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Testing alternative designs for a roadside animal detection system using a driving simulator

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Abstract

Objectives: A Roadside Animal Detection System (RADS) was installed in January 2012 along Highway 41 through Big Cypress National Preserve in Florida, USA in an attempt to reduce wildlife-vehicle collisions. The system uses flashing warning signs to alert drivers when a large animal is near the road. However, we suspected that the RADS warning signs could be ignored by drivers because they resemble other conventional signs. We hypothesized that word-based warning signs (current design) are less effective than picture-based signs at catching drivers' attention. **Methods:** We used a driving simulator to test (1) the effects of the RADS on collision rate, driver speed, and latency to brake; and (2) whether the RADS would be more effective if warning signs were picture-based. Participants were randomly assigned to one of three treatments: no warning (control), word-based RADS signs (current design), and picture-based RADS signs (proposed design). During the simulations, a deer entered the road in front of the driver, and we recorded whether drivers "crashed" or not. **Results:** Both the picture-based and word-based RADS signs resulted in significantly lower crash probabilities. The picture-based RADS signs performed better than the word-based signs in reducing speed and latency to brake, although the effect varied between twilight and night. However, the word-based RADS signs still did produce significant reductions in speed and braking latency. **Conclusions:** We conclude that the word-based RADS in Big Cypress should help prevent dangerous wildlife-vehicle collisions, but that redesigning the warning signs to be picture-based could yield even greater benefits.

Keywords

Animal detection system, animal-vehicle collisions, driving simulator, traffic safety, RADS

Introduction

Collisions between large mammals and vehicles are costly for wildlife and humans alike. In Sweden, road-kills are responsible for an average loss of between 1 and 12 percent of the population size of medium- and large-sized mammal species (Seiler et al. 2004). Road-kill disproportionately affects small reptiles, amphibians, and mammals, but collisions with large mammals are most frequently reported (Huijser and McGowen 2003). This is because collisions with large mammals come at a greater cost to humans; in the United States, they cause 211 deaths, 29,000 injuries, and more than $1 billion USD in property damage every year (Huijser et al. 2007). Likewise, large animal-vehicle collisions (hereafter LAVCs) take a heavy toll on wildlife populations, through increased mortality and reduced landscape connectivity. In fact, roads are thought to be one of the greatest threats to wildlife worldwide (Noss and Cooperider 1994; Trombulak and Frissel 2000; Forman et al. 2003; Smith 2003; Laurance et al. 2014).

The most common measures used to reduce the incidence of LAVCs are static warning signage, wildlife fencing and ecopassages (e.g., overpasses, underpasses, and tunnels/culverts). The first, static warning signage, has been shown to be largely ineffective; drivers easily habituate to it and fail to make adequate reductions in speed (Huijser et al. 2007). The other two measures are largely successful, but they come with limitations. On its own, wildlife fencing merely creates another barrier to animal movement throughout the landscape (Smith 2003), so it is rarely a standalone mitigation method for large, wide-ranging animals, though it can be a useful interim measure (Jaeger and Fahrig 2004). Using fences in combination with ecopassages is a common strategy, but the effectiveness of ecopassages is almost never evaluated in a BACI design (van der Ree et al. 2007; Lesbarrères and Fahrig 2012) and they can be very expensive (several million USD; Huijser et al. 2007). In addition, their installation is disruptive to traffic, meaning that they are rarely installed unless a road is being widened or a new road built (Smith 2003; Huijser et al. 2007). Because of the cost and difficulty of installation, ecopassages cannot be installed at every location that could benefit from one.

Roadside Animal Detection Systems (RADS) are a relatively new alternative to the previously listed measures. RADS use sensors (e.g. motion-sensing, thermal, infrared) to detect when large animals are near the road; when an animal is detected, the sensors send a signal to lights on warning signs, which begin to flash. Unlike fencing and ecopassages, RADS are not intended to keep wildlife off of the road, but rather to alert drivers when there is an increased risk of a collision. Because the lights only activate when a large animal is detected near the road, it should decrease the likelihood of drivers habituating to the warning signs. In addition, RADS are easier to install than ecopassages and are less expensive, ranging from $11,500–$60,000 USD plus installation and maintenance costs (Huijser and McGowen 2003), so they could potentially be deployed on a larger scale. RADS were first installed and tested in 1993 in Switzerland (Kistler 1998, Tschuden 1998; cited in Huijser and McGowen 2003). Since then, many more systems have been implemented in North America and in Europe:

in 2006, there were 34 separate locations with RADS installed (14 inactive), with 27 more planned (Huijser et al. 2006).

Despite the promising nature of the technology, the success of a particular RADS depends largely on its ability to influence human behavior. However, studies to evaluate driver response to RADS in the field have encountered significant difficulties (reviewed in Huijser and McGowen 2003). For example, false triggers—instances where the system activates when no large animal is present, often caused by vegetation or deep snow—have been a common problem. Over time, this could cause driver habituation and skew the results of a field evaluation. Broken sensors and loss of power have also been an issue in certain locations, especially where weather conditions are severe, e.g., excess rain or snow. As a result of these technical challenges, it is hard to draw conclusions from previously collected data; however, one study of a RADS at a deer crossing that did not experience malfunctions until after the study period found that the system reduced driver speed by 6.5 km/h at night and 3 km/h during the day (Gordon et al. 2004).

We circumvented these difficulties by using a driving simulator to evaluate how a RADS affects driver behavior. Our study is the first to use a driving simulator to assess a RADS; however, simulator studies have been used to assess driver reaction to variations in road signs, e.g. Hammond and Wade (2004). The use of a driving simulator is ideal for evaluating RADS in many ways: first, it provides a controlled setting in which to observe driver behavior, with no confounding effects of weather, time of day, or equipment malfunction. Second, it allows us to safely assess the risk of an animal-vehicle collision; in a simulated setting, this can be done with no threat to humans or wildlife, as well as generating a much larger sample of potential collisions than could be observed in the field.

Another key feature of the simulator is that the controlled setting allows us to compare alternative designs for the RADS; in this case, designs for warning signage. Bond and Jones (2013) show that drivers rate warning signs with silhouettes of animals (picture-based) higher than text-only signs (word-based) in their ability to reduce speed and increase alertness. Both picture- and word-based signs have been used in RADS systems (reviewed in Huijser and McGowen 2003); however, the two alternatives have never been compared in a controlled setting. It is possible that one design could produce the desired reduction in speed and/or increase in alertness more often or with a greater magnitude. For identifying best practices in animal-vehicle collision mitigation, we sought to determine which design yields greater potential benefits.

In this study, we asked (1) does the presence of a RADS have an effect on driver speed, latency to brake when an animal enters the road unexpectedly (treated here as a proxy for alertness), and/or the probability of animal-vehicle collisions? and (2) do word-based and picture-based RADS signs perform differently? Because the use of a driving simulator removes the technical challenges often experienced in the field, we can evaluate whether RADS have the potential to significantly affect driver behavior and reduce crashes with wildlife. If so, it will be worthwhile to invest in research and development to overcome these challenges.

Methods

Focal RADS

In January 2012, an experimental RADS (manufactured by Simrex Corporation) was installed in Big Cypress National Preserve (BCNP) on Highway 41 near Turner River in Collier County, Florida, USA. Daisy-chained infrared sensors, spaced approximately 153 m apart and placed just beyond the road shoulder on both sides of Highway 41, create a detection beam parallel to the road surface spanning 2.1 km. The system is designed specifically to detect large wildlife, so the infrared beam is 46 cm above the ground and will not detect shorter animals. The standard yellow diamond warning signage is word-based, not picture-based, and reads, "WARNING WILDLIFE ON ROADWAY REDUCE SPEED." These warning signs are placed every 610 m. In addition, an informational sign informs drivers of the RADS system 0.8 km before entering the animal detection area (Fig. 1).

The 2.1-kilometer-long road segment was identified by federal and state wildlife agencies as a critical hotspot for road-kills of the federally endangered Florida panther (*Puma concolor coryi*), whose population is currently estimated at 100–180 individuals (FFWCC 2014). Five panther road-kills occurred at this location between 2004 and 2009, of which four were breeding-age females. Although collisions with Florida panthers were the catalyst for this experimental installation, a successful RADS would also benefit other large wildlife, such as Florida black bear (*Ursus americanus floridanus*), and white-tailed deer (*Odocoileus virginianus*). Since its installation, the RADS has experienced a large number of false triggers during daylight hours, which could potentially reduce its effectiveness as a warning system.

Driving simulator

The driving simulator was provided and programmed by the Research in Advanced Performance Technology and Educational Readiness Lab at the University of Central Florida's Institute for Simulation and Training. They programmed the simulator to create a digital version of the RADS installation site on Highway 41. Using this digital version of the roadway and surroundings as a base, three alternatives were created: one had no RADS warning signs (control), another included word-based RADS signs (which reflects the Highway 41 RADS), and the third included redesigned, picture-based RADS warning signs (Fig. 1).

Participants

The use of human subjects in this research was approved by the UCF Institutional Review Board, IRB number SBE-13-09322. Ninety people participated in the simulator experiment between 15 July and 18 August 2013. The participants were either students

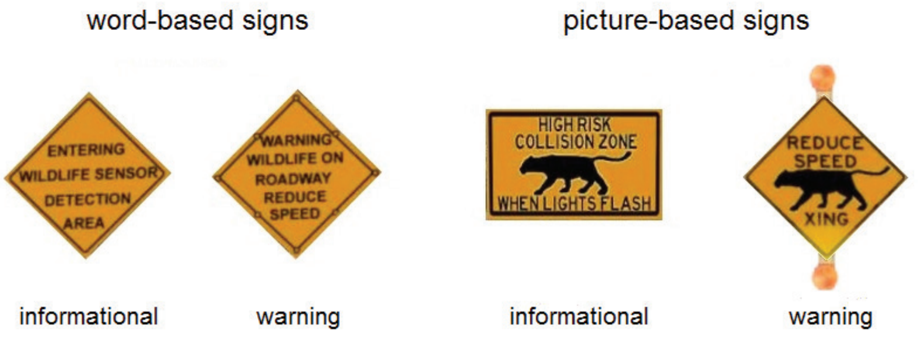

Figure 1. Images of the RADS signs used in the driving simulator. Left: simulated images of the Highway 41 RADS signs, including a word-based informational sign posted 0.8 km before entering the animal detection area and four word-based warning signs with 8 LED lights that flash when animals break the infrared beam parallel to the road. Right: simulated images of the modified RADS signs, which feature a picture-based informational sign and four picture-based flashing warning signs.

or employees of the University of Central Florida or members of the surrounding community. Undergraduate students were offered course credit as incentive to participate, while all other participants received a small monetary compensation. All were at least 18 years old, and all had been licensed to drive for at least one year.

Participants were recruited systematically so that there were 30 participants in each age group (age group 1 = 18–24 years, age group 2 = 25–44 years, age group 3 = 45+ years). We recruited into these age groups to obtain a more balanced participant pool, and because age is known to affect driver behavior: young or inexperienced drivers make up a disproportionate amount of accidents on the road because they have an underdeveloped ability to recognize hazards, yet tend to overestimate their own driving skills (reviewed in Deery 2000).

Participants in each age group were assigned to a treatment (control, word-based RADS, or picture-based RADS) using a systematic random design: i.e., the first member of each age group tested was assigned to the control treatment; the second, word-based; third, picture-based; fourth, control, *etc*. Thus, exactly one-third of each age group was assigned to each treatment.

Participants were told that they were participating in a study aiming to evaluate driver response to various hazards on the road. The full nature of the study, i.e., the intent to evaluate the RADS, was not disclosed to the participants until debriefing after the testing session. This was done so that participants did not anticipate seeing animals on the road, which could affect their responses.

Simulator experiment

Each participant completed six runs in the driving simulator, three "twilight" scenarios and three "night" scenarios. We chose these times of day because these are the times that collisions with large animals are more likely to occur (Danks and Porter 2010; Neumann et al. 2012), and also because in Big Cypress National Preserve, there is a nighttime speed limit of 45 mph (72 km/h), while during the day (and twilight) the speed limit is 60 mph (97 km/h). This was reflected in the speed limit signs programmed in the simulation. Before participants began the six runs, there was an acclimation period during which the participant was able to familiarize themselves with and become accustomed to the driving simulator. A five-minute break was offered between each run, during which the participant could walk around, get water, or eat.

In each set of three runs, there was one target run featuring an animal hazard in which a deer entered the road directly in front of the car at a certain point in the run. The other two were non-target runs, meaning that they did not include an animal hazard, but instead a different type of hazard (either a car crashed on the roadside or a driver entering the road in front of the participant suddenly) to prevent the participant from realizing the true purpose of the study. Each run featured only one hazardous situation. Participants completed the six runs in a random order.

Each run featured a 0.8 km baseline period at the beginning, a 0.8-km zone after the RADS informational sign, and a 2.1 km RADS zone. All hazards, animal or not, occurred within the RADS zone. Driver speed and brake pressure were automatically recorded every 0.014 seconds. We also recorded whether or not a participant crashed into the animal hazard during target runs.

Analyses

We only analyzed the target runs, in which participants were presented with an animal hazard. Each participant completed one target run during the twilight scenario and one during the night scenario. Because each participant was tested both at night and twilight, which had different speed limits, the effects of these factors were tested using paired methods. All statistical tests were performed in JMP® (version 10, SAS Institute Inc., Cary, NC, USA) and figures generated using JMP® or R Statistical Computing software (version 3.0.2, R Foundation for Statistical Computing, Vienna, Austria, 2013).

Pairwise comparisons between twilight and night

To assess whether there was a significant difference in crashes between runs that occurred at twilight vs. those at night, we performed McNemar's chi-squared test for paired samples. To test whether driver speed was greater at twilight than at night, we used Wilcoxon's signed rank test (1-tailed). The speed considered was the average speed between the point where the participant entered the RADS sensor array and the point just before the deer appeared in the road. We used a nonparametric test because the differences between the pairs were not normally distributed (Shapiro-Wilk test, W = 0.953, p = 0.00260). To test if there was a difference in latency to brake (measured as the distance between the location where the participant started braking and the location of the deer on the road) between night and twilight, we again used Wilcoxon's signed rank test (1-tailed) (Shapiro-Wilk test, W = 0.945, p = 0.00131). We excluded data from six participants who did not brake in response to the animal hazard in one or both of their target runs: four participants from the control treatment, one participant each from the word- and picture-based treatments; three participants from age group 1 and three participants from age group 2.

Effect of RADS

To assess whether treatment or age had an effect on the probability of crashing, we fit a multiple logistic regression model using "crash" (yes/no) as the dependent binomial outcome and treatment (control, word-based RADS, and picture-based RADS) and age group as fixed factors. We intended to do this analysis for both twilight and night, but so few crashes occurred at night (n = 2) that the logistic model becomes unstable and uninformative. Therefore, this analysis was done only for twilight.

We used One-Way Analysis of Variance (ANOVA) to assess whether treatment or age had an effect on speed or latency to brake (measured as the distance between the location where the participant started braking and the location of the deer on the road). Separate ANOVAs were done for twilight and night datasets.

Results

Descriptive statistics

We tested 43 females and 47 males. Mean age (yrs.) and standard error in age group 1 was 20.4 ± 1.98 (range 18–24); age group 2, 30.3 ± 4.45 (range 25–41); age group 3, 52.2 ± 5.62 (range 45–65). Of the 90 participants, 30 crashed (Table 1).

Table 1. Number of crashes per factor.

Factor	Number of crashes			
	Control	Word-based	Picture-based	Total
Treatment	18	8	4	30
	Age group 1	Age group 2	Age group 3	Total
Age group	18	6	6	30
	Twilight	Night		Total
Time of day	28	2		30
	Males	Females		Total
Gender	13	17		30

Pairwise comparison of crashes occurring in twilight vs. night runs

There were 30 total crashes observed in our experiment. During twilight runs, participants crashed 31% of the time (n = 28 crashes), while in night runs, participants crashed 2% of the time (n = 2 crashes). This difference is significant (McNemar's χ^2 = 22.3214, DF = 1, $p < 0.00001$; Table 1). Thus, we analyzed the effect of experimental factors separately for twilight and night. However, since only 2 crashes occurred at night, we were only able to further analyze crashes that occurred in twilight simulations.

Effect of RADS on crash rate

The overall model for crash probability was highly significant (χ^2 = 24.9, DF = 5, $p < 0.0001$). The independent variables treatment and age group had a significant influence on crash likelihood (respectively, χ^2 = 17.5, DF = 2, p = 0.0002; χ^2 = 7.08, DF = 2, p = 0.0290; effect likelihood ratio tests).

Between levels of experimental factors, participants in the youngest age group (age group 1) were significantly more likely to crash than those in the oldest age group (age group 3; Tables 1 and 2). There was no significant difference in crash rate between age groups 1 and 2 or 2 and 3. Participants in the control treatment were significantly more likely to crash than those in the word-based treatment or the picture-based treatment (Tables 1 and 2). There was no significant difference in crash rate between the word-based treatment and the picture-based treatment.

Pairwise comparison of speed in twilight vs. night runs

Mean speed of participants during twilight runs was 93.7 km/h ± 1.21 SE and ranged from 70–160 km/h, compared to a nighttime average of 78.2 km/h ± 1.24 SE with a range of 23.0–160 km/h. Extreme outliers (>3 standard deviations from the mean) were seen in both twilight and night and were from the same participant; these were removed from further analyses. The average difference in speed between twilight and night runs for a participant was 15.4 km/h ± 1.09 SE faster at twilight than night, with a range of -20.4–34.1 km/h. This difference is significant (Wilcoxon signed rank test with continuity correction, W = 120, $p < 1.0\text{e-}13$).

Effect of RADS on speed

The overall twilight model for speed was significant (F = 2.55, DF = 8 and 80, p = 0.0159). Both treatment and age group had a significant influence on speed, and there was no interaction between treatment and age group (Table 3). Between the different treatments, participants in the control treatment (mean speed 97.0 km/h) drove faster than those in

Table 2. Crash probabilities between treatments and age groups. Odds ratios showing likelihood of a member of the first group crashing compared to the likelihood of a member of the second group crashing. A dagger (†) indicates significant odds ratios at $\alpha = 0.10$ while an asterisk (*) indicates effects significant at $\alpha = 0.05$.

Comparison	Odds Ratio	$p > \chi^2$	Lower 95%	Upper 95%
age group 1 vs. age group 2	3.54	0.0514†	0.993	14.1
age group 1 vs. age group 3	5.15	0.0114*	1.43	21.5
age group 2 vs. age group 3	1.46	0.591	0.36	6.06
control vs. word-based	6.29	0.0026*	1.85	25.4
control vs. picture-based	14.0	<0.0001*	3.59	68.9
word-based vs. picture-based	2.22	0.267	0.546	10.1

Table 3. ANOVA table for average speed of participants within the RADS zone at twilight. An asterisk (*) indicates effects significant at $\alpha = 0.05$.

Factor	DF	SS	F ratio	p > F
age group	2	211.4	3.19	0.0464*
treatment	2	327.0	4.94	0.00951*
age group*treatment	4	136.8	1.03	0.396

the picture-based treatment (89.5 km/h), but not the word-based treatment (92.2 km/h) (Tukey-Kramer HSD, $p = 0.0098$ and 0.137, respectively; Fig. 2). Participants in age group 3 drove significantly slower than those in age group 2 at $\alpha = 0.1$ (Tukey-Kramer HSD, $p = 0.0560$) but there were no other significant differences between the age groups (Fig. 2).

Nighttime speed data were transformed using the Box-Cox transformation to meet the assumption of normal residuals. The overall nighttime model was not significant ($F = 1.75$, DF = 8 and 80, $p = 0.0991$), and no factor significantly affected speed.

Pairwise comparison of braking distance in twilight vs. night runs

Mean braking distance during twilight runs was 45.7 m before the deer's location on the road (±1.99 SE; range 14.4–79.8), compared to 51.7 m during night runs (±1.81 SE; range 22.2–79.8). The average paired difference between night braking start distance and twilight braking start distance was that participants braked 5.93 m earlier at night than twilight (±2.80 SE), though there was a very wide range (-57.4 m–65.1 m). This difference is significant (Wilcoxon signed rank test with continuity correction, $W = 2350$, $p = 0.00274$).

Effect of RADS on braking distance

Both the twilight and nighttime overall models were significant ($F= 3.77$, DF = 8 and 75, $p = 0.0009$ and $F = 3.81$, DF = 8 and 78, $p = 0.0008$, respectively; nighttime

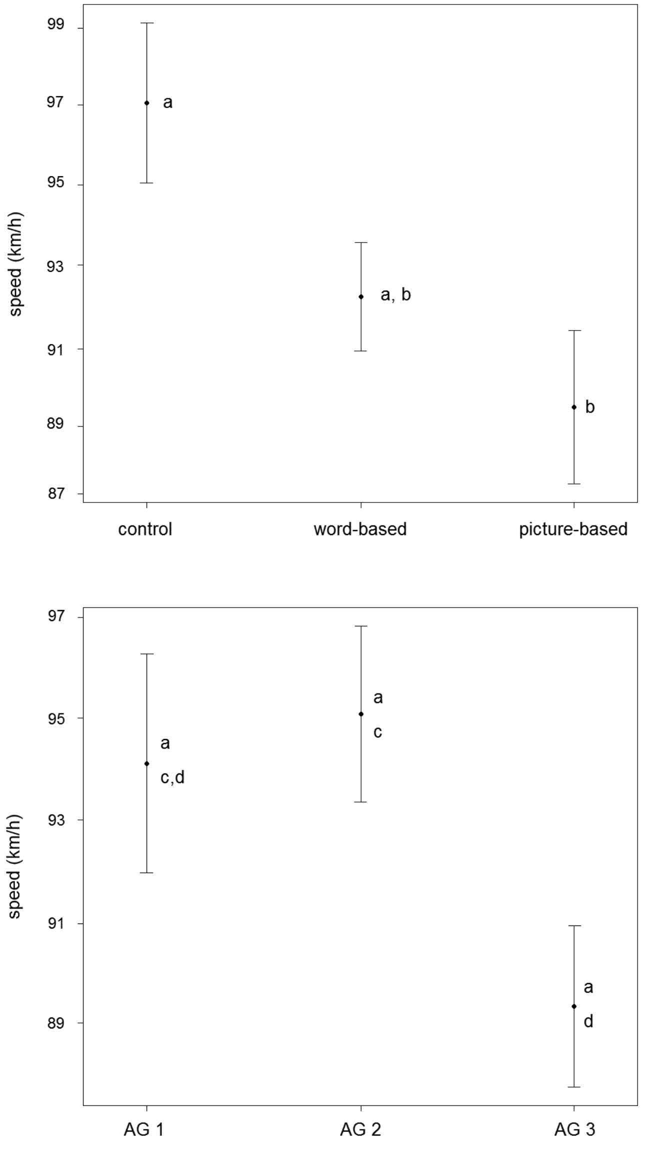

Figure 2. Participant speed at twilight by treatment and age group. Means and standard errors of speeds (mph) of participants at twilight in: **Top**- the three treatments; **Bottom**- the three age groups. Significantly different treatments have different letters next to them (a's and b's indicate significant differences at α= 0.05; c's and d's indicate significant differences at α= 0.10). n=30 for word- and picture-based treatments; n= 29 in control because we removed an outlier (>3 standard deviations from the grand mean).

braking distance data were transformed using the Box-Cox transformation to meet the assumption of normal residuals). At twilight, braking distance was influenced by treatment, though the effect of age group was also significant at α = 0.1 (Table 4). There was no significant interaction between treatment and age. Participants in both the pic-

Table 4. ANOVA tables for braking distance. The distance considered is the distance at which participants began to brake when the deer ran out in front of them during the simulation. Separate ANOVAs were calculated for twilight and night data. A dagger (†) indicates effects significant at α= 0.10 while an asterisk (*) indicates effects significant at α= 0.05.

time of day	factor	DF	SS	F ratio	p > F
twilight	age group	2	331.9	2.91	0.0605†
	treatment	2	1121.8	9.85	0.0002*
	age group*treatment	4	252.9	1.11	0.358
night	age group	2	110.4	2.16	0.122
	treatment	2	426.5	8.36	0.0005*
	age group*treatment	4	236.9	2.32	0.0643†

ture-based and word-based treatments began to brake earlier than participants in the control treatment (on average, 8.09 m and 7.59 m earlier, respectively; Tukey-Kramer HSD, p = 0.0007 and p = 0.0017, respectively; Fig. 3). There was no significant difference in braking distance between participants in the picture-based and word-based groups (Tukey-Kramer HSD, p = 0.968; Fig. 3).

At night, braking distance was influenced by treatment, but not age, although the interaction between treatment and age was significant at α = 0.10 (Table 4). Participants in the picture-based treatment started to brake on average 5.53 m before participants in the control treatment (significant difference; Tukey-Kramer HSD, p = 0.0006; Fig. 3) and 3.04 m before participants in the word-based treatment (significant at α =0.1; Tukey-Kramer HSD, p = 0.0725; Fig. 3). Participants in the word-based treatment started to brake 2.49 m before participants in the control treatment, but this difference was not significant (Tukey-Kramer HSD, p = 0.189).

Because the interaction between age and treatment at night was close to being significant at α = 0.05, and because we tested a relatively small sample of participants, we investigated the interaction for any trends indicating that the different RADS designs affected participants differently within an age group. Within age group 1, the youngest age group, those in the picture-based group braked on average 7.76 m before those in the control group (Tukey-Kramer HSD, p = 0.0749). Within age group 3, the oldest age group, those in the picture based group braked on average 7.81 m before those in the word-based group (Tukey-Kramer HSD, p = 0.0714).

Discussion

In our simulator study, we found that the RADS produced significant positive outcomes: participants in RADS treatments reduced their speed, braked earlier in response to an animal in the road, and were involved in animal-vehicle collisions less often. In addition, the picture-based RADS signs were more effective than the word-based RADS signs at reducing driver speed at twilight, and the same was true of differ-

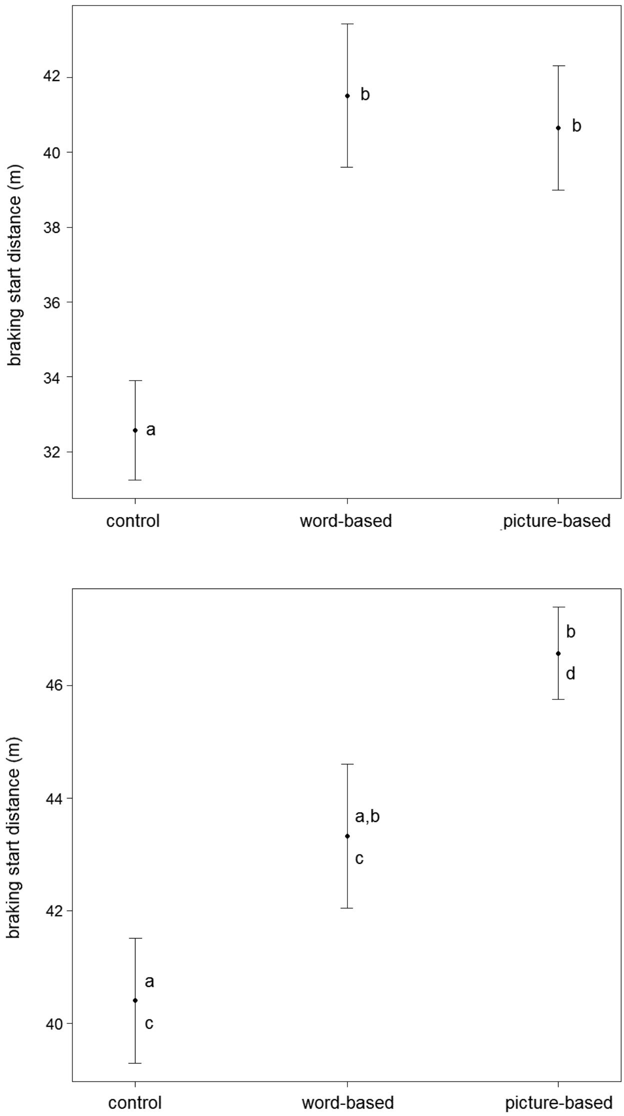

Figure 3. Braking distances by treatment. Means and standard errors of braking distances (m). Significantly different treatments have different letters next to them (a's and b's indicate significant differences at $\alpha = 0.05$; c's and d's indicate significant differences at $\alpha = 0.10$). **Top**- the three treatments at twilight. Control n = 26, word- and picture-based n = 29 because we removed outliers (>3 standard deviations from the grand mean); **Bottom**- in the three treatments at night. Control n = 27, word- and picture-based n = 30. Nighttime data were transformed using the Box-Cox transformation, but values in this figure are untransformed.

ences in reaction time (braking distance) at night. These results lend empirical support to Bond and Jones' (2013) survey results reporting that drivers rate picture-based signs higher for increasing alertness. Although fewer crashes occurred in the picture-based treatment than in the word-based treatment, this difference was not significant. However, this could be the result of our relatively low sample of crashes; in a larger study with more participants, we suspect that these trends would become significant.

The reduction in mean speed at twilight from 97 km/h in the control group to 89.5 km/h in the picture-based group (7.5 km/h difference) may seem small, but previous work shows that a change of this size could greatly reduce crash probability. In a meta-analysis of crash rates before and after speed limit changes on rural roads in Europe and the United States, Finch et al. (1994) fit a model predicting that with a 1 mph (1.6 km/h) decrease in speed, there is a corresponding 5% decrease in crash rate. Taylor et al. (2002) also found that as speed increases, crash rate increases, and particularly concerning severe crashes: in their model, a 10% increase in the mean speed on a roadway predicts a 30% increase in fatal and serious crashes. Therefore, our observed differences in speed would result in tangible safety benefits for humans and wildlife.

We also found significant differences in driver behavior at twilight and at night. Average speed was lower at night, which is almost certainly due to the different speed limits at twilight and night (60 mph vs. 45 mph). This reduction in speed was accompanied by earlier braking distances and a greatly reduced number of crashes at night. The lower nighttime speed limit in Big Cypress National Preserve was put in place to reduce animal-vehicle collisions, especially collisions with Florida panthers, and our simulator data support the potential effectiveness of this measure.

Our study also re-confirmed that age plays a significant role in driver safety, with participants in age group 1 being much more likely to crash than participants in age group 3. The difference between age groups 1 and 2 was very close to being significant as well, and we believe that with a larger sample size of crashes, the difference would probably be significant. This trend highlights the need to educate younger drivers about the danger of animal-vehicle collisions.

The trends within the interaction of RADS treatment and age group on braking start distance are also worth considering. Drivers in both the youngest and oldest age groups started braking earlier in response to picture-based RADS signs. Because the animal entered the road at the same point for all participants, the distance at which participants started braking is a proxy for brake reaction time. Brake reaction time (BRT) is the amount of time that passes between the moment the stimulus appears and when the driver's foot actually reaches the pedal (Shinar 2007). Contained within BRT is perception reaction time (PRT), the amount of time that passes between when a stimulus reaches a driver and the driver initiates a response. The BRT is therefore affected by the PRT; if people are primed to expect a stimulus, their PRT (and therefore, BRT) should be reduced. The slower the PRT, the longer the stopping distance, increasing the chance of collision (Shinar 2007). Thus, it appears that for two of three age groups tested, the picture-based RADS signs did a better job of priming participants to expect an animal, and therefore may be more effective in preventing collisions.

Simulator validity

Behaviors observed in a driving simulator may not accurately reflect real-life behaviors. The validity of using driving simulators to predict real-world crash rate was reviewed by Rudin-Brown et al. (2009). Although simulators cannot perfectly recreate real-world driving conditions, Rudin-Brown et al. conclude that the use of a simulator is acceptable if it recreates conditions with enough validity to measure the behavior being investigated. Behavioral validity can be absolute—do the simulator observations exactly match those in the real world?—or relative—do simulator observations have the same direction and similar magnitude to those in the real world? (Blaauw 1982). If the goal of a simulator experiment is to measure the effect of one treatment vs. another, as is often the case in human factors research, ensuring that simulators have adequate relative validity is more important than ensuring absolute validity (Törnros 1998).

In many studies evaluating driver speed, simulations achieved relative validity but not absolute validity (Törnros 1998; Klee et al. 1999; Godley et al. 2002; Bella 2008), though absolute validity has been documented (Yan et al. 2008). It is more common for simulations to achieve absolute validity in addition to relative validity with regard to certain behaviors (reviewed in Kaptein et al. 1996), such as lateral position of the vehicle in the lane (Törnros 1998) and route choice.

Future directions

To determine whether the results of our simulator study reflect responses to the RADS in the real world, our future research will validate the simulator data using field data. We will test the relative and absolute validity of our speed results by comparing speeds recorded during the simulation experiment to field recordings of speed through the RADS zone in Big Cypress National Preserve (as in Godley et al. 2002). We predict that speeds of participants in the simulator may be higher than those observed on the road, since previous studies have shown that when the road is relatively straight, participants drive faster in simulators (Boer et al. 2000). By comparing the simulator data to real-world data, we will gain a solid foundation from which to make management recommendations about the design and effectiveness of RADS.

Conclusions

Roadside animal detection systems are a promising technology to reduce the frequency of animal-vehicle collisions, but empirical testing has been difficult because of system malfunctions in the field. We overcame these difficulties by studying the effects of a particular RADS using a driving simulator, and our data suggest that RADS can indeed produce the intended results on crash probability, driver speed, and latency to brake. With improved RADS technology, these systems could be deployed on a larger scale as a cost-effective way to improve safety for humans and wildlife.

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