Do Humans Possess a Superior Location Memory for Snakes?

Andrew C. Gallup[*]

Psychology and Evolutionary Behavioral Sciences Programs, SUNY Polytechnic Institute, Utica, NY, 13502 USA

[*]Author for correspondence (a.c.gallup@gmail.com)

Snakes have been a recurrent survival threat throughout human evolutionary history, and, as a result, these animals disproportionately induce attention and fear. Consistent with the predictions of Snake Detection Theory, a large body of literature has demonstrated that both humans and non-human primates possess visual adaptations for rapidly detecting snakes. The current research examined whether people also possess cognitive biases for remembering the locations of these dangerous animals. Three preregistered studies ($N = 69$), all of which used within-subjects designs with college students in the United States, were conducted to assess how the spatial recall for snakes compared to other recurrent survival threats: lions and spiders. Results show that the location memory for snakes was greater than for lions ($p < .05$) but equivalent to that of spiders. In addition, the findings indicate that differences in location memory across studies were driven primarily by threat rather than arousal and negative valence. Overall, these studies suggest that humans do not possess a superior location memory specific for snakes. Limitations to the current research and suggestions for future work in this area are discussed.

Introduction
Snake Detection Theory (SDT) posits that snakes have been a driving force in shaping the primate visual system (Isbell, 2006; 2009). While not all tests of SDT have been supported (see Wheeler et al., 2011), and other theories regarding the evolution of the primate visual system have been proposed (e.g., Sussman et al., 2013), research shows that humans rapidly detect snakes in standard visual search tasks (e.g., Gallup & Meyers, 2021; LoBue & DeLoache, 2008; Öhman et al., 2001) and continue to possess a superior detection of these animals even under challenging attentional conditions (Kawai & He, 2016; Soares et al., 2014). Neurological studies measuring event related potentials also reveal that images of snakes and other snake stimuli (i.e., snake scales) elicit larger neurological activation compared to matched control images (Van Strien et al., 2014a,b; Van Strien et al., 2016; Van Strien & Isbell, 2017). Snakes even elicit specific

neural responses in infants 7–10 months old, suggesting an inborn mechanism for rapid detection (Bertels et al., 2020).

Possessing a good memory for snakes, and the spaces they typically inhabit, would likely be highly adaptive (Nairne et al., 2007; 2012). While snakes can move and disperse across fairly large distances, individuals tend to remain within home ranges and are most often found in particular locations (Howze et al., 2019). For example, radio-telemetry data shows that king cobras (*Ophiophagus hannah*), which are the most dangerous snakes in the world, travel along high-use movement corridors and spend roughly half of their time near shelter sites (Silva et al., 2018). In the first explicit test of whether humans possess an enhanced location memory for snakes, Gallup (2021) found that the spatial recall for these animals within 3 × 3 arrays was significantly better compared to flowers and frogs. However, given this study used just one threatening stimulus, the enhanced location memory for snakes could be due to an arousal-enhanced binding effect (see Mather & Nesmith, 2008) rather than a cognitive predisposition particular to snakes.

To evaluate the specificity of snakes on location memory, three studies were conducted to assess how the spatial recall for snakes compares to other predators: lions (Study 1) and spiders (Studies 2 and 3). Similar to snakes, large-bodied felids like lions have been a recurrent predation threat during human evolution (Coss et al., 2009; Hart & Sussman, 2005; Treves & Naughton-Treves, 1999), and studies of visual search have revealed a comparable rapid detection of these animals (Yorzinski et al., 2014). Venomous spiders have likely also been a recurrent threat to human and non-human primates, and, as a result, humans possess visual adaptations to avoid arachnids (New & German, 2015). For example, infants appear to possess a perceptual template for spiders (Rakison & Derringer, 2008), and spiders are detected more quickly than non-threatening stimuli among both children and adults (LoBue, 2010). Spiders are also a good comparison to snakes when assessing spatial memory since they tend to stay in particular locations and many previous studies have explicitly matched these animals (e.g., Kawai & Koda, 2016; Shibasaki & Kawai, 2011; Soares & Esteves, 2013; Van Strien et al., 2014a).

Study 1
Methods
(a) Participants
This study was preregistered at AsPredicted.org (#73051: URL: https://aspredicted.org/in56u.pdf), and the sample size was determined by a power analysis using G*Power 3.1 (Faul et al., 2007). With power of 0.9 to detect a medium effect ($\eta_p^2 = .09$), a total sample of 23 was needed. Thus, 23 college students (14 females; age $M \pm SD$: 20.60 ± 3.64) participated in this research during the Fall 2021 semester. Recruitment occurred through the psychology pool at

a public research university in the northeastern United States. Each participant received course research credit for completing the study.

(b) Design

This experiment was conducted online using Google Forms and followed a similar design and procedure to Gallup (2021). Twenty-four snake images from LoBue & DeLoache (2008) were used alongside an equal number of impala and African lion images obtained from Yorzinski et al. (2014). After standardizing the size (3.81 × 5.05 cm) and transferring these new images to grayscale, a total of eight 3 × 3 arrays were created to include all 72 images, each with a different set of three images from each category positioned in random order (Figure 1).

(c) Procedure

The eight 3 × 3 arrays were presented one at a time, and participants were provided 10 seconds to study the image locations within each array prior to recall. Participants were instructed to set a timer using the stopwatch feature on their mobile phone, or any other timer they had access to, in order to monitor their time and ensure they spent no more or no less than 10 seconds studying each array. Participants were again reminded to set their timer prior to viewing each array, and to only begin once they were ready. Immediately thereafter, they had to reconstruct the positions of each image using a key labeled #1–9 and with each impala, lion, and snake picture presented below (Figure 2). The images at the bottom were always grouped by category, but the left-right order of their presentation was counterbalanced across arrays. During the recall, participants had to specify the prior location of each image according to the #1–9 key, using each location just once, and there was no time limit for responding.

(d) Analysis

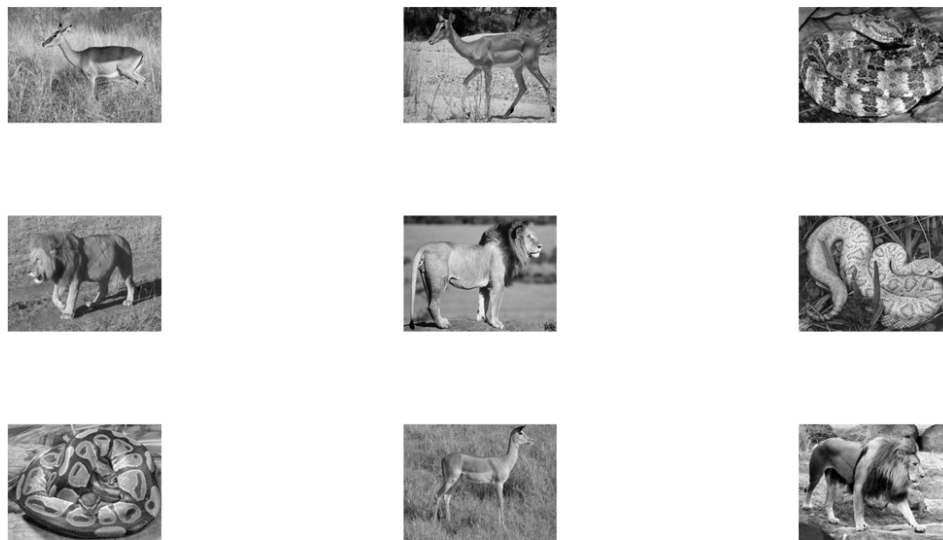The proportion of correct locations was calculated for each

Figure 1. Sample 3 × 3 array from Study 1 with three images each of impalas, lions, and snakes. The image locations were randomized for each trial, and participants were given 10 seconds to study each array.
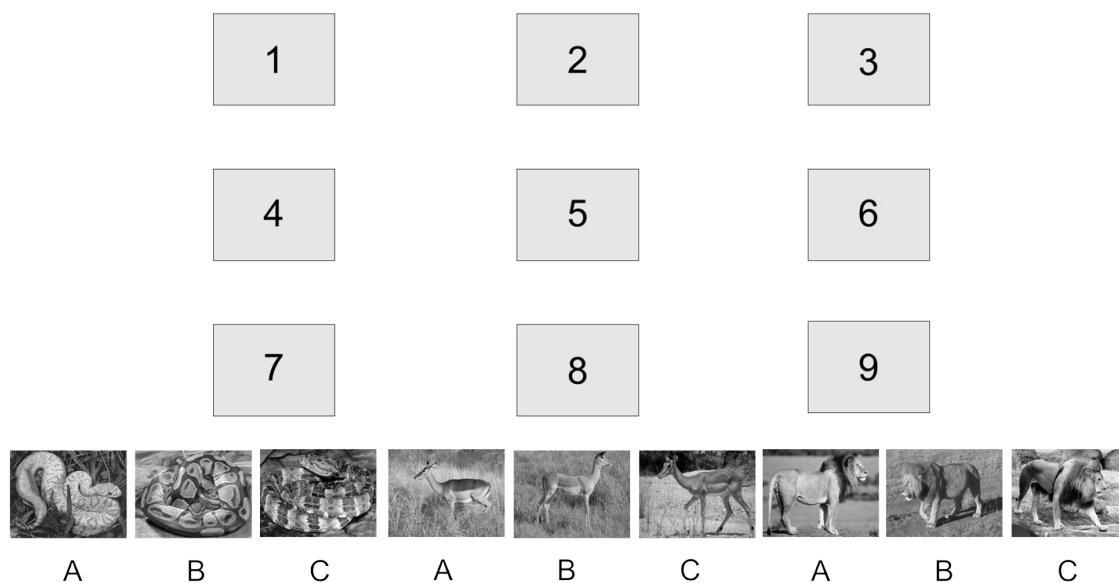

Figure 2. Sample key from Study 1 that participants used to identify the location of each impala, lion, and snake presented in the previous array.

image category (impala, lion, snake) across trials, and a repeated-measures ANOVA was run with image category entered as a within-subjects factor. Pairwise comparisons were then assessed using LSD simple effects tests. All statistical tests were performed in jamovi 2.0.1 (The jamovi project, 2021), and in-text descriptive statistics are represented by $M \pm SD$.

Results

There was a significant main effect of image category, representing a large effect size ($F_{2,44} = 7.980$, $p = .001$, $\eta_p^2 = .266$; Figure 3). As predicted, participants remembered a greater proportion of snake locations (0.471 ± 0.229) compared to locations with impalas (0.368 ± 0.234; $p < .001$) or lions (0.400 ± 0.237; $p = .013$). However, there was no difference in the location memory of impalas and lions ($p = .222$).
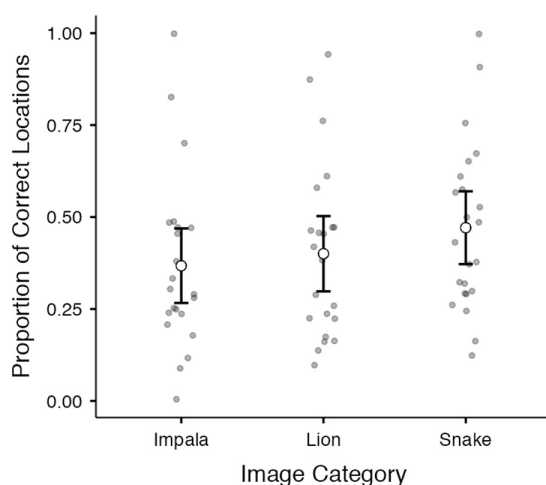

Figure 3. The proportion of correct locations remembered across the image category condition in Study 1. There was a significant main effect ($p < .01$), with participants remembering a greater proportion of snake locations than either impalas or lions ($ps < .05$).

Note: observed scores and $M \pm$ 95% CI are represented.

Discussion

These findings suggest that humans may possess a cognitive bias for remembering the location of snakes. Although lions have been a recurrent predation threat to humans, these animals are far more mobile and hold considerably larger home ranges or territories compared to snakes (Lehmann et al., 2008), and the movement patterns and landscape preferences of African lions are highly variable across seasons and driven by changes in prey abundance (Kittle et al., 2016). Thus, while selection favored the rapid detection of lions as predators to humans (Yorzinski et al., 2014), the memory of the particular locations in which they had been spotted in the past may not be as predictive of future encounters when compared to snakes.

The similarities in the visual characteristics between lions and impalas is a notable limitation to this study. The patterning and image complexity of these images were more matched than the snake images, which could have led to both greater prioritization and recollection for snakes. Therefore, to further test the selectivity of our spatial recall for snakes, a second study was conducted including another recurrent survival threat with a more comparable level of visual complexity and distinctiveness: spiders.

Study 2

Methods

(a) Participants

This study was also preregistered at AsPredicted. org (#78166: URL: https://aspredicted.org/4zw97.pdf). Following the same power analysis and recruitment method as Study 1, 23 college students (14 females; age $M \pm SD$: 20.00 ± 2.12) participated during the Fall 2021 semester. Each participant again received course research credit for completing the study.

(b) Design, procedure & analysis

This experiment was also conducted online using Google Forms, and the same 24 snake images from Study 1 were

Figure 4. Sample 3 × 3 array from Study 2 with three images each of mushrooms, spiders, and snakes. The image locations were randomized for each trial, and participants were given 10 seconds to study each array.

used alongside an equal number of mushroom and spider images from LoBue (2010). After standardizing the size (3.81 × 5.05 cm) and transferring these new images to grayscale, a total of eight 3 × 3 arrays were created to include all 72 images in the same manner as in Study 1 (Figure 4). The procedure and analysis were also the same as Study 1.

Results
Unlike Study 1, there was no significant main effect of image category ($F_{2,44} = 0.230$, $p = .796$, $\eta_p^2 = .010$; Figure 5). In this case, though similar, the mean number of snake locations recalled (0.348 ± 0.177) was actually lower than that of both mushrooms (0.366 ± 0.223) and spiders (0.370 ± 0.196).
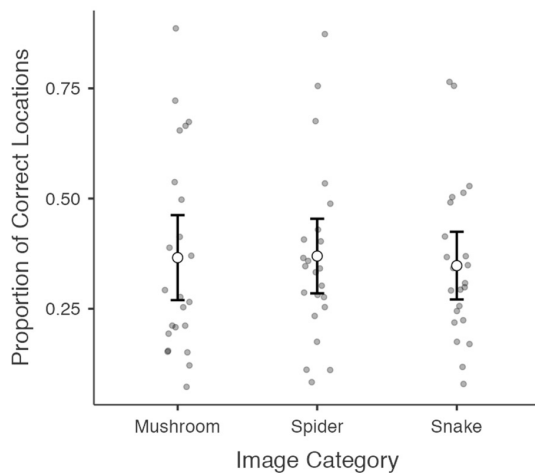

Figure 5. The proportion of correct locations remembered across the image category condition in Study 2. There was no significant difference across the three image categories.

Note: observed scores and $M \pm 95\%$ CI are represented.

Discussion
No difference emerged in the spatial recall of mushroom, spider, and snake images. Given the inconsistency in these findings in relation to prior results, a third study was conducted to further compare the location memory for snakes and spiders. In this case, mushroom images were replaced by cockroaches (Lobue, 2010). A recent study found that cockroaches were rated as significantly more unpleasant than snakes and spiders, while all three were viewed as equally arousing (Grimaldos et al., 2021). Therefore, this study included three image categories that were all high in arousal, while also providing the opportunity to differentiate between image categories by threat (snakes and spiders > cockroaches) and negative valence (cockroaches > snakes and spiders).

Study 3
Methods
(a) Participants
This study was also preregistered at AsPredicted.org (#79330: URL: https://aspredicted.org/ew73h.pdf). Following the same power analysis and recruitment method as Studies 1 and 2, 23 college students (12 females; age $M \pm SD$: 20.00 ± 2.10) participated during the Fall 2021 semester. Each participant again received course research credit for completing the study.

(b) Design, procedure & analysis
This experiment was also conducted online using Google Forms, and the same 24 snake images from Studies 1 and 2 were used alongside the same 24 spider images in Study 2. In this case, however, the mushrooms were replaced by 24 cockroach images from LoBue (2010). All other aspects of the design (Figure 6), procedure, and analysis were identical to Studies 1 and 2.
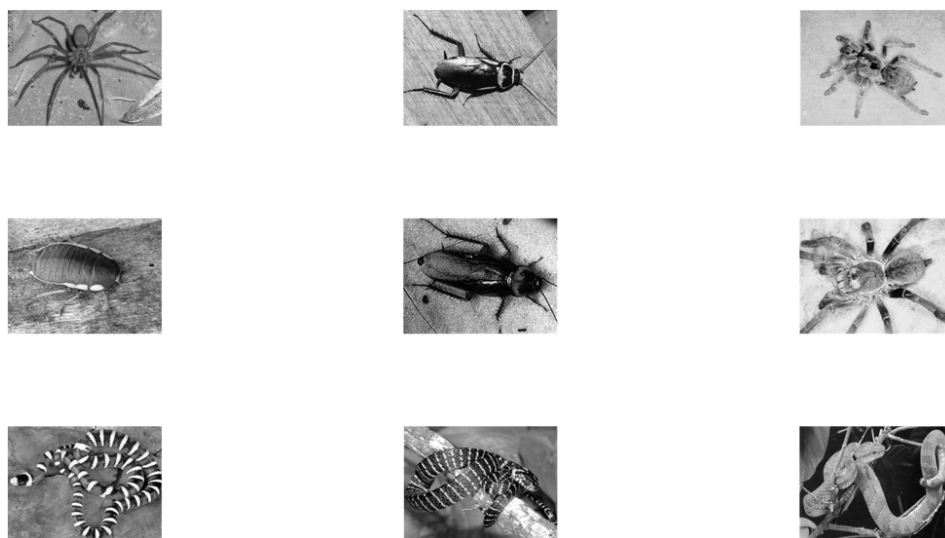

Figure 6. Sample 3 × 3 array from Study 3 with three images each of cockroaches, spiders, and snakes. The image locations were randomized for each trial, and participants were given 10 seconds to study each array.

Results

There was a significant main effect of image category, representing a large effect ($F_{2,44} = 4.500$, $p = .017$, $\eta_p^2 = .170$; Figure 7). In this case, participants remembered a greater proportion of snake (0.382 ± 0.238; $p = .020$) and spider (0.397 ± 0.205; $p = .012$) locations compared to locations with cockroaches (0.293 ± 0.146). Similar to Study 2, however, there was no difference in the location memory of snakes and spiders ($p = .711$).
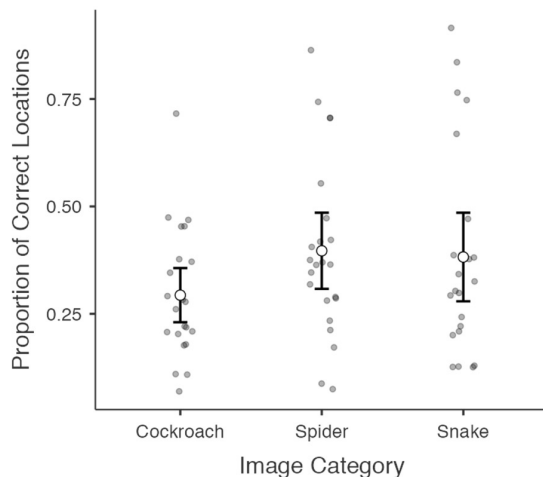

Figure 7. The proportion of correct locations remembered across the image category condition in Study 3. There was a significant main effect ($p < .05$), with participants remembering a greater proportion of snake and spider locations compared to cockroaches ($ps < .05$).

Note: observed scores and $M \pm 95\%$ CI are represented.

Discussion

Coupled with the results from Study 2, the findings from this experiment cast doubt on the view that humans possess a superior location memory for snakes. Similar to Study 2, there was no difference in the spatial recall for snakes and spiders. However, the location memory for both of these animals was significantly higher than the recall of cockroaches. Therefore, as predicted, this study suggests that differences in location memory across studies are driven primarily by threat rather than arousal and negative valence.

General discussion

To examine the specificity of snakes in improving spatial recall, the current studies, which were all preregistered, investigated whether location memory for snakes exceeded that for other salient and recurrent evolutionarily threats: lions and spiders. Study 1 found that a greater proportion of snake images were correctly recalled compared to both lions and impalas. Therefore, while snakes and lions are both rapidly detected by humans (Yorzinski et al., 2014), this study provides the first evidence that the locations of snakes are recalled to a higher degree than lions. Coupled with previous research (Gallup, 2021), these findings are consistent with the view that humans evolved to limit contact with snakes both through rapid detection and memory of the locations in which they have been spotted previously.

Follow-up experiments were conducted using spiders as a more comparable stimulus possessing distinctive morphology and similar image complexity. Despite previous research showing that both snakes and spiders are feared and selectively garner our attention (e.g., LoBue, 2010; New & German, 2015; Öhman & Mineka, 2003), Study 2 found no difference in the location memory of these animals compared to mushrooms. Consequently, Study 3 was conducted, again comparing images of snakes and spiders, but now including cockroaches as the third image type. Cockroaches have previously been paired with spider images in visual search tasks (LoBue, 2010), and research suggests that, despite not being inherently dangerous or threatening, people actually fear cockroaches just as much or more than they do spiders and snakes (Grimaldos et al., 2021). The findings from this final study revealed a significant main effect of image type, with a greater spatial recall both for snakes and spiders in comparison to cockroaches. There was again, however, no difference in the location memory for snakes and spiders. Therefore, contrary to some previous studies showing a prioritization of snakes over spiders in visual search, there does not appear to be a difference in the location memory for these threatening animals.

Snake and spider phobias are amongst the most common phobias (Oosterink et al., 2009), and it makes sense from an evolutionary perspective that humans would possess neurological adaptations to spot, remember, and avoid these dangerous animals (Seligman, 1971). In addition to having a distinctive morphology and locomotion – few terrestrial animals even approximate the resemblance or movement of snakes or spiders – some species of snakes and spiders are venomous. This adds a substantial layer of threat, as a single and fleeting encounter with a venomous snake or spider could be debilitating or even deadly. Since many spiders tend to stay within particular locations as sit-and-wait predators, it is perhaps not surprising that humans show a similarly high location memory for these animals compared to snakes. Given the ability to strike from a distance, however, snakes pose a greater risk, which likely explains the superior detection of these animals over competing stimuli in visual search tasks (Kawai & Koda, 2016; Shibasaki & Kawai, 2011; Soares & Esteves, 2013).

Limitations to this research should be acknowledged. First, the online nature of these studies inhibited the monitoring of participant responding during testing. However, previous research suggests that participants follow instructions and attend to research items equally well when presented online or in the laboratory (Ramsey et al., 2016), and in this case participants were given detailed instructions and again reminded of the procedure prior to testing. Second, the procedures for reconstructing the 3 × 3 arrays likely measured short-term memory capacity, whereby attentional capture could be contributing to the reported effects. Given the proposed advantages to recalling the locations of recurrent evolutionary threats would apply primarily to long-term memory, future studies could employ more ecologically valid tasks with surprise recall tests designed to measure long-term capacity. In addition, further research could improve on controlling for image distinctiveness across image categories.

Overall, the current findings suggest that humans do

not possess a superior location memory specific for snakes. While the spatial recall of snakes was relatively high in relation to other stimuli, including lions, it was equivalent to that of spiders, which represent a similar recurrent survival threat with comparable distinctiveness in appearance, movement, and visual complexity. Therefore, while selection has produced visual adaptations that enable a superior detection of snakes in relation to spiders, the same does not appear to be true for remembering their prior locations.

Acknowledgements
I am grateful to Vanessa LoBue and Jessica Yorzinski for providing the stimuli for the location memory tasks.

Author contributions
ACG is the sole contributor to this work.

Ethical statement
The experiments were conducted in accordance with approved human ethics guidelines and approved by the local Institutional Review Board (#IRB-2021-6 for Study 1, #IRB-2021-9 for Study 2, and #IRB-2021-10 for Study 3). All participants provided informed consent prior to testing.

Data accessibility & program code
The datasets from this research are available here: https://doi.org/10.7910/DVN/LABIKP

References
Bertels, J., Bourguignon, M., De Heering, A., Chetail, F., De Tiège, X., Cleeremans, A., & Destrebecqz, A. (2020). Snakes elicit specific neural responses in the human infant brain. *Scientific Reports*, *10*(1), Article 7443. https://doi.org/10.1038/s41598-020-63619-y

Coss, R. G., Fitzhugh, E. L., Schmid-Holmes, S., Kenyon, M. W., & Etling, K. (2009). The effects of human age, group composition, and behavior on the likelihood of being injured by attacking pumas. *Anthrozoös*, *22*(1), 77–87. https://doi.org/10.2752/175303708X390491

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191. https://doi.org/10.3758/BF03193146

Gallup, A. C. (June 24–July 2, 2021). *Enhanced location memory for snakes and the group vigilance hypothesis of yawning* [poster presentation]. Human Behavior and Evolution Society Meeting, Virtual Meeting. https://osf.io/cbhpe

Gallup, A. C., & Meyers, K. (2021). Seeing others yawn selectively enhances vigilance: An eye-tracking study of snake detection. *Animal Cognition*, *24*(3), 583–592. https://doi.org/10.1007/s10071-020-01462-4

Grimaldos, J., Duque, A., Palau-Batet, M., Pastor, M. C., Bretón-López, J., & Quero, S. (2021). Cockroaches are scarier than snakes and spiders: Validation of an affective standardized set of animal images (ASSAI). *Behavior Research Methods*, *53*(6), 2338–2350. https://doi.org/10.3758/s13428-021-01577-7

Hart, D., & Sussman, R. W. (2005). *Man the hunted: Primates, predators, and human evolution*. Westview Press. https://doi.org/10.4324/9780429499081

Howze, J. M., Sash, K. J., Carroll, J. P., & Smith, L. L. (2019). A regional scale assessment of habitat selection and home range of the eastern rat snake in pine-dominated forests. *Forest Ecology and Management*, *432*, 225–230. https://doi.org/10.1016/j.foreco.2018.09.018

Isbell, L. A. (2006). Snakes as agents of evolutionary change in primate brains. *Journal of Human Evolution*, *51*(1), 1–35. https://doi.org/10.1016/j.jhevol.2005.12.012

Isbell, L. A. (2009). *The fruit, the tree, and the serpent: Why we see so well*. Harvard University Press. https://doi.org/10.4159/9780674054042

Kawai, N., & He, H. (2016). Breaking snake camouflage: Humans detect snakes more accurately than other animals under less discernible visual conditions. *PLoS ONE*, *11*(10), Article e0164342. https://doi.org/10.1371/journal.pone.0164342

Kawai, N., & Koda, H. (2016). Japanese monkeys (*Macaca fuscata*) quickly detect snakes but not spiders: Evolutionary origins of fear-relevant animals. *Journal of Comparative Psychology*, *130*(3), 299–303. https://doi.org/10.1037/com0000032

Kittle, A. M., Bukombe, J. K., Sinclair, A. R. E., Mduma, S. A. R., & Fryxell, J. M. (2016). Landscape-level movement patterns by lions in western Serengeti: Comparing the influence of inter-specific competitors, habitat attributes and prey availability. *Movement Ecology*, *4*, Article 17. https://doi.org/10.1186/s40462-016-0082-9

Lehmann, M. B., Funston, P. J., Owen, C. R., & Slotow, R. (2008). Home range utilisation and territorial behaviour of lions (*Panthera leo*) on Karongwe Game Reserve, South Africa. *PLoS ONE*, *3*(12), Article e3998. https://doi.org/10.1371/journal.pone.0003998

LoBue, V. (2010). And along came a spider: An attentional bias for the detection of spiders in young children and adults. *Journal of Experimental Child Psychology, 107*(1), 59–66. https://doi.org/10.1016/j.jecp.2010.04.005

LoBue, V., & DeLoache, J. S. (2008). Detecting the snake in the grass: Attention to fear relevant stimuli by adults and young children. *Psychological Science*, *19*(3), 284–289. https://doi.org/10.1111/j.1467-9280.2008.02081.x

Mather, M., & Nesmith, K. (2008). Arousal-enhanced location memory for pictures. *Journal of Memory and Language*, *58*(2), 449–464. https://doi.org/10.1016/j.jml.2007.01.004

Nairne, J. S., Thompson, S. R., & Pandeirada, J. N. S. (2007). Adaptive memory: Survival processing enhances retention. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*(2), 263–273. https://doi.org/10.1037/0278-7393.33.2.263

Nairne, J. S., VanArsdall, J. E., Pandeirada, J. N. S., & Blunt, J. R. (2012). Adaptive memory: Enhanced location memory after survival processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *38*(2), 495–501. https://doi.org/10.1037/a0025728

New, J. J., & German, T. C. (2015). Spiders at the cocktail party: An ancestral threat that surmounts inattentional blindness. *Evolution and Human Behavior*, *36*(3), 165–173. https://doi.org/10.1016/

j.evolhumbehav.2014.08.004

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General*, *130*(3), 466–478. https://doi.org/10.1037/0096-3445.130.3.466

Öhman, A., & Mineka, S. (2003). The malicious serpent: Snakes as a prototypical stimulus for an evolved module of fear. *Current Directions in Psychological Science*, *12*(1), 5–9. https://doi.org/10.1111/1467-8721.01211

Oosterink, F. M. D., De Jongh, A., & Hoogstraten, J. (2009). Prevalence of dental fear and phobia relative to other fear and phobia subtypes. *European Journal of Oral Sciences*, *117*(2), 135–143. https://doi.org/10.1111/j.1600-0722.2008.00602.x

Rakison, D. H., & Derringer, J. (2008). Do infants possess an evolved spider-detection mechanism? *Cognition*, *107*(1), 381–393. https://doi.org/10.1016/j.cognition.2007.07.022

Ramsey, S. R., Thompson, K. L., McKenzie, M., & Rosenbaum, A. (2016). Psychological research in the internet age: The quality of web-based data. *Computers in Human Behavior*, *58*, 354–360. https://doi.org/10.1016/j.chb.2015.12.049

Seligman, M. E. P. (1971). Phobias and preparedness. *Behavior Therapy*, *2*(3), 307–320. https://doi.org/10.1016/S0005-7894(71)80064-3

Shibasaki, M., & Kawai, N. (2011). Visual searching for fear-relevant stimuli: Snakes draw our attention more strongly than spiders do. *Cognitive Studies: Bulletin of the Japanese Cognitive Science Society*, *18*(1), 158–172. https://doi.org/10.11225/jcss.18.158

Silva, I., Crane, M., Suwanwaree, P., Strine, C., & Goode, M. (2018). Using dynamic Brownian Bridge Movement Models to identify home range size and movement patterns in king cobras. *PLoS ONE*, *13*(9), Article e0203449. https://doi.org/10.1371/journal.pone.0203449

Soares, S. C., & Esteves, F. (2013). A glimpse of fear: Fast detection of threatening targets in visual search with brief stimulus durations. *PsyCh Journal*, *2*(1), 11–16. https://doi.org/10.1002/pchj.18

Soares, S. C., Lindström, B., Esteves, F., & Öhman, A. (2014). The hidden snake in the grass: Superior detection of snakes in challenging attentional conditions. *PLoS ONE*, *9*(12), Article e114724. https://doi.org/10.1371/journal.pone.0114724

Sussman, R. W., Tab Rasmussen, D., & Raven, P. H. (2013). Rethinking primate origins again. *American Journal of Primatology*, *75*(2), 95–106. https://doi.org/10.1002/ajp.22096

The jamovi project (2021). *jamovi* (Version 1.6) [Computer Software]. https://www.jamovi.org

Treves, A., & Naughton-Treves, L. (1999). Risk and opportunity for humans coexisting with large carnivores. *Journal of Human Evolution*, *36*(3), 275–282. https://doi.org/10.1006/jhev.1998.0268

Van Strien, J. W., Christiaans, G., Franken, I. H. A., & Huijding, J. (2016). Curvilinear shapes and the snake detection hypothesis: An ERP study. *Psychophysiology*, *53*(2), 252–257. https://doi.org/10.1111/psyp.12564

Van Strien, J. W., Eijlers, R., Franken, I. H. A., & Huijding, J. (2014a). Snake pictures draw more early attention than spider pictures in non-phobic women: Evidence from event-related brain potentials. *Biological Psychology*, *96*, 150–157. https://doi.org/10.1016/j.biopsycho.2013.12.014

Van Strien, J. W., Franken, I. H. A., & Huijding, J. (2014b). Testing the snake-detection hypothesis: Larger early posterior negativity in humans to pictures of snakes than to pictures of other reptiles, spiders and slugs. *Frontiers in Human Neuroscience*, *8*, Article 691. https://doi.org/10.3389/fnhum.2014.00691

Van Strien, J. W., & Isbell, L. A. (2017). Snake scales, partial exposure, and the Snake Detection Theory: A human event-related potentials study. *Scientific Reports*, *7*, Article 46331. https://doi.org/10.1038/srep46331

Wheeler, B. C., Bradley, B. J., & Kamilar, J. M. (2011). Predictors of orbital convergence in primates: A test of the snake detection hypothesis of primate evolution. *Journal of Human Evolution*, *61*(3), 233–242. https://doi.org/10.1016/j.jhevol.2011.03.007

Yorzinski, J. L., Penkunas, M. J., Platt, M. L., & Coss, R. G. (2014). Dangerous animals capture and maintain attention in humans. *Evolutionary Psychology*, *12*(3), 534–548. https://doi.org/10.1177/147470491401200304