek shade in hot, sunny weather and that horses might avoid shaded areas to escape biting insects (Duncan and Cowtan, 1980; Keiper and Berger, 1982). The present and previous (Holcomb et al., 2013) studies do not support that idea. In contrast, Heleski and Murtazashvili (2010) suggested that horses with docked tails may have shown greater shelter-seeking behavior than those with undocked tails to avoid insects in hot weather. A similar lack of difference in insect avoidance behavior was observed in shaded and unshaded dairy cattle (Kendall et al., 2007).

There were no differences in RT, RR, or SK due to time of day, and sweating was rarely observed. The RT remained within normal reference ranges (RT = 37.7, SD = 0.5°C; Kahn and Line, 2010), and although RT usually increases in horses throughout the day (Piccione et al., 2002), there was no difference due to time of day in this study. The RR was slightly greater than the normal range for RR of 10 to 14 breaths/min (Kahn and Line, 2010) but is consistent with RR reported elsewhere for horses under summer conditions (Honstein and Monty, 1977; Kaminski et al., 1985). The lack of differences in these measures, as well as the observation of minimal sweating, suggests that access to and use of shade enabled horses to adequately thermoregulate under the weather conditions they experienced.

Horses showed slight decreases in HCT, cortisol, and N:L following d 0, although they remained within the normal ranges for HCT of 27%–43% (Kahn and Line, 2010), cortisol of 2.5 to 6.5 μg/dL (Stull and Rodiek, 1988; Stull and Rodiek, 2002), and N:L of 0.8 to 2.8 (Morris, 1996). Dehydration can be indicated by elevated HCT. Elevated cortisol is considered a hallmark of stress-related activation of the hypothalamic-pituitary-adrenal (**HPA**) axis, and N:L increases in response to elevated cortisol. Cortisol levels in resting horses have been documented to exhibit a circadian rhythm with peak concentration in the morning and low concentration in the evening (Stull and Rodiek, 1988). The HCT, cortisol, and N:L values found in this study are consistent with results of our previous study (Holcomb et al., 2013), which suggested that the conditions experienced by these horses did not cause dehydration or elicit a stress response from the HPA axis.

Preference testing of horses has been employed to determine their preferred spatial orientation during transport (Smith et al., 1994), type and flow rate of water delivery (Nyman and Dahlborn, 2001), flavors (Randall et al., 1978; Kennedy et al., 1999; Goodwin et al., 2005), type of roughage (Müller and Udén, 2007), and training techniques (von Borstel et al., 2009) and their ability to see another horse (Houpt and Houpt, 1988). One limitation of preference tests is that the magnitude of preference may not reflect the actual importance of a resource (Kirkden and Pajor, 2006), nor does it indicate whether a lack of the resource results in suffering (Mills, 2006). The strength of horses' motivation to use shade and the structure was not measured in this study. However, future research using motivation tests would provide important additional insight into both shade and structure use.

Another limitation of preference tests is the possibility that factors other than those included in the experimental analysis could affect animals' choices. To reduce the potential effects of resource location bias, feed and water were provided equally in both shaded and unshaded areas. Because horses are social animals that often show behavioral synchrony in herd activities (Souris et al., 2007), horses in this study were individually housed with approximately 6 m of open space between pens. It is possible that the location of horses relative to sun or shade was affected by their conspecifics. Our data collection method did not support analysis of synchrony, and this behavior should be considered for future research. Additionally, horses living in larger enclosures may show different preferences for shade use, especially if greater freedom of movement allows them to choose between additional resources such as a grass pasture, a breezy area, or social contact.

An existing structure providing the shade was located only across the south end of the pens, and the horses' preference may have been related to the shade position within the pen or from the sights and sounds, activity, and other unknown environmental factors. Alternative pen sizes or ratios of shaded to unshaded areas could also produce different results than the present study with a pen area of 74 m^2, which was larger than the FASS minimum recommendation of 13.7 m^2 for a single horse (FASS, 2010). In addition, the open-sided shade structure in this study allowed free air movement; restricted air flow beneath structures with one or more walls (shelters) may have been a negative factor in shelter-seeking behavior by horses in summer (Heleski and Murtazashvili, 2010).

The climate during the summer in Davis, California, is arid and hot with cloudless skies. Other weather conditions, such as a hotter ambient temperature, different levels of solar radiation, high humidity, and elevated nighttime temperature could influence the responses of horses to available shade. Young and aged horses, those in poor body condition, and horses with compromised health may also value shade differently than healthy, mature horses.

Implications

Individually housed, healthy, mature horses showed a preference for using shade and the shade structure in hot, sunny weather. Preference for shade was greatest before and during peak solar radiation and then again several hours later following peak T_{BGT}, rather than during peak T_{BGT} as expected. Time of day and conditions under which horses prefer shade may differ by geographic location, and these should be considered in making management decisions regarding shelter from the sun. Results of this study support inclusion of recommendations to provide shade to horses located in hot, sunny environments when developing best practice guidelines for care of domestic horses.

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