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Efficacy of an online native snake identification search engine for public use

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Abstract: Visual methods of species identification are used both in research and recreational contexts because they are inexpensive, non-invasive, and believed to be effective among uniquely identifiable individuals. We examined the ability of the general public to identify live snakes (Serpentes) that are native to the United States using an online snake identification search engine (SISE) produced by the North America Brown Tree Snake Control Team (NABTSCT) website, http://www.nabtsct.net. The SISE consisted of participants answering 7 descriptive questions concerning a snake and then reviewing photographs of snakes that matched that description. Using 3 species of snakes native to Texas, USA, 21% of 395 participants were able to correctly identify all of the snakes using the online SISE, 54% correctly identified 2 snakes, 18% correctly identified 1 snake, and only 7% could not identify any snakes. Participants identified the distinctly marked checkered garter snake (*Thamnophis marcianus*) more readily (87% of participants) than the gopher snake (*Pituophis catenifer*) and Trans-Pecos rat snake (*Bogertophis subocularis*; 55% and 46% of participants, respectively). The probability of participants correctly identifying a snake using the online SISE increased substantially if ≥4 of the 7 descriptive questions were answered correctly. The age of participants and affinity toward snakes affected participant ability to correctly answer questions about snake morphology and identify snakes. In general, participants who displayed fear of snakes were less likely to correctly identify snake species than those who expressed a snake-neutral or enthusiast attitude. Additionally, younger participants performed better, on average, than older participants. Most participants (97%) claimed they would be able to use the online SISE to correctly identify other snakes in the future. We believe the public can use the online SISE to identify snakes, and hence, it can be an educational tool for the public to learn about an often neglected wildlife suborder.

Key words: *Bogertophis subocularis,* internet, native snake species, *Pituophis catenifer*, search engine, Serpentes, snake identification, taxonomic key, *Thamnophis marcianus*, United States

Snake (Serpentes) identification can be difficult, especially for the general public, because species can be similar in appearance, a general negative stigma concerning snakes potentially creates situational stress, and a fear of potential danger exists with venomous or aggressive species (Corbett et al. 2005). Morrison et al. (1983) found that Australians who had different experience levels with snakes and varying education levels could identify approximately 1 of 5 Australian snakes. Although Corbett et al. (2005) found that most U.S. citizens could identify rattlesnakes (*Crotalus* spp.) as venomous with 81% accuracy, the investigators did not analyze the ability of the general public to identify other venomous species.

Unfortunately, much of the general public is unlikely to own a snake identification handbook, and even more unlikely to have that handbook available or accessible at the moment when encountering a snake. An online snake identification system could be extremely useful to the general public who work in their yards or recreate outdoors where they can access the internet quickly via a cell phone, tablet, or laptop, and be able to identify a snake as a potential venomous threat or a non-venomous species. In addition, wildlife biologists and ecologists may find value in such a system for identifying snake species on research sites or other environmental locations, especially considering the number of species of snakes and potential color variations within species.

For example, 68–76 species of snakes occur just in Texas, USA (the exact number of species is debated), and the number increases to 115 if subspecies are included (Texas Parks and Wildlife 2019).

A quick and easy-to-use guide can assist conservation enthusiasts in differentiating native from exotic species. Such a guide can be extremely beneficial because invasive species introductions are occurring worldwide at an alarming rate and are considered to be an ecological threat to conservation (Meyerson and Mooney 2007). Approximately 50,000 invasive species occur within the United States, causing annual environmental damages and losses in excess of $100 billion (Pimentel et al. 2005). For example, the brown tree snake (*Boiga irregularis*) is an invasive species on the island of Guam whose population explosion during the 1960s caused extensive ecological damage on the island (Rodda et al. 1992). Also, nearly half of the species are considered at risk of extinction primarily because of invasive species (Pimentel et al. 2005). In addition, misidentification of species can have conservation implications for threatened and endangered species (Somaweera et al. 2010). Therefore, the ability of the general public to identify invasive species could be a useful tool in early detection and prevention of invasive species introduction.

The North America Brown Tree Snake Control Team (NABTSCT) is working to prevent the accidental introduction of the brown tree snake into the continental United States through a collaborative group effort involving federal and state agencies as well as private organizations. Among the many preventative efforts of the group, a snake identification search engine (SISE) for the NABTSCT website (http://www.nabtsct.net) was developed, which includes a database of native snakes in the continental United States, along with photographs and information sheets about those snakes. Information sheets include data concerning snake morphology, habitat, feeding habits, and a distribution map. This database was placed on the NABTSCT website to assist the general public in their ability to identify native snakes and therefore, by default, help the general public to identify non-native snakes.

The use of individual color pattern to identify species is attractive as a relatively inexpensive, non-intrusive method for identification and may allow identification at a distance, of which examples of identifying species by color pattern include caecilians (Apoda; Wright and Minott, 1999), salamanders (Urodela; Hagstrom 1973, Loafman 1991), frogs (Anura; Kurashina et al. 2003, Bradfield 2004), turtles (Testudines; McDonald et al. 1996), lizards (Lacertilia; Rodda et al. 1988), and snakes (Sheldon and Bradley 1989, Moon et al. 2004). Nonetheless, the method has not been evaluated in most patterned species, and important methodological considerations remain poorly studied. Although several validation studies have been conducted, these typically focus on a small number of highly experienced researchers. In the field, however, the method may also be used by less experienced assistants or by citizen scientists.

The objective of our study was to determine if participants could correctly identify live snake specimens to species using the online SISE. We hypothesized that individuals with higher snake affinities would be better able to identify snakes and that the youngest age group (i.e., 18–25 years old) would have a better ability to identify snakes than the middle or older age groups. We conjectured that less fear of snakes will equate to a person's ability to focus on greater detail concerning snake morphology and color pattern and that the youngest age class has been exposed to reptiles via television (e.g., *Crocodile Hunter*, *Swamp People*, *Animal Planet*, *National Geographic WILD*) more so than middle-to-older age groups and thus, desensitized this generation of their potential fear. We hypothesized that answering more descriptive questions correctly on the online SISE would increase participants' abilities to correctly identify snakes. We further contend increased access to a snake identification system, such as the one on http://www.nabtsct.net, will aid the public in identifying snakes and, therefore, hopefully increase their knowledge and appreciation of snakes.

Methods

To determine the usefulness of the online snake identification search engine, our investigation was conducted in 3 parts, which included a pre-survey questionnaire, snake identification via the online SISE, and a post-survey questionnaire. Research was conducted during February through October 2015 on the campus of Texas A&M University-Kingsville (TAMUK). Participants were solicited in advance and gave consent to participate in the survey (Human Subject IRB Protocol 2009-164). Due to low risk status to human subjects and prior approval, the current project was expedited and a new IRB number was not issued. Participants (n = 395) were associated with TAMUK, either as undergraduate students (n = 170), graduate students (n = 53), serving as faculty or staff (n = 99; e.g., secretaries, physical plant, grounds maintenance employees), or as walk-in participants having contractual agreements with TAMUK (n = 73; e.g., construction workers, custodial personnel). Every study that uses inferential statistics must make a judgment concerning the relationship between the sampled population and the inferential population (Kendall and Stuart 1983). We believe that our sample was representative of the general public because they represented 6 ethnic cultures (Hispanic, 53%; Caucasian, 23%; African-American, 13%; Asian, 4%; Indian, 4%; Other (Native American/Alaskan/Pacific Islander, 3%), 4 education levels (high school diploma, 20%; some college, 49%; bachelor's degree, 24%; graduate and professional degree, 7%), and hailed from various economic backgrounds from 7 countries. Students who participated in the study were education (n = 81), sociology/psychology (n = 59), engineering (n = 56), and agriculture (n = 27) majors; therefore, the majority of students who participated in the study likely had little prior experience or knowledge of snakes. We believe that our sampled population is no more biased with more or less ability than the average person, and thus, representative of the general public.

Pre-survey questionnaire

The pre-survey questionnaire consisted of 10 questions that were used to categorize participants by age class (i.e., 18–25, 26–40, and 41+ years old) and determine participants' affinity toward snakes (i.e., Afraid, Neutral, or Enthusiast). Wilson (1993) introduced the idea that humans inherently have both a genetic aversion to snakes and a fascination for snakes. Snake affinity was determined using a 40-point system based on the participants' answers to 8 questions (Appendix 1). Our questionnaire included 3-, 5-, and 6-point scale questions; Jacoby and Matell (1971) indicated that 3-point scales are sufficient and appropriate. Using a bell-shaped curve, an overall score of 0-9 was defined as no-to-low affinity or "Afraid," 10–31 points was defined as moderate affinity or "Neutral," and 32–40 points was deemed high affinity or "Enthusiast" toward snakes.

Online snake identification search engine

The online SISE is a web-based, interactive field guide to assist users in identifying native snakes of the United States based on user answers to 7 descriptive questions concerning snake morphology. Three native Texas snakes were used to assess the online SISE. A gopher snake (*Pituophis catenifer*), a Trans-Pecos rat snake (*Bogertophis subocularis*), and a checkered garter snake (*Thamnophis marcianus*) were captured in southern Texas and held in captivity within individual 208-l terraria on the TAMUK campus for the duration of the study according to standards set by Institutional Animal Care and Use Protocol (ACUC 2009-04-09). These species of snakes were selected to test the online SISE because they represented different levels of color pattern distinction. Checkered garter snakes have a unique color pattern with multiple colors and were considered easier to correctly identify, whereas the colors and patterns of gopher and Trans-Pecos rat snakes are similar to other snake species, and therefore potentially more difficult to correctly identify. The snakes were provided food and water *ad libitum*, a 5-cm layer of Exo-Terra snake bedding, shelter cover, heating rock and cool rock for thermoregulation, and a ventilation cover.

During the SISE assessment, participants were asked to identify the 3 snakes previously described by using the online SISE located within the NABTSCT Snake Identification System webpage at http://www.nabtsct.net. Live specimens were placed individually in an enclosed 113-l terraria with only a thin layer of Exo-Terra snake bedding and no hiding cover so participants could view the entire snake. One of the previously described snakes was displayed at each of 3 separate stations, which were surrounded by 3 90 x 120-cm cardboard,

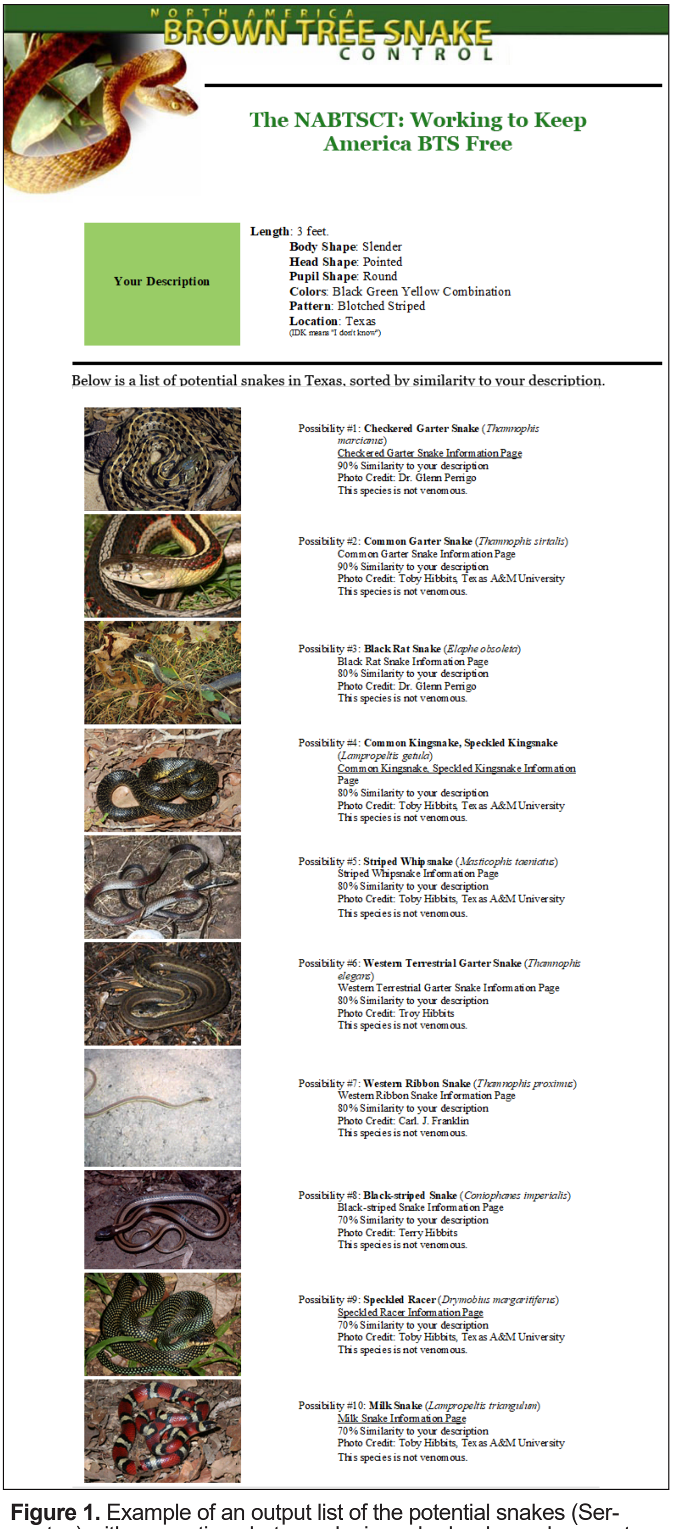

Figure 1. Example of an output list of the potential snakes (Serpentes) with respective photographs in ranked order and percent similarity provided by the snake identification search engine on the North America Brown Tree Snake Control Team website (http://www.nabtsct.net), based on the responses to 7 descriptive questions (i.e., green box labeled Your Description). Snake identification search engine evaluation, 2015, Texas A&M University-Kingsville, USA.

self-standing tri-fold poster boards to block participants from viewing a snake at another station. Stations also contained a computer with a 48-cm monitor screen, which provided participants access to the online SISE descriptive questions and photos of the search results. Participants were randomly assigned snake order. Participants were given survey directions verbally, and written directions were available at each station. At each station, participants were allowed unlimited time to view the live specimen, answer the 7 descriptive questions asked by the online SISE, review the search results that included a photograph, description, and similarity index to the participant's description of the snake (Figure 1), identify each snake, and print the results of their search before moving to the next station. We believed it was important to allow participants to be as close as possible to the snake and to have an unlimited amount of viewing time because presumably if participants were unsuccessful under this scenario, then we assume they also would not be successful in identifying snakes in the wild from a greater distance and with limited viewing time.

The 7 descriptive questions of the online SISE included total length, body shape, head shape, pupil shape, color pattern, color, and location (i.e., state in which the snake was observed). Because the snakes were in captivity, participants were informed that all of the snake locations were from Texas. The SISE web page contained labeled photographic examples of snakes that exhibited each body shape, head shape, pupil shape, and color pattern as examples to assist users in differentiating morphology characteristics. Participants also

Table 1. Total points accumulated from 8 questions on the pre-survey questionnaire to determine snake (Serpentes) affinity (Afraid = 0–9 points, Neutral = 10–31 points, Enthusiast = 32–40 points) of 395 people who participated in the online native snake identification search engine. Snake identification search engine evaluation, 2015, Texas A&M University-Kingsville, USA.

	18–25 years old			26–40 years old			40+ years old		
Variable	Afraid	Neutral	Enthusiast	Afraid	Neutral	Enthusiast	Afraid	Neutral	Enthusiast
Number of participants	24	140	56	14	66	27	19	37	12
% of participants	6.1	35.4	14.2	3.5	16.7	6.8	4.8	9.4	3.0
Mean (±SE)	3.5±0.4	21.1±0.2	35.9±0.4	3.4±0.6	21.0±0.5	35.4±0.5	3.0±0.4	21.3±0.5	36.8±0.8
Range	0–6	15–26	32–40	0–6	14–27	33–40	0–6	15–25	32–40
Median	3.5	21.0	36.0	4.0	22.0	35.0	4.0	22.0	36.5
Mode	3	22	36	4	23	35	4	20	36

were provided with the option to choose "I Don't Know" as an answer to any of the above questions. An investigator was available at all times during the assessment to answer methodology questions, help with printing the search results, and ensure that participants followed directions correctly.

Post-survey questionnaire

After completion of the SISE assessment, participants were asked to complete a post-survey questionnaire that assessed their perspective of the SISE. In addition, participants were asked to list any problems they had answering questions or with identifying snakes, and if they could offer recommendations, suggestions, or comments about improvements to the SISE.

Statistical analysis

We used Cronbach's alpha (Cronbach 1951) to assess reliability (internal consistency; Tavokal and Dennick 2011) of our pre-test survey questions as indicators of their affinity/disaffinity for snakes. We used a chi-square test to examine the frequency distribution of participants' age and affinity toward snakes. Analysis of variance was used to determine the effects of participant age group and snake affinity as well as their interaction on the total number of snakes a participant could identify and on the number of survey questions correctly answered. These dependent variables are count data and assumptions underlying analysis of variance were not satisfied; analysis on a "log + 1" was not effective in improving heteroscedasticity, and a rank transformation is not appropriate for models that include interaction terms (Conover 1999). Therefore, we analyzed normal scores following Mansouri and Chang (1995); means and standard errors are presented on the observed scale. We created a subset of data that included respondents who answered survey questions correctly, and we tested effects of age class, affinity level, and survey question (as well as their 2- and 3-way interactions) on the proportion of correctly identified snakes for each species using hierarchical modeling of a log-linear model following Bishop et al. (1975) and Sokal and Rohlf (2012). To control error rates, we tested simple main effects only following a significant interaction, and we tested simple effects only if simple main effects were significant (Kirk 2013; also see Carmer and Swanson 1973, Wester 2018). Descriptive statistics were used to evaluate participants' answers to specific questions within the post-survey questionnaire. In all analyses, we determined significance using an α-level of 0.05.

Results

Pre-survey questionnaire

Cronbach's alpha was $\alpha = 0.983$ ($n = 395$ with $p = 8$ survey items), indicating that our 8 pre-test survey items reliably indicated participants' attitudes/affinity or disaffinity toward snakes. Pre-survey questionnaire analysis showed that of the 395 participants, 24, 140, and 56 participants within age class of 18–25 years

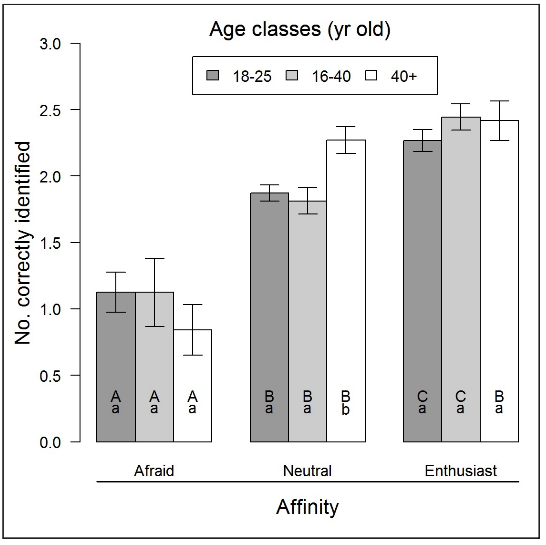

Figure 2. Interaction of participant age class (i.e., 18–25, 26–40, and 41+ years old) and snake (Serpentes) affinity (i.e., afraid, neutral, and enthusiast) on the total number of snakes correctly identified by 395 participants using the online snake identification search engine on the North America Brown Tree Snake Control Team website (http://www.nabtsct.net). Mean bars with the same uppercase letter are not different ($P > 0.05$) between snake affinities within the same age class. Mean bars with the same lowercase letter are not different ($P > 0.05$) between age classes within the same snake affinity. Snake identification search engine evaluation, 2015, Texas A&M University-Kingsville, USA.

old were classified with the snake affinity of afraid, neutral, and enthusiast, respectively; within the group 26–40 years old, 16, 64, and 27 participants were classified as afraid, neutral, and enthusiast, respectively; and within the age class of 41+ years old, 19, 37, and 12 participants were classified as afraid, neutral, and enthusiast, respectively (Table 1). We observed an effect between participant age class and snake affinity ($\chi^2_4 = 12.2$, $P = 0.02$), with 82% of the chi-square value attributed to the afraid snake affinity. Age classes 41+ years and 18–25 years had more than and less than expected proportions of their populations, respectively, with an afraid and enthusiast affinity toward snakes.

Online snake identification search engine

General trends concerning participant performance were apparent across all snakes. Participants performed better in identifying the checkered garter snake (87% of participants) than the gopher (55% of participants) and Trans-Pecos rat snakes (46% of participants). Participant age and snake affinity interacted ($F_{2,386} = 2.45$, $P = 0.0457$) in their effects on the total number of snakes correctly identified (Figure 2). Snake affinity affected number of snakes identified for each age group ($P < 0.0001$ for each of $F_{1,386}$ = 20.81, 16.37, and 25.95, respectively, for age groups 18–25, 26–40, and 41+ years old). As expected, participants classified as having an afraid affinity toward snakes were less likely to correctly identify snakes than those in the neutral affinity, while those classified in the enthusiast affinity who were ≤40 years old performed the best (Figure 2). For example, 73% of the 59 participants classified as afraid only could correctly identify ≤1 snake species, whereas 95% of the 95 participants classified as enthusiasts could correctly identify at least 2 of the 3 snake species (Table 2). Although age class affected ($F_{1,386} = 5.68$, $P = 0.0037$) number of snakes correctly identified for participants who had neutral affinity, age class had no effect for participants with afraid ($F_{1,386} = 0.80$, $P = 0.4522$) or enthusiast ($F_{1,386} = 0.70$, $P = 0.4948$) affinities (Figure 2, Table 2). Participants >40 years old and classified as having a neutral or enthusiast affinity toward snakes performed similarly in their ability to correctly identify snakes (Figure 2). Age differences within snake affinities were not apparent in participants' ability to correctly identify snakes, except within the neutral affinity groups where participants 41+ years old performed better than the younger groups (Figure 2).

The number of correctly answered survey questions interacted with snake species in their effects on ability to correctly identify snakes ($F_{2,789} = 6.24$, $P = 0.0021$; Figure 3). This interaction was largely ($F_{1,789} = 6.0$, $P = 0.0146$) comprised of the contrast between checkered garter snakes compared with gopher and Trans-Pecos rat snakes; the effect of number of correctly answered survey questions on ability to identify snakes was similar ($F_{1,789} = 2.93$, $P = 0.0873$) between gopher and Trans-Pecos rat snakes. The odds of correct identification increased 676%, 1,341%, and 9,680% for every additional survey question answered correctly for gopher snakes, checkered garter snakes, and Trans-Pecos rat snakes, respectively. The probability of correct identification increased greatly for all species if >4 survey questions were correctly answered (Figure 3).

Table 2. Percent of participants (N = 395) within each age class and snake (Serpentes) affinity who correctly answered the 7 snake morphological descriptive questions of the online snake identification search engine (http://www.nabtsct.net) for each snake. Snake identification search engine evaluation, 2015, Texas A&M University-Kingsville, USA.

	Snake affinity												
	Afraid				Neutral				Enthusiast				
	Age group				Age group				Age group				
	18–25 (n = 24)	26–40 (n = 16)	40+ (n = 19)	Affinity ave.	18–25 (n = 140)	26–40 (n = 64)	40+ (n = 37)	Affinity ave.	18–25 (n = 56)	26–40 (n = 27)	40+ (n = 12)	Affinity ave.	Age ave.
Checkered garter snake (*Thamnophis marcianus*)													
Correct identification	0.71	0.56	0.53	0.61b[1]	0.89	0.88	0.95	0.90a	0.97	1.00	1.00b	0.98a	
18–25													0.89A[2]
26–40													0.86A
40+													0.84A
Total length	0.88	1.00	0.95		0.98	1.00	1.00		1.00	1.00	1.00		
Body shape	0.71	0.81	0.84		0.88	0.97	1.00		0.98	1.00	1.00		
Head shape	0.83	0.88	0.68		0.91	0.92	0.97		0.96	1.00	1.00		
Pupil shape	1.00	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00		
Color	1.00	1.00	1.00		0.99	0.98	1.00		1.00	1.00	1.00		
Color pattern	0.50	0.62	0.58		0.88	0.95	0.95		0.98	1.00	1.00		
Gopher snake (*Pituophis catenifer*)													
Correct identification	0.29	0.31	0.21	0.27a[1]	0.56	0.52	0.65	0.56b	0.68	0.74	0.67	0.69b	
18–25													0.56A[2]
26–40													0.54A
40+													0.53A
Total length	0.83	1.00	0.84		0.98	0.97	1.00		1.00	1.00	1.00		
Body shape	0.79	0.88	0.84		0.88	0.89	0.97		0.88	0.93	1.00		
Head shape	0.75	0.94	0.53		0.87	0.84	0.84		0.89	0.85	0.75		

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Pupil shape	0.88	1.00	0.95		0.96	0.98	1.00		0.98	1.00	1.00		
Color	1.00	1.00	1.00		0.99	1.00	1.00		1.00	1.00	1.00		
Color pattern	0.46	0.75	0.42		0.78	0.81	0.89		0.82	0.93	0.83		
Trans-Pecos rat snake (*Bogertophis subocularis*)													
Correct identification	0.12	0.12	0.10	0.12a[1]	0.41	0.42	0.68	0.45b	0.62	0.70	0.75	0.66c	
18–25													0.43A[2]
26–40													0.45A
40+													0.55A
Total length	0.92	1.00	0.89		0.98	0.97	1.00		1.00	1.00	1.00		
Body shape	0.83	0.81	0.79		0.84	0.86	0.92		0.84	0.85	1.00		
Head shape	0.58	0.62	0.47		0.80	0.80	0.81		0.80	0.85	0.83		
Pupil shape	1.00	1.00	0.89		0.93	0.94	1.00		0.96	0.96	1.00		
Color	1.00	1.00	1.00		1.00	1.00	1.00		1.00	1.00	1.00		
Color pattern	0.42	0.62	0.47		0.62	0.50	0.76		0.75	0.92	0.67		

[1] Proportion correctly identified among affinity groups followed by the same lowercase letter are not significantly different ($P < 0.05$).
[2] Proportion correctly identified among age classes followed by the same uppercase letter are not significantly different ($P < 0.05$).

Twenty-one percent of participants were able to identify all of the snakes using the online system, 54% identified 2 out of the 3 snakes, 18% identified 1 out of the 3 snakes, and 7% could not identify any snakes (Table 2). Most participants (>88%) answered all the survey questions correctly for the checkered garter snake; however, they experienced greater difficulty in correctly answering survey questions for the other snakes (Table 3). In general, 97–98%, 95–100%, and 99–100% of participants, respectively, correctly answered questions of snake length, pupil shape, and snake color but varied in their ability to correctly answer questions of body shape (85–92% of participants), head shape (77–92% of participants), and color pattern (64–88% of participants; Table 3).

Incorrect answers within the snake survey would reduce the percent similarity match and ranked order of the correct snake within the output results (Table 4). However, different incorrect answers would result in different ranked orders, which would affect the probabilities of participants selecting the correct snake. For example, if a participant correctly answered all questions correctly for the Trans-Pecos rat snake except for head shape, even though the percent similarity match of correct responses would remain at 83%, the ranked output for the Trans-Pecos rat snake would change from 2 to 3 to 5 for incorrect answers of "I don't know," "round" or "triangular," and "pointed," respectively (Table 4).

Combinations of incorrect responses for head shape, pupil shape, and color pattern resulted in even further reductions of percent similarity match and ranked order of the correct snake within the output list of snakes. For example, if a participant incorrectly answered the questions of head shape and color pattern, then the ranked order for the checkered garter snake, gopher

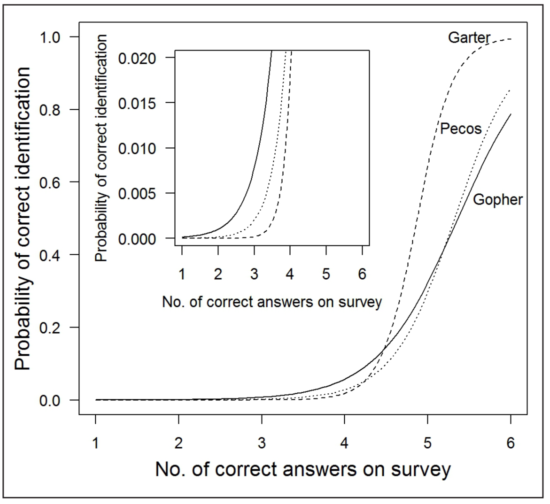

Figure 3. The probability of correct identification of a checkered garter snake (*Thamnophis marcianus*), gopher snake (*Pituophis catenifer*), and Trans-Pecos rat snake (*Bogertophis subocularis*) interacted with the number of correct answers to 7 descriptive questions asked by the online snake identification search engine on the North America Brown Tree Snake Control Team website (http://www.nabtsct.net). Inset: the probability of correct identification was highest for gopher snakes and lower for checkered garter and Trans-Pecos rat snakes when number of correct answers was between 3 and 4, but highest for checkered garter snakes and lower for Trans-Pecos rat and gopher snakes when number of correct answers was >4. Snake identification search engine evaluation, 2015, Texas A&M University-Kingsville, USA.

snake, and Trans-Pecos rat snake would reduce to as low as twelfth, ninth, and twenty-fourth within the snake output list. Ranked order of Trans-Pecos rat snakes was most affected by incorrect responses than the other two snakes. For example, 2, 3, and 6 incorrect responses would result in ranked orders as low as ninth, sixteenth, and thirty-sixth for gopher snakes, but the same incorrect responses would result in ranked orders as low as twenty-fourth, thirty-first, and sixtieth for Trans-Pecos rat snakes.

Concerning the effects of affinity, age class, and survey question on individual snake identification, 2-way and 3-way interactions did not occur for gopher and Trans-Pecos rat snakes (Table 5). However, snake identification differed among age class levels, affinity levels, and survey questions (Table 2). For these snakes, snake enthusiasts performed better than participants with neutral affinities, followed by participants with affinities considered afraid of snakes (Table 2). In addition, the younger participants performed better than the older participants concerning the gopher snake, while the older participants performed better than the other age classes for the Trans-Pecos rat snake (Table 2). Due to the interaction of age and affinity for participants identifying checkered garter snakes, those variants were analyzed separately. When analyzed by affinity, of those afraid of snakes, the youngest age class performed better than the other age groups, those with a neutral affinity displayed the opposite effect with the oldest age class performing better than the other age groups, while enthusiasts displayed no difference among ages (Table 2). When analyzed by age, participants who were neutral and those who were snake enthusiasts performed better than those afraid of snakes (Table 2). Finally, although the proportion of correctly identified snakes differed among correctly identified survey questions, these proportions varied only between 80–85%, 55–67%, and 45–65% for checkered garter snakes, gopher snakes, and Trans-Pecos rat snakes, respectively.

Post-survey questionnaire

Sixty-seven (17%) of the 395 participants claimed that their nervousness about being in a room with snakes most likely affected their ability to correctly answer morphological questions about each snake. When asked about the ease of answering the descriptive questions concerning the morphology of snakes within the SISE, 31% of participants claimed that they were unsure about head shape, 47% were unsure about the snakes' color pattern, 16% were unsure about body shape, 8% were unsure about color, and only 4% were unsure about pupil shape. Even though 92% of participants claimed that the online photographic examples of head shape and color pattern helped them with their answers to those questions, these were the most often missed questions within the SISE. Although 100% of participants reported that they were given sufficient time to answer all of the questions on the SISE web page, 78% reported that spending more time examining the snakes could have increased their ability to correctly identify them. Also 97% of survey participants believed they would be able to use the online SISE to correctly identify other snakes in the future.

Table 3. Number of participants ($N = 395$) who answered the snake (Serpentes) morphological descriptive questions correctly and either identified the snake correctly or incorrectly using the snake identification search engine at http://www.nabtsct.net. Snake identification search engine evaluation, 2015, Texas A&M University-Kingsville, USA.

	Snake morphological descriptive questions											
	Length		Body shape		Head shape		Pupil shape		Color		Color pattern	
Snake species Response[1]	*N*	%[2]	*N*	%[2]	*N*	%[2]	*N*	%[2]	*N*	%[2]	*N*	%[2]
Checkered garter snake (*Thamnophis marcianus*)												
Snake ID correct	344	87	330	84	330	84	345	87	344	87	328	83
Snake ID incorrect	45	11	32	8	32	8	50	13	49	12	18	5
Question correct	389	98	362	92	362	92	395	100	393	99	346	88
Gopher snake (*Pituophis catenifer*)												
Snake ID correct	217	55	204	52	192	49	218	55	218	55	206	52
Snake ID incorrect	166	42	147	37	140	35	165	42	176	44	100	25
Question correct	383	97	351	89	332	84	383	97	394	99	306	77
Trans-Pecos rat snake (*Bogertophis subocularis*)												
Snake ID correct	178	45	161	41	156	40	174	44	179	45	164	42
Snake ID incorrect	208	53	175	44	148	37	202	51	216	55	87	22
Question correct	386	98	336	85	304	77	376	95	395	100	251	64

[1] Response includes participants who correctly identified the snake to species (i.e., snake ID correct), participants who identified the snake to a wrong species (i.e., snake ID incorrect), and participants who answered the snake survey question correctly (i.e., question correct).
[2] Percentage of participants who answered the snake survey question correctly divided by the total number of participants.

Table 4. Results to the 7 morphological descriptive questions asked of participants by the online snake identification search engine of the North America Brown Tree Snake Control Team website (http://www.nabtsct.net) to aid in identifying 3 native U.S. snake (Serpentes) species (i.e., gopher snake [*Pituophis catenifer*], checkered garter snake [*Thamnophis marcianus*], and Trans-Pecos rat snake [*Bogertophis subocularis*]). Results of percent similarity match and snake ranking for 3 snakes as generated by the snake identification system, if participants provided all correct responses but varied by the single row response. Snake identification search engine evaluation, 2015, Texas A&M University-Kingsville, USA.

	Snakes used in assessment of snake identification search engine[1]					
Question	Gopher snake		Checkered garter snake		Trans-Pecos rat snake	
Response option	% match [2]	Ranking[3]	% match	Ranking	% match	Ranking
Total length (only one choice accepted)						
<30 cm	83%	1	90%	1	83%	1
30–60 cm	83%	2	100%●[4]	1	83%	1
61–90 cm	83%	2	100%●	1	83%	1
91–120 cm	100%●	1	100%●	1	100%●	1
121–150 cm	100%●	1	90%	3	100%●	1
151–180 cm	100%●	1	90%	3	100%●	1
181–210 cm	100%●	1	90%	3	100%●	1
>210 cm	83%	1	90%	1	83%	1
IDK[5]	100%	1	100%	1	100%	1
Body shape (only 1 choice accepted)						
Slender	100%●	1	100%●	1	100%●	1
Fat	83%	2	90%	1	83%	1
IDK[5]	100%	1	100%	1	100%	1
Head shape (only 1 choice accepted)						
Slightly larger than neck	83%	6	90%	1	100%●	1
Pointed	67%	16	100%●	1	83%	5
Triangular	100%●	1	90%	1	83%	3
Round	83%	6	90%	1	83%	3
IDK[5]	100%	6	100%	1	100%	2
Pupil shape (only 1 choice accepted)						
Round	100%●	1	100%●	1	100%●	1
Elliptical	83%	2	90%	1	83%	2
IDK[5]	100%	1	100%	1	100%	1
Color (multiple choices accepted)						
Brown	100%●	1	100%●	2	100%●	1
Blue	83%	1	86%	2	83%	1
Green	83%	1	86%	2	83%	1
Black	100%●	1	100%●	1	83%	1
Red	83%	1	86%	2	83%	1
Orange	83%	3	86%	3	83%	2

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Pink	83%	1	86%	2	83%	1
Yellow	100%●	1	100%●	2	100%●	1
White	83%	1	86%	2	83%	1
Grey	83%	6	86%	2	83%	3
Combination	100%●	1	100%●	1	100%●	1
IDK[5]	100%	1	100%	2	100%	1
Color pattern (multiple choices accepted)						
Solid	86%	2	89%	3	86%	2
Banded	86%	3	89%	5	87%	1
Blotched	100%●	1	100%●	1	100%●	1
Diamond	86%	2	89%	2	87%	1
Striped	86%	2	100%●	1	87%	1
Spotted	86%	3	100%●	1	87%	2
Speckled	86%	3	89%	3	87%	2
Location (all 50 states included – select state where snake was seen)						
Texas (for purposes of our survey)						

[1]Snake species used during the assessment of the online snake identification search engine (http://www.nabtsct.net) were a gopher snake (*Pituophis catenifer*), checkered garter snake (*Thamnophis marcianus*), and Trans-Pecos rat snake (*Bogertophis subocularis*).
[2]Percent match = the % similarity match of the selected response options selected by participants compared to the correct descriptive responses for each snake species.
[3]Ranking = placement of the correct species within the list of the potential 127 snake species that occur within the United States.
[4]● = correct response for the selected snake species as listed within the snake identification system programming.
[5]IDK = I don't know.

Discussion

We believe the SISE performed satisfactorily because 75% of the participants were able to identify at least 2 of the 3 snakes correctly, and especially so because most of the participants likely had no formal education or training with reptiles, having an educational background in non-wildlife-oriented fields. As expected, those afraid of snakes were less likely to correctly identify snakes than the average participant. Such participants admitted during the post survey questionnaire that they were uncomfortable being so near to snakes, even though they realized the snakes were contained within a terrarium. They admitted that their fear preoccupied their thoughts and made them pay less attention to detail than participants of other affinity groups. By contrast, snake enthusiasts seemed fascinated by the snakes and appeared to sit closer to the glass of the terrariums to observe snakes than the average participant. Their fascination with snakes may have led them to observe greater details about the snakes, thus leading them to a correct identification. If those who were classified as afraid are removed from this study, then the percent of participants who correctly identified at least 2 snakes would increase. Removing the participants from the analysis who were afraid would be a fair assessment of the actual success of the online SISE because it is unlikely a person who is afraid of snakes would take the time to observe a free-ranging specimen and then go online to identify it. However, an educational program developed specifically for those afraid of snakes would be beneficial to assist this demographic in overcoming their fear of snakes, and thus, participate in the SISE.

No snake affinity group correctly identified all snakes. Incorrect snake identifications may have been caused by participants' assumptions that they had correctly answered the questions about the snake's morphology; therefore, the snake should be at the top of the output list. An alternate reason for an incorrect identification

Table 5. Log-linear analyses to test effects of participant age group (i.e., 18–25, 26–40, and 41+ years old), snake (Serpentes) affinity (i.e., afraid, neutral, enthusiast) on number of survey questions answered correctly for 3 native U.S. snake species (i.e., gopher snake [*Pituophis catenifer*], checkered garter snake [*Thamnophis marcianus*], and Trans-Pecos rat snake [*Bogertophis subocularis*]). Snake identification search engine evaluation, 2015, Texas A&M University-Kingsville, USA.

Snake	Checkered garter snake			Gopher snake			Trans-Pecos rat snake		
Statistical design variable	df	χ^2	*P*	df	χ^2	*P*	df	χ^2	*P*
Age group	na[1]	na	na	46	15.1	0.99	46	59.6	0.0867
Snake affinity	na	na	na	46	140.8	0.0001	46	288.0	0.0001
Question	49	154.4	0.0001	49	23.6	0.99	49	44.6	0.6523
Age x Affinity	24	134.8	0.0001	24	11.9	0.98	24	15.4	0.91
Age x Question	30	5.3	0.99	30	2.9	0.99	30	4.2	0.99
Affinity x Question	30	8.7	0.99	30	3.4	0.99	30	3.9	0.99
Age x Affinity x Question	20	2.6	0.99	20	2.4	0.99	20	3.5	0.99

[1]Single variable analyses were not conducted if significant ($P < 0.05$) interactions occurred.

could be that certain participants did not take the time to examine the full list of snakes within the output list before making a decision. Although participants had as much time as they desired to spend with each snake, many expressed concern about needing to return to their daily routine. In addition, information on where participants were born or where they grew up could be a geographic or heritage bias that was not taken into account. However, even though participants had some difficulty answering certain morphological identification questions about each snake, most believed that they would be able to correctly identify snakes using the online system in the future.

Most participants correctly identified the checkered garter snake, but identification of the Trans-Pecos rat snake and the gopher snake was more variable. This result was anticipated; we predicted that people would display a general difficulty in identifying snakes with less distinctive patterns and color combinations than the bright yellow and black pattern exhibited by the checkered garter snake. Unique colors and patterns improve our ability to identify species (Kaufman 2011).

Our assumption that younger participants would perform better than older participants also appeared true. Reasons for this could be 2-fold. One, millennials have been potentially exposed to more information concerning reptiles via television, YouTube, and the internet, and thus may have lost some fear about snakes. Knowledge gap hypothesis states that fear reduces as people gain knowledge (Bonfadelli 2002). Secondly, millennials grew up with the internet and appear to display a greater confidence and knowledge of its use (Twenge et al. 2010). Although not tested within this study, younger participants appeared less intimidated by an online identification system and maneuvered through the system with ease.

We received positive feedback from most participants about the online SISE. Suggestions for improvement included: (1) make additional color choices available to describe a snake and to supplement that change with photographic examples of each color, and (2) have multiple photographic examples of head shape, body shape, and color pattern so participants can clearly see differences between each morphological characteristic. Participants believed that incorporating the above 2 suggestions would reduce time required to correctly identify a snake. We believe the online SISE would improve its user-friendliness if such suggestions were incorporated. For example, the current Generation Z demands immediate information at their fingertips (Twenge et al. 2010). Although not analyzed, the average time participants took to identify a snake was <12 minutes. Reducing time to acquire this information is preferable, which likely could result in an increased use of the online SISE.

The online SISE is a living system, meaning that new information as it becomes available concerning snake species and additional photographs of snakes will be used to update the system. Such information and photographs can be sent to the first author so that the online SISE can be as current as possible. The online SISE may be ideal for citizen science groups to learn of the snake species that occur in their region. The ease of the SISE can be demonstrated in schools to educate children about a historically lesser-known group of wildlife (i.e., reptiles), to educate the difference between venomous and non-venomous snakes, and to educate the ecological value of snakes to children. Perhaps someday the old belief that the only good snake is a dead snake can fade and a new generation of appreciation for all species can arise. Public education and advertisement of the online SISE may increase its use by the public as a general tool for education and identification of snakes.

The improvement of prevention systems for invasive species should be a priority among both governmental organizations and scientific researchers (Waage and Reaser 2001). Public outreach and education are essential in increasing awareness of invasive species. Morgan and Gramann (1989) found that following education in the sciences related to wildlife, students' attitudes toward wildlife generally improve. The addition of educational tools, such as the online SISE, can help prevent potential spread and impacts of invasive species (Mack et al. 2000).

The online SISE could aid in early detection of invasive snakes through identification and reporting by the general public. It allows for identification in less time and uses a tournament-type methodology to weed out the species that don't match, which can reduce misidentification. For example, as known hitchhikers within various means of transport, brown tree snakes disperse from the island of Guam in cargo, which include household shipments that are being received and ultimately opened by civilians in their homes (Rodda et al 1992, Kahl et al. 2012*a*). If a brown tree snake were to be found in household goods, an unsuspecting civilian could be the first to encounter it, and prompt identification and reporting would be crucial to prevent its spread.

Use of the online SISE for the identification of brown tree snakes and native snakes is a progressive management tool. The brown tree snake was also added to the SISE database to aid in the identification of this species as an invasive threat to the continental United States (Kahl et al. 2012*b*). The online location of the system on the NABTSCT website may also provide a positive impact on public education of brown tree snakes, as users may choose to examine other information on the website if the SISE proved useful to them. This system may be expanded in the future to contain information on other threatening invasive snake species for identification purposes as well. Similar surveys should be performed in the future using the online SISE with live brown tree snakes and native snakes to determine the ability of the general public to use the system to identify exotic snakes.

Management implications

Our study demonstrated the educational value of the online SISE as well as a practical management application because of the capability for it to discern between venomous and non-venomous snakes. With the advent of the internet as a feature on mobile devices, the SISE can be now accessed nearly anywhere. Thus, a person who is working or recreating outdoors and sees a snake can access the SISE web page of the NABTSCT website, answer a few descriptive characteristics about the snake they are observing, and quickly determine if it is a venomous species. However, we acknowledge that our online SISE is currently limited to areas that are covered by cellular or Wi-Fi service. Many people have an innate fear of snakes, believe all are venomous, and instinctively kill them upon sight. The SISE illustrates the potential value of a user-friendly, online snake identification system to stop such misperceptions about an ecologically beneficial taxa. Future expansion of the website and the SISE may also allow for the addition of data by the general public, such as snake sightings and localities, to a database, which would then alert government wildlife agencies of the potential spread of harmful invasive species such as the brown tree snake.

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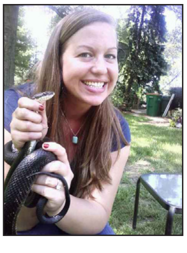

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Appendix 1. The questionnaire and key to determine the age classification and snake (Serpentes) affinity (i.e., Afraid, Neutral, or Enthusiast) of each participant of the online snake identification search engine of the North America Brown Tree Snake Control Team website (http://www.nabtsct.net). Snake identification search engine evaluation, 2015, Texas A&M University-Kingsville, USA.

Please answer all questions truthfully and to the best of your knowledge. Please circle the letter corresponding to the answer that best suits you. We need to get a real sense of your feelings and knowledge of snakes in order to correctly analyze the data collected in this survey. Thank you for your time and participation.

1. **What is your current age:**
   a. 18–25
   b. 26–40
   c. over 40

2. **Have you ever or do you currently own a snake as a pet?**
   a. Yes (Automatic snake enthusiast)
   b. No

3. **If you were taking a walk outside, and saw a snake nearby, your immediate reaction would be:**
   a. (0) Run the other way
   b. (1) Leave it be and walk widely around the area
   c. (3) Kill it, or find something to kill it with
   d. (4) Stand there and watch the snake, possibly trying to see if you know what type of snake it is
   e. (5) Try to pick it up if you don't find it threatening

4. **The thought of snakes (or conversation about snakes) makes you:**
   a. (0) Cringe or shudder
   b. (1) Think of something else or quickly change the topic of conversation
   c. (2) Indifferent, as long as it is only a thought and not a real live snake
   d. (3) Recall the last time you had to kill a snake
   e. (5) Interested or excited

5. **How would you best describe your feelings toward snakes?**
   a. (0) Fearful
   b. (1) Not afraid, but do not like snakes
   c. (2) Indifferent; don't really like them, but don't feel a need to kill them unless they are threatening.
   d. (3) Defensive; if you see a snake, you have no hesitation in trying to kill it because it could be dangerous.
   e. (5) Enthusiastic or interested; you enjoy learning about snakes and are not fearful or defensive of them.

6. **If you are at the Zoo and enter the snake area, you:**
   a. (0) Would not want to go into the snake area at all.
   b. (3) Would not mind walking through the area and checking out the animals.
   c. (5) Would like to see all the different types of snakes and learn about them.

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Rate your responses to the following questions. Use the rating scale of 0 = Never, 1 = No, 2-3 = Somewhat, 4 = Yes, and 5 = Gladly. Circle the response that fits you best.

	Never	No	Somewhat		Yes	Gladly
7. How willing would you be to hold a snake?	0	1	2	3	4	5
8. How willing would you be to stand next to a person holding a snake?	0	1	2	3	4	5
9. How willing would you be to watch a documentary about snakes?	0	1	2	3	4	5
10. How willing would you be to watch a movie that features snakes (ex: Snakes on a Plane, Anaconda, etc.)?	0	1	2	3	4	5

– THANK YOU –

For researcher use

Overall score:__________

Scoring system

Question 3:	0	1		3	4	5
Question 4:	0	1	2	3		5
Question 5:	0	1	2	3		5
Question 6:	0			3		5
Question 7:	0	1	2	3	4	5
Question 8:	0	1	2	3	4	5
Question 9:	0	1	2	3	4	5
Question 10:	0	1	2	3	4	5

Rating system

0–9 pts = Afraid of snakes
10–31 pts = Neutral
32–40 pts = Snake enthusiast