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Factors associated with human tolerance of snakes in the southeastern United States

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Conservation of snakes is influenced by humans' beliefs, attitudes, and behaviors toward these often-maligned animals. We investigated public attitudes toward snakes through an online survey of undergraduate students (n = 743) at a large public university in a southeastern U.S. state. We used behavioral intent (i.e., how a person would react if they encountered a snake) to assess tolerance of different snake species. We also examined various predictors of tolerance including demographic attributes and a variety of cognitive (e.g., knowledge, value orientations) and affective (e.g., emotions) social-psychological variables. Tolerance of snakes varied based on whether the snake was venomous or non-venomous: about 36% of students said they were likely to kill venomous snakes they encountered, compared with 9% who said they would kill non-venomous snakes and 21% of students who said they would kill snakes whose identity was uncertain. However, most students (54%) could not distinguish between venomous and non-venomous species. Value orientations and emotions were strong predictors of tolerance for snakes, suggesting snake outreach and management strategies should account for both cognitive and affective antecedents of behavior.

KEYWORDS

attitudes, behaviors, emotions, human-wildlife conflict, knowledge, reptiles, venomous, wildlife value orientations

1 Introduction

Snakes provide many benefits to both the natural environment and humans. In addition to playing key roles in trophic systems and serving as important ecological indicators (Mullin and Seigel, 2009; Ceríaco, 2012), snakes also protect agricultural products and mitigate disease transmission by controlling rodent populations (Onyishi et al., 2021). Furthermore, snakes provide opportunities for medicinal advancement *via* development of therapeutic drugs using venom (Vyas et al., 2013; Waheed et al., 2017).

They also support the production of various goods such as food (Klemens and Thorbjarnarson, 1995) and raw materials such as cosmetics and clothing (Ceríaco, 2012; Ijeomah et al., 2017).

Despite these benefits, humans often treat snakes with hostility and animosity, contributing to global population declines among many snake species (Gibbons et al., 2000; Prokop et al., 2009). Negative public perceptions of snakes associated with intense fear, disdain, and misunderstanding fuel persecution of snakes around the world (Fredrikson et al., 1996; Knight, 2008; LoBue and DeLoache, 2008; Souchet and Aubret, 2016; Rádlová et al., 2019; Kontsiotis et al., 2022). Although the probability of dying from a snake bite is close to zero (Morgan et al., 2004; Langley et al., 2014; Chippaux, 2017), fear of snakes and snakebites is among the most prevalent animal phobias (Agras et al., 1969; Pandey et al., 2016). Further, snakes often rank as among the most disliked animals globally (Šurinová, 1971; Kellert, 1982). The effectiveness and success of snake conservation and management efforts are often limited by such negative perceptions, with the majority of resources instead allocated to conserve larger, more charismatic wildlife species such as birds and mammals (Czech et al., 1998; Kaltenborn et al., 2006; Martín-López et al., 2007; Prokop et al., 2009; Ceríaco, 2012; Torkar, 2015). Furthermore, snakes can face direct negative consequences of interactions with humans in the form of intentional killings, which may represent a substantial portion of overall snake mortality and subsequent population decline (Dodd, 1987; Bonnet et al., 1999; Gibbons et al., 2000; Whitaker and Shine, 2000; Christoffel, 2007; Balakrishnan, 2010; Crawford and Andrews, 2016; Pandey et al., 2016).

1.1 Measuring tolerance of snakes

Given the ecological and utilitarian value of snakes and the numerous threats they face, a better understanding of the psychological mechanisms that encourage or suppress human tolerance for these animals is needed to effectively guide regional conservation and management efforts (Gibbons, 1988; Dickman, 2010; Flykt et al., 2013; Struebig et al., 2018; Kontsiotis et al., 2022). Understanding tolerance is key to predicting people's potentially harmful actions toward snakes (Brenner and Metcalf, 2020), which can significantly impact conservation (Nilsson et al., 2020). However, the factors that influence wildlife tolerance are not well understood (Treves and Bruskotter, 2014; Bruskotter et al., 2015; Brenner and Metcalf, 2020). Although the meaning of the term "tolerance" is often debated (Bruskotter and Fulton, 2012; Treves et al., 2013; Brenner and Metcalf, 2020), tolerance toward species such as snakes is often represented by incorporating measures of people's behavioral intent or behavior (Treves and Bruskotter, 2014; Bruskotter et al., 2015). In the context of human-wildlife interactions, tolerance can be defined on a spectrum from specific actions that positively affect wildlife such as habitat restoration (i.e., stewardship behaviors) to passive acceptance of wildlife (i.e., tolerance) to specific actions that negatively affect wildlife such as intentional killings (i.e., intolerance; Bruskotter and Fulton, 2012; Treves 2012; Bruskotter and Wilson, 2014; Bruskotter et al., 2015; St. John et al., 2018). Studies addressing the concept of tolerance have generally been directed at large predatory carnivores (Bruskotter and Fulton, 2012; Treves 2012; Treves and Bruskotter, 2014; St. John et al., 2018; Casola et al., 2020), including reptiles such as alligators (Skupien et al., 2016). Very few have focused on tolerance toward snakes (Onyishi et al., 2021; Kontsiotis et al., 2022). For the purposes of our study we use behavioral intentions, which represent an individual's expectations regarding how they will behave in a given situation, as a proxy for tolerance (Bruskotter and Fulton, 2012; Treves, 2012; Bruskotter and Wilson, 2014; St. John et al., 2018). Behavioral intent can be a stronger correlate of overt behavior than beliefs, attitudes, or other potential antecedents (Fishbein and Ajzen, 2010; Liu et al., 2020).

Although research specifically focused on tolerance of snakes is limited, comparable studies of factors impacting human responses to other potentially dangerous wildlife species can offer some insights. Social-psychological research on human-wildlife interactions indicates that a variety of factors interact to influence behavior and potential for coexistence in dynamic ways (Christoffel, 2007; Keener-Eck et al., 2020a; König et al., 2020). Kollmuss and Agyeman (2002) proposed a comprehensive model of pro-environmental behavior suggesting human actions result from a combination of both external and internal factors. External factors include various socio-demographic and contextual variables, including social and cultural norms (Kollmuss and Agyeman, 2002; Jordan et al., 2020). Internal factors include past experience, knowledge, emotions, values and attitudes, and behavioral intentions (Kollmuss and Agyeman, 2002). Studies focused specifically on human-wildlife interactions and tolerance reveal a similar structure, whereby "outer" or external factors such as past experience with a species and beliefs about costs and benefits interact with "inner" or internal variables such as values and attitudes to influence (Kansky et al., 2016). In this paper, we examine how many of these external and internal variables combine to influence tolerance for snakes.

1.2 Factors influencing tolerance of snakes

Socio-demographic variables such as age, gender, and place of residence have been linked to snake-related beliefs, value orientations, attitudes, and behaviors (Vaske et al., 2011; Ceríaco, 2012; Liordos et al., 2018). Some studies suggest fear of snakes is more prominent in children and declines over time (Fredrikson et al., 1996; Doctor et al., 2008), but other research indicates younger respondents may be more tolerant of snakes than older respondents (Liordos et al., 2018; Vaughn et al., 2022). Several studies have shown that, compared to men, women tend to exhibit more negative attitudes, lower tolerance, and greater fear of snakes (Prokop et al., 2009; Pinheiro et al., 2016; Polák et al., 2016; Liordos et al., 2018). Finally, rural residents tend to exhibit more negative attitudes toward certain wildlife species than urban residents (Kleiven et al., 2004; Smith et al., 2014; Liordos et al., 2017). For example, Ceríaco (2012) found that individuals living in rural communities were more likely to persecute snakes than those living in urban areas. Collectively, these patterns reveal normative responses to species based on context that can permeate cultures and potentially impact tolerance on larger scales (Brom et al., 2020).

Past experience is a critical factor predicting wildlife-related behavior and behavioral intent (Rohan, 2000; Kollmuss and Agyeman, 2002; Christoffel, 2007; Manfredo, 2008; Kansky et al., 2016). According to Fazio and Zanna (1981), attitudes formed as a result of direct experiences are generally associated with high levels of certainty, enhanced stability over time, and strong resistance to opposition. For example, one study demonstrated that previous hands-on experience with snakes was associated with lower fear levels and more positive attitudes toward snake conservation (Torkar, 2015). Similarly, Pinheiro et al. (2016) found that past experience with snakes was associated with reduced negative attitudes and fear. Other research has demonstrated the positive impacts that in-person encounters with snakes as part of educational programming can have on participants' knowledge and attitudes (Morgan and Gramann, 1989; Ballouard et al., 2012). Past experiences with snakes may also be shaped by media exposure. For instance, Ballouard et al. (2013) suggested that fear of snakes may be linked to negative depictions of these animals in various media sources, a phenomenon that has been documented with other potentially frightening wildlife species such as wolves (Casola et al., 2020) and sharks (Beall et al., 2022).

In addition to the aforementioned external factors, a variety of internal factors unique to individuals also play a role in influencing wildlife-related behavior. Knowledge is another factor that helps predict an individual's perceptions about and reactions to specific wildlife species (Bright and Manfredo, 1996; Kollmuss and Agyeman, 2002). Kellert (1985) found that as knowledge about wolves increased, attitudes toward these animals became more positive, though positive attitudes toward controversial species may wane over time (Treves et al., 2013). In another study, researchers demonstrated that previous knowledge of rattlesnakes was associated with more positive attitudes toward these species (Christoffel, 2007). However, other researchers have shown that accurate knowledge of environmental issues does not necessarily translate to positive attitudes or behaviors (Ajzen et al., 2011; Heberlein, 2012). This stance was reinforced by Morgan and Gramann (1989), who reported that increased knowledge of snakes failed to make children's attitudes toward snakes more positive. It is important to note that knowledge of wildlife is multidimensional and can be assessed in different ways ranging from self-reported knowledge to objective assessments (White et al., 2018). In addition to knowledge of basic biological and ecological principles and natural history (Kellert, 1994), species identification is an important skill in wildlife sciences (Randler, 2008; White et al., 2018). Rapid species identification of snakes is particularly important so that humans can discern and respond to immediate threats such as venomous species (Fančovičová et al., 2020). In this study, we assessed knowledge of snakes using a combination of self-reported natural history knowledge and objective identification skills.

Values represent another internal factor that guides actions related to wildlife (Kollmuss and Agyeman, 2002; Jacobs et al., 2014), including snakes (Keener-Eck et al., 2020a). Fulton et al. (1996) suggested a cognitive hierarchy, wherein fundamental values, long-lasting beliefs or mental constructs that reflect our most basic desires and objectives, can be used to predict more specific attitudes and subsequent behaviors. Wildlife value orientations (WVOs) represent basic belief patterns that provide context for values within the wildlife domain (Fulton et al., 1996; Vaske and Manfredo, 2012; Jacobs et al., 2013). Value orientations are an intangible factor that has been shown to influence human coexistence with carnivore species across multiple contexts (Jacobsen et al., 2021). With respect to snakes, studies have shown that people with stronger mutualistic WVOs are most likely to demonstrate positive attitudes toward rattlesnakes (Keener-Eck et al., 2020b) and most likely to support conservation of both venomous and non-venomous snake species (Kontsiotis et al., 2022).

Many researchers have pointed out a shortcoming of the cognitive hierarchy, however: it fails to adequately address affective drivers of behaviors (Jacobs, 2012; Larson et al., 2016). Human-wildlife interactions are often emotionally charged events in which affective responses such as fear and excitement play a large role in dictating an individual's actions (Hudenko, 2012). In recent years, there has been a push for more comprehensive evaluations of the emotional components of attitudes toward wildlife (Morris et al., 2002; Manfredo, 2008; Hudenko, 2012; Jacobs, 2012), including snakes (Castillo-Huitrón et al., 2020). For example, one study linked positive valence, or more pleasant emotions, to more mutualistic WVOs (Abidin and Jacobs, 2019). A handful of studies have also addressed affective attitudes toward snakes by incorporating measures of fear (Constantine et al., 2001; Öhman et al., 2001; Prokop and Fancovicova, 2013; Rádlová et al., 2020). However, few studies have addressed a wider range of human emotions other than fear when it comes to perceptions of and subsequent behaviors toward snakes, highlighting and opportunity for future research (Castillo-Huitrón et al., 2020).

1.3 Research gaps and study objectives

Research focused on human tolerance of snakes and its correlates is growing, but significant knowledge gaps persist (Christoffel, 2007; Christoffel and Lepczyk, 2012; Kontsiotis et al., 2022). Although some work has examined public perceptions of snakes in North America (Christoffel, 2007; Keener-Eck et al., 2020a; Keener-Eck et al., 2020b; Vaughn et al., 2022), most studies have centered on other global contexts where risks posed by venomous species are typically more prominent (Balakrishnan, 2010; Tomažič, 2011; Ceríaco, 2012; Torkar, 2015; Pandey et al., 2016; Pinheiro et al., 2016; Liordos et al., 2018; Landová et al., 2020; Rádlová et al., 2020; Onyishi et al., 2021; Kontsiotis et al., 2022). This skewed pattern illuminates the need for more research on tolerance of snakes in the United States, particularly in the southern region of the country where snake diversity tends to be highest (AZ Animals, 2022). We chose to focus our study on college students. Although this particular population may not have a specific affinity or disdain for snakes, the perceptions and behaviors of college students can impact the future of wildlife conservation in a variety of ways, from tangible stewardship activities to broader policy support (Larson et al., 2021). Using a case study of undergraduate students at a large public university in the southeastern U.S., our study addressed the need for a more comprehensive understanding of the variables that influence tolerance of snakes. We focused on the following objectives that began with an investigation of external and internal behavioral antecedents and ended with a specific focus on tolerance (operationalized as actions taken when encountering a snake):

1. Characterize students' past experience with snakes and demographic correlates;
2. Determine students' knowledge of snakes, including both natural history and identification knowledge, and demographic correlates;
3. Characterize students' value orientations toward snakes and demographic correlates;
4. Identify students' emotional responses to snakes and demographic correlates;
5. Measure students' tolerance (i.e., behavior intentions) for venomous and non-venomous snakes and identify demographic and social-psychological correlates of tolerance.

2 Methods

We focused on undergraduate students enrolled in several different courses at a large public university in the southeastern U.S. state of North Carolina. Although these courses were based in natural resource and life science departments, they were introductory-level and included students from a wide variety of backgrounds and majors who presumably had a wide range of experiences with snakes. We intentionally selected these classes to examine perspectives of a wide array of students with diverse disciplinary interests and backgrounds, including many who were not predisposed to study natural resource topics and might be taking the courses to fulfill the science requirement for their general education curriculum.

2.1 Participants

Over the course of two semesters (Fall 2019 and Spring 2020), we surveyed 743 undergraduate students enrolled in four different courses (e.g., Conservation of Natural Resources, Biology in the Modern World). Our survey distribution strategy varied based on instructor preferences. In some classes, we approached potential participants in the classroom, briefly introduced the research, and provided them with a link to the questionnaire that could be accessed on their devices. In other classes, we distributed a link to the questionnaire *via* an email through their professors or teaching assistants. The survey research protocol was approved by the university's Institutional Review Board (IRB #20906) prior to data collection.

2.2 Survey instrument and data analysis

Our survey instrument, designed and administered in Qualtrics, focused on several types of variables that might influence students' tolerance toward snakes.

2.2.1. Demographic variables

We asked participants to provide demographic information, including their gender (recoded as 0=male and 1=female), race/ethnicity (recoded as 0 = White and 1 = Black, indigenous, or People of Color), the year they were born (which we used to calculate age, recoded as 0=ages 18 to 23 and 1 = all other ages), the type of area they grew up in based on population size (recoded as 0 = rural or less than 50,000 residents and 1 = urban or 50,000 or more residents), and their major (recoded as 0 = Agriculture/Life Sciences, Natural Resources, and Veterinary Medicine and 1 = all other majors).

2.2.2. Past experience with snakes

We presented respondents with a list of six possible snake-related experiences that might occur at varying frequencies and asked them to select all of the experiences that applied to them. Some of these were direct experiences (e.g., "I have been bitten by a snake," "My pet has been bitten by a snake before"), and some of these were indirect experiences (e.g., "I have heard accounts of dangerous snakes or snakebites from friends and family," "I have learned about venomous snakebite accounts through the media"). Responses were coded as 1 = has experienced or 0 = has not experienced. For analyses, we divided the list into negative (e.g., snakebites and fear-inducing direct or indirect encounters) and positive experiences (e.g., educational encounters that paint snakes in a positive light). We calculated a sum for the total number of negative experiences, which ranged from 0 to 5. There was only one item on the positive list (e.g., "I have learned about snakes through educational programs"). We also asked participants to reflect on their encounters with snakes in the media and indicate the extent to which they believe snakes are portrayed negatively in the media using a 5-point Likert-type scale (1 = always to 5 = never). We analyzed associations between demographic variables and past experience using regression models with experience scores as the dependent variable. We used linear models for the scaled negative experiences and media portrayal variables, and a logistic model for the binary positive/educational experience variable.

2.2.3. Knowledge of snakes

We presented participants with three statements about the natural history of snakes (e.g., "all snakes are carnivorous", "snake skin is dry to the touch") and asked them to respond with either true, false, or uncertain. We also provided participants with images of two different native snake species—a northern watersnake (*Nerodia sipedon*) and a pygmy rattlesnake (*Sistrurus miliarius*)—and asked them to indicate whether the depicted species was venomous or non-venomous. Participants could also select 'uncertain' as their answer. Responses for all questions were coded as 0 = incorrect and 1 = correct. If participants selected 'uncertain', their response was considered incorrect. The number of correct natural history questions (ranging from 0 through 3) and correct identification questions (ranging from 0 through 2) were summed separately. We used principal components analysis (PCA) to examine the dimensionality of the five knowledge questions (Supplemental Table 1). We analyzed associations between demographic variables and knowledge of snakes using two linear regression models with natural history knowledge and identification accuracy as dependent variables.

2.2.4. Wildlife value orientations related to snakes

To assess WVOs toward snakes, we asked participants to indicate their level of agreement with four statements (adapted from Teel and Manfredo, 2010) using a five-point Likert scale ranging from 1 (strongly agree) to 5 (strongly disagree). Two of the statements reflected dominionistic WVOs, while the other two reflected mutualistic WVOs related to snakes. We separated the pairs of statements for our data analyses to create a dominionistic variable and mutualistic variable and recoded both scales so that -2 represented strong disagreement and +2 represented strong agreement. We used PCA to test scale dimensionality with regards to the four WVO items (Supplemental Table 2). We analyzed associations between demographic variables and WVOs using two linear regression models with mutualistic and dominionistic values as dependent variables.

2.2.5. Emotional reactions to snakes

We used the Self-Assessment Manikin (SAM; Bradley and Lang, 1994) to assess affective responses toward snakes (Morris et al., 2002). We provided respondents with two different images of snakes, one of which featured a venomous timber rattlesnake (*Crotalus horridus*) poised in striking posture and the other which showed a smaller, non-venomous rough green snake in a non-threatening position (*Opheodrys aestivus*). We then asked respondents to indicate, using SAM, how each of these images made them feel on spectrums from unpleasant to pleasant, relaxed to stimulated, and controlled to controlling. This study focused on measures of pleasantness and intensity, both of which were measured on five-point scales ranging from 1 (unpleasant or relaxed) to 5 (pleasant or stimulated). We analyzed associations between demographic variables and emotional responses to snakes using two linear regression models with pleasantness and intensity scores as dependent variables.

2.2.6. Tolerance of snakes

To measure tolerance, or behavioral intent, with respect to snakes, we asked participants to indicate which of the following three behaviors they would most likely engage if they encountered a snake "right outside of your residence": 1= "kill it or get someone else to," 2 = "relocate it or get someone else to," or 3 = "leave it alone." This strategy followed Bruskotter et al.'s (2015) recommendation to use behavioral measures to predict tolerance. Our questions featured three different scenarios, based on if respondents were: (a) confident the snake was non-venomous, (b) confident the snake was venomous, and (c) uncertain whether the snake was venomous or non-venomous (though this last option was only included on the 2020 survey instrument). Although this strategy primarily focused on a situational view of tolerance or wildlife acceptance capacity (Zinn et al., 2000; Brenner and Metcalf, 2020), it offers a tangible proxy for how individuals might respond to snakes across broader contexts.

To explore demographic and social-psychological correlates of tolerance, we conducted three multinomial logistic regression models for each of the three tolerance scenarios (i.e., non-venomous, venomous, and uncertain). 'Leave alone' was used as the reference category (vs. 'relocate' and 'kill') in all three models. We incorporated the following independent variables in each model: past experiences with snakes that were positive/educational, past experiences that were negative, perception of negative media portrayals, natural history knowledge, identification accuracy, mutualistic WVO, dominionistic WVO, valence and intensity of emotional responses to snakes, as well as demographic variables (e.g., age, gender, race/ethnicity, residence type, and major) (Table 1). Data analyses were conducted in R (R Core Team, 2014).

3 Results

3.1 Sample characteristics

We received 743 completed surveys, including 340 from the 2019 semester and 403 from the 2020 semester. Respondent ages ranged from 17 to 49 years (M = 20, SD = 2.35); 95.0% of respondents were 19 to 23 years old, a range that encompasses the traditional ages for undergraduate students. The majority of respondents were female (60.5%) and White (72.6%), reflecting the demographic ratios of the institution. Only 22.3% of our respondents were majoring in Agriculture/Life Sciences, Natural Resources, or Vet Medicine (hereafter Agriculture/Life Science-related), while the remaining 77.7% had other majors not related to wildlife or natural resources. Approximately half (48.9%) of our respondents grew up in areas with less than 50,000 residents, while the other half (50.7%) grew up in areas with 50,000 or more residents.

3.2 Past experience with snakes

Most (81.8%) respondents indicated they had learned about snakes through an educational program. However, 92.9% of students reported at least one negative experience with snakes, and 64.9% of respondents reported two or more negative snake experiences. The most commonly-cited negative past experience was hearing about venomous snake bite accounts through the media, an indirect type of encounter. Most students who reported negative experience with snakes cited indirect encounters. For instance, the most commonly-cited negative past experiences were hearing about venomous snakes or snake bites through the media (81.6%) or *via* friends and friends (59.7%). Only a few respondents reported direct encounters such as being bitten by a snake (5.9%) or having a pet bitten by a snake (10.6%). Race/ethnicity (B = -0.323, $p < 0.001$) and type of

TABLE 1 Variables in multinomial logistic regression model predicting tolerance of snakes among college students in North Carolina, USA (N = 743).

Variable	Definition	Mean	SD
PositiveExperience	Total number of educational past experiences (Scale: 0 to 1)	0.82	0.39
NegativeExperience	Total number of negative past experiences (Scale: 0 to 5)	1.99	1.07
NegativeMedia	Perceived negative portrayal of snakes in media (Scale: 1 = always to 5 = never)	2.06	0.58
NaturalHistoryKnowledge	Total number of correct natural history questions (Scale: 0 to 3)	1.38	1.03
IdentificationAccuracy	Total number of correct identification questions (Scale: 0 to 2)	0.58	0.69
DominionisticValues	Mean dominionistic score (Scale: -2 = strongly agree to +2 = strongly disagree)	0.69	0.81
MutualisticValues	Mean mutualistic score (Scale: -2 = strongly disagree to +2 = strongly agree)	0.14	0.83
VenomousValence	Pleasantness score toward photo of timber rattlesnake (Scale: 1 = unpleasant to 5 = pleasant)	2.26	1.07
VenomousIntensity	Intensity score toward photo of timber rattlesnake (Scale: 1 = relaxed to 5 = stimulated)	3.30	1.13
NonVenomousValence	Pleasantness score toward photo of rough green snake (Scale: 1 = unpleasant to 5 = pleasant)	3.61	1.21
NonVenomousIntensity	Intensity score toward photo of rough green snake (Scale: 1 = relaxed to 5 = stimulated)	2.28	1.12
Gender	Dummy variable: 0 if male, 1 if female	0.61	0.49
Race	Dummy variable: 0 if White, 1 if non-white	0.27	0.45
Age	Dummy variable: 0 if 18-23 years, 1 if other	0.05	0.22
Residence	Dummy variable: 0 if under 50,000, 1 if over 50,000	0.51	0.50
Major	Dummy variable: 0 if Agricultural/Life Sciences, Natural Resources, or Vet Medicine, 1 if other	0.78	0.42

10.3389/fcosc.2022.1016514

residence (B = -0.185, p = 0.022) were significant predictors of the total number of negative past experiences, with White students and those residing in rural areas reporting more negative experiences with snakes. The only demographic attribute correlated with positive snake experiences was race/ ethnicity (B = -0.531, p = 0.012); more White students indicated they had participated in an educational program about snakes.

Most (84.1%, M = 2.06, SD = 0.58) respondents indicated they felt snakes were portrayed negatively in the media either always or often. Gender (B = -0.158, p < 0.001) and major (B = 0.103, p = 0.049) were both significant predictors; female respondents and those enrolled in Agriculture/Life Science-related majors were most likely to claim that snakes are portrayed negatively in the media.

3.3 Knowledge of snakes

Only 16.6% of respondents answered all three natural history questions correctly (M = 1.38, SD = 1.03). Students enrolled in Agriculture/Life Sciences-related majors scored higher than students majoring in other disciplines (B = -0.383, p < 0.001). Only 11.8% of respondents answered both identification questions correctly, while 53.8% answered neither correctly (M = 0.58, SD = 0.69). Students had a slightly easier time identifying the venomous snake species (32.4% identified that correctly) than the non-venomous species (25.6%), but it was clear that most students struggled between venomous and non-venomous snakes. Gender (B = -0.120, p = 0.024) was the only demographic variable that had a significant effect on snake identification accuracy, with males more likely to correctly identify snakes than females.

3.4 Value orientations related to snakes

Considering WVOs related to snakes, the average mutualistic score across all respondents was 0.14 (SD = 0.83), while the average dominionistic score across all respondents was 0.69 (SD = 0.81). Both mutualistic (B = 0.146, p = 0.021) and dominionistic (B = 0.258, p < 0.001) WVO scores were significantly associated with gender, with males expressing higher dominionistic WVOs and lower mutualistic WVOs than females. Average dominionistic scores were also significantly affected by race/ethnicity (B = -0.137, p = 0.042), with White respondents expressing stronger dominionistic values.

3.5 Emotional reactions to snakes

For the photo of the venomous timber rattlesnake, the average pleasantness score was 2.26 (SD = 1.07) and the average intensity score was 3.30 (SD = 1.13). Pleasantness for this venomous species was significantly affected by age (B = 0.363, p = 0.049), gender (B = -0.246, p = 0.003), and major (B = -0.269, p = 0.006), with respondents who were older, males, and enrolled in Agriculture/Life Science-related majors indicating they felt more pleasant about this photo. Intensity for the venomous species was significantly affected by both race/ ethnicity (B = -0.253, p = 0.009) and gender (B = 0.197, p = 0.023); White students and females had a more intense reaction to the photo of the timber rattlesnake.

For the photo of the non-venomous rough green snake, the average pleasantness score was 3.61 (SD = 1.21), while the average intensity score was 2.28 (SD = 1.12). There were no significant predictors of pleasantness for the rough green snake photo. In terms of intensity, gender was the only significant predictor (B = 0.209, p = 0.014), with males expressing a less intense reaction when compared with females.

3.6 Tolerance of snakes

When encountering a non-venomous snake (that students were sure they could identify), the majority of respondents (61.8%) said they would likely leave it alone and only 8.5% said they would kill the snake (Figure 1). When encountering a venomous snake (that students were sure they could identify), the majority of respondents said they would likely relocate the snake or ask someone else to move it (38.8%), followed closely by killing the snake or asking someone else to kill it (35.5%). For snakes whose identity was unknown, slightly more than half of respondents indicated their intention to either relocate (36.2%) or kill the snake (20.6%).

For the model in which the respondent was certain the snake was non-venomous (Nagelkerke R^2 = 0.239), respondents who expressed lower mutualism values (OR = 0.564, p = 0.010), higher dominionistic values (OR = 4.593, p < 0.001), less pleasant responses toward the non-venomous snake photo (OR = 0.533, p < 0.001), and lower levels of natural history knowledge (OR = 0.743, p = 0.090) were most likely to kill a snake (Table 2). The only significant predictor of relocating the snake was total number of negative past experiences with snakes (OR = 1.181, p = 0.050).

For the scenario in which the respondent was certain the snake was venomous (Nagelkerke R^2 = 0.312), respondents who expressed weaker mutualistic scores (OR = 0.566, p < 0.001), stronger dominionistic scores (OR = 2.495, p < 0.001), and unpleasant responses toward the venomous snake photo (OR = 0.614, p < 0.001) demonstrated an increased likelihood of killing the venomous snake (Table 3). Female students were more likely to kill venomous snakes (or request that others kills snakes) when compared with males (OR = 1.078, p = 0.040). There were no significant predictors of relocating the venomous snake.

For the scenario in which the respondent was uncertain whether the snake was venomous or non-venomous (Nagelkerke

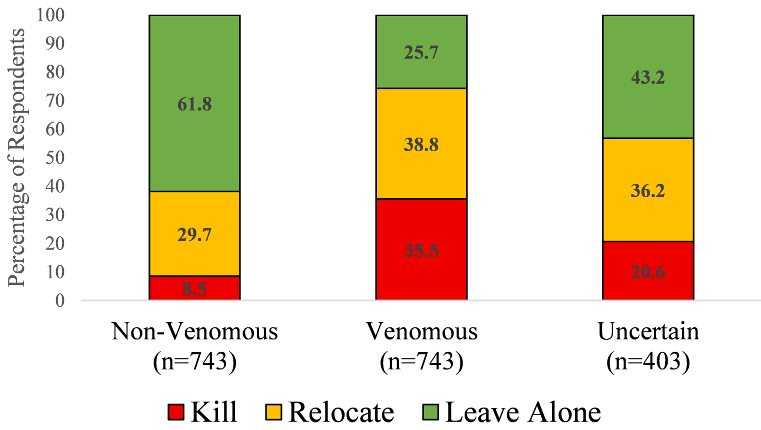

FIGURE 1
Frequency of reported tolerance of snakes (measured as intent to kill, relocate, or leave alone snake that was found "right outside of your residence") among college students (n = 743) in North Carolina based on three hypothetical scenarios: encountering a non-venomous snake, a venomous snake, or a snake whose identity is uncertain. Sample size for the uncertain snake scenario (n = 403) is smaller because this option was only presented in the second year of the survey.

R^2 = 0.274), respondents who expressed stronger dominionistic (OR = 2.113, p = 0.002) and weaker mutualistic (OR = 0.513, p = 0.001) scores were more likely to kill a snake (Table 4). In this scenario, respondents who had grown up in urban areas were more likely to relocate the snake when compared with respondents who grew up in rural areas rural (OR = 0.661, p = 0.046).

4 DISCUSSION

Our results focused on college students in the southeastern U.S. suggest relatively low levels of tolerance toward all types of snakes and particularly snakes thought to be venomous, reflecting patterns seen in other studies in other regions of the country (Christoffel, 2007; Keener-Eck et al., 2020a) and other parts of the world (Pandey et al., 2016; Onyishi et al., 2021; Kontsiotis et al., 2022). However, our analysis of social-psychological and demographic factors yielded more nuanced insight into college students' tolerance of snakes and the variables that influence it, highlighting opportunities to improve human-snake interactions. Many students reported negative experiences with snakes in the past, but most of these negative experiences were indirect in nature (e.g., hearing about snakes and snakebites in the media). Most students also expressed low levels of natural history knowledge and snake identification skills. Students often experienced negative and intense emotional responses to snakes – especially venomous snakes. Furthermore, many students intended to kill venomous snakes or snakes they could not identify (a likely scenario given their limited identification accuracy). Some students even indicated they would kill a snake they knew was non-venomous, though tolerance for non-venomous snakes (8.5% of students likely to kill these snakes) was significantly higher than tolerance for venomous (35.5% likely to kill) or unknown snakes (20.6% likely to kill).

Although tolerance of snakes in our study was variable, some broader social patterns suggest tolerance may be increasing. Students in our study who expressed mutualistic WVOs were generally more tolerant of snakes than students who expressed dominionistic WVOs. This trend might bode well for snake conservation because Americans, in general, are shifting from dominionistic toward mutualistic WVOs (Manfredo and Zinn, 1996; Manfredo et al., 2020), a trend that may be even more pronounced among younger generations (Manfredo et al., 2021). However, in our study, students were more likely to express dominionistic WVO scores associated specifically with snakes, suggesting that the broader shift toward mutualistic WVOs among college students may be less pronounced when snakes are the focal species (Vayer et al., 2021; Manfredo et al., 2020b). This finding suggests many students believe humans are superior to snakes, even if they do not feel that way about other species. We also found that, on average, male students reported higher dominionistic scores and lower mutualism scores than female students, mirroring previous studies exploring the effects of gender on WVOs (Kellert and Berry, 1987; Zinn and Pierce, 2002; Hermann et al., 2013). This evidence suggests that managers and educators could use information about WVOs and correlates to predict public preferences for wildlife management and guide planning and communication strategies related to controversial species, potentially including snakes (Vaske et al., 2011; Jacobs et al., 2014; Miller et al., 2018).

Emotions that arise during experiences with wildlife are thought to affect wildlife-related attitudes and subsequent

TABLE 2 Parameter estimation from the multinomial logistic regression model predicting tolerance of non-venomous snakes (measured as reaction to seeing a non-venomous snake "right outside of your residence") among college students in North Carolina (n = 743).

Variable	Kill			Relocate		
	β (SE)	Wald	OR	β (SE)	Wald	OR
Constant	-2.042 (1.636)	1.558		-1.343 (0.822)	2.669	
Gender (female)	0.075 (0.347)	0.047	1.078	-0.028 (0.181)	0.025	0.972
Race (BIPOC)	0.205 (0.372)	0.304	1.227	0.080 (0.196)	0.166	1.083
Age (non-traditional)	-0.931 (1.130)	0.678	0.394	-0.653 (0.447)	2.132	0.521
Residence (urban)	-0.324 (0.337)	0.925	0.723	0.232 (0.178)	1.705	1.261
Major (non-ag/NR)	-0.436 (0.414)	1.107	0.647	0.208 (0.222)	0.879	1.234
PositiveExperience	-0.585 (0.379)	2.388	0.557	-0.361 (0.236)	2.344	0.697
NegativeExperience	0.125 (0.159)	0.613	1.133	0.166 (0.085)	3.849	1.181**
NegativeMedia	-0.381 (0.266)	2.050	0.683	-0.024 (0.153)	0.025	0.976
NaturalHistoryCorrect	-0.297 (0.175)	2.872	0.743*	-0.043 (0.088)	0.245	0.958
IdentificationCorrect	0.305 (0.243)	1.578	1.3157	-0.154 (0.128)	1.435	0.857
DominionisticValues	1.525 (0.295)	26.665	4.593***	0.022 (0.120)	0.034	1.022
MutualisticValues	-0.573 (0.223)	6.579	0.564***	0.021 (0.123)	0.030	1.022
NonVenomousValence	-0.629 (0.183)	11.833	0.533***	-0.003 (0.102)	0.001	0.997
NonVenomousIntensity	0.138 (0.179)	0.593	1.148	0.151 (0.102)	2.183	1.163

The "leave snake alone" category (61.8%, n = 459) was considered as the reference for comparisons with the other tolerance categories of "kill" (8.5%, n = 63) and "relocate" (29.7%, n = 221).
*, **, and *** denote statistical significance of alpha at 0.10, 0.05, and 0.001, respectively.
Model Fit Statistics: $\chi^2(1386) = 1609.4$, $p < 0.001$, Nagelkerke pseudo-$R^2 = 0.239$.
Model depicts likelihood of killing or relocating the snake versus leaving it alone.

behaviors (Hudenko, 2012; Larson et al., 2016; Castillo-Huitrón et al., 2020), which may explain why emotional responses played an important role in predicting tolerance toward snakes in our study. Our finding that a photo of a rattlesnake elicited greater arousal and lower valence than a photo of a rough green snake could be explained by risk perceptions and fear. Landová et al. (2020) found that psychophysiological responses to images of fear-inducing venomous snake species were stronger than responses elicited by images of non-venomous snakes. Because fear in all situations is characterized by high arousal and low pleasantness (Russell et al., 1989), it makes sense that our respondents experienced greater unpleasantness and stimulation toward the rattlesnake photo. Interestingly, these intense emotions were reported from simply viewing a photo, not directly encountering a snake in the real world. These patterns support previous research suggesting that perceived threat and aposematic signalling for certain species such as snakes can significantly impact the way humans think about and respond to them (Souchet and Aubret, 2016). Emotions might also help to explain female students' inclination to kill all snakes (and particularly venomous snakes), a finding we did not expect. Although female students expressed stronger mutualistic values typically linked to tolerance, they also showed stronger emotional reactions to snakes (i.e., negative valence and high intensity) relative to their male counterparts. These findings highlight the relative power of affect over cognitions when determining an individual's behavior towards wildlife, a trend that has also been observed in studies of other human populations (Larson et al., 2016).

College students' negative experiences with snakes were not directly related to behavior intent in our models. However, some studies suggest past experiences with wildlife may influence key antecedents of tolerance (Kansky et al., 2016), including attitudes and behaviors towards snakes (Onyishi et al., 2021). For example, Deiruter (2002) suggested direct experiences with

TABLE 3 Parameter estimation from the multinomial logistic regression model predicting tolerance of venomous snakes (measured as reaction to seeing a venomous snake "right outside of your residence") among college students in North Carolina (n = 743).

Variable	Kill			Relocate		
	β (SE)	Wald	OR	β (SE)	Wald	OR
Constant	0.009 (0.862)	0.179		0.623 (0.753)	2.717	
Gender (female)	0.471 (0.229)	4.228	1.600**	0.199 (0.206)	0.928	1.220
Race (BIPOC)	-0.166 (0.250)	0.441	0.847	-0.172 (0.222)	0.600	0.842
Age (non-traditional)	-0.411 (0.570)	0.519	0.663	0.196 (0.413)	0.227	1.217
Residence (urban)	0.151 (0.222)	0.459	1.163	0.320 (0.202)	2.508	1.377
Major (non-ag/NR)	0.359 (0.272)	1.740	1.433	0.173 (0.237)	0.537	1.189
PositiveExperience	-0.437 (0.299)	2.143	0.646	-0.195 (0.285)	0.469	0.823
NegativeExperience	0.159 (0.108)	2.179	1.172	-0.134 (0.096)	1.930	0.875
NegativeMedia	-0.031 (0.192)	0.027	0.969	-0.059 (0.178)	0.109	0.943
NaturalHistoryCorrect	0.064 (0.111)	0.339	1.067	0.070 (0.100)	0.489	1.072
IdentificationCorrect	0.077 (0.160)	0.230	1.080	-0.003 (0.143)	0.001	0.997
DominionisticValues	0.914 (0.170)	28.816	2.495***	-0.262 (0.139)	3.572	0.769*
MutualisticValues	-0.568 (0.156)	13.194	0.566***	0.198 (0.145)	1.866	1.218
VenomousValence	-0.488 (0.136)	12.957	0.614***	-0.135 (0.113)	1.428	0.874
VenomousIntensity	0.001 (0.118)	0.000	1.001	0.077 (0.103)	0.560	1.080

The "leave snake alone" category (25.7%, n = 191) was considered as the reference for comparisons with the other tolerance categories of "kill" (35.5%, n = 264) and "relocate" (38.8%, n = 288).
*, **, and *** denote statistical significance of alpha at 0.10, 0.05, and 0.001, respectively.
Model Fit Statistics: $\chi^2(1392) = 1414.7$, p = 0.33, Nagelkerke pseudo-R^2 = 0.312.
Model depicts likelihood of killing or relocating the snake versus leaving it alone.

wildlife, including extractive, appreciative, and fear or negative experiences, contribute to the formation of WVOs. We found that students who grew up in rural areas had more negative experiences with snakes than urban respondents, aligning with other research showing negative experiences with wildlife are more common among rural residents (Kretser et al., 2009). The fact that most students believed snakes were portrayed negatively in the media, combined with the fact that the most-cited negative past experience with snakes was hearing about venomous snake bites, highlight the capacity for media to influence wildlife-related attitudes, particularly regarding potentially dangerous species (Murray and Foote, 1979; Jacobson et al. 2011; Muter et al. 2012; Beall et al., 2022). It should be noted, however, that many students also reported positive experiences with snakes, typically in the form of educational programming. White respondents were more likely to have both negative and positive experience with snakes, possibly reflecting cultural differences in exposure to nature among racial/ethnic groups that begin at an early age and could impact wildlife-related behaviors later in life (Larson et al., 2010; Kellert et al., 2017). Collectively, these findings highlight an array of factors that shape indirect and direct past experiences with snakes, both positive and negative, supporting other research examining people's experiences with nature (Soga et al. 2016). Although these experiences did not correlate strongly with our measure of tolerance (i.e., behavior intent in a specific situation) for college students, future research should continue to explore how past experiences with fear-inducing species like snakes impact humans' proclivity for tolerance and peaceful coexistence (Keener-Eck et al., 2020b; Kontsiotis et al., 2022).

Respondents' low overall levels of knowledge about snakes' natural history and identification may explain why knowledge

TABLE 4 Parameter estimation from the multinomial logistic regression model predicting tolerance of snakes that were not know to be venomous or non-venomous (measured as reaction to seeing an unknown type of snake "right outside of your residence") among undergraduate students in North Carolina (n = 403).

Variable	Kill			Relocate		
	β (SE)	Wald	OR	β (SE)	Wald	OR
Constant	-0.329 (1.578)	0.044		0.688 (1.218)	0.319	
Gender (female)	0.464 (0.332)	1.951	1.590	0.207 (0.257)	0.652	1.230
Race (BIPOC)	-0.040 (0.363)	0.012	0.962	-0.273 (0.291)	0.878	0.761
Age (non-traditional)	-0.375 (0.879)	0.182	0.687	-1.098 (0.682)	2.590	0.333
Residence (urban)	-0.090 (0.317)	0.080	0.914	0.508 (0.255)	3.987	1.661**
Major (non-ag/NR)	0.810 (0.580)	1.948	2.247	0.132 (0.421)	0.099	1.142
PositiveExperience	-0.779 (0.432)	3.248	0.459*	-0.677 (0.356)	3.612	0.508*
NegativeExperience	-0.031 (0.153)	0.040	0.970	-0.120 (0.123)	0.938	0.887
NegativeMedia	0.077 (0.237)	0.106	1.080	-0.266 (0.211)	1.593	0.766
NaturalHistoryCorrect	0.202 (0.156)	1.675	1.224	-0.073 (0.124)	0.341	0.930
IdentificationCorrect	0.372 (0.223)	2.779	1.451*	0.128 (0.179)	0.507	1.136
DominionisticValues	0.748 (0.247)	9.146	2.113***	-0.147 (0.178)	0.679	0.864
MutualisticValues	-0.667 (0.207)	10.371	0.513***	0.001 (0.172)	0.000	1.001
VenomousValence	-0.265 (0.219)	1.465	0.767	-0.207 (0.160)	1.668	0.813
VenomousIntensity	0.181 (0.188)	0.925	1.198	0.114 (0.148)	0.595	1.121
NonVenomousValence	-0.332 (0.188)	3.098	0.718*	0.075 (0.154)	0.239	1.078
NonVenomousIntensity	-0.150 (0.197)	0.581	0.861	-0.247 (0.162)	2.327	0.781

The "leave snake alone" category (43.2%, n = 174) was considered as the reference for comparisons with the other tolerance categories of "kill" (20.6%, n = 83) and "relocate" (36.2%, n = 146).
*, **, and *** denote statistical significance of alpha at 0.10, 0.05, and 0.001, respectively.
Model Fit Statistics: $\chi^2(726) = 725.6$, p = 0.50, Nagelkerke pseudo-R^2 = 0.274.
Model depicts likelihood of killing or relocating the snake versus leaving it alone.

did not directly predict tolerance for snakes in our study. This trend has been documented in past studies examining knowledge about wildlife across America (Kellert, 1980; Zinn and Andelt, 1999). More recently, Christoffel (2007) found that residents from eight counties in Michigan and Minnesota had little knowledge about both non-venomous and venomous snakes. Another study in Australia found that common local snake species were frequently misidentified (Wolfe et al., 2020). Students in our sample with majors related to Agriculture/Life Sciences, Natural Resources, or Veterinary Medicine tended to answer more natural history questions correctly, but even among this group snake-related knowledge and identification skills were limited. Students' inability to correctly identify snakes poses a major conservation challenge, as nearly two thirds of students failed to recognize a venomous snake species. We found that, when in doubt, students may assume a snake is venomous and respond in a more intolerant fashion by killing or relocating the animal. Inability to differentiate between venomous and non-venomous snake species could result in poorly informed decision-making that exacerbates active persecution of snakes, whether that behavior is intentional or not.

Weak links between knowledge and behavior in our study support research suggesting that factual information about a given species (sometimes referred to as "the cognitive fix") may not be enough to significantly influence attitudes or behavioral intentions with respect to that species (Heberlein, 2012; Skupien et al., 2016). This may disconnect between knowledge, attitudes, and behaviors may be particularly pronounced for species that elicit fear in humans, including bats (Prokop and Tunnicliffe, 2008), spiders (Prokop and Tunnicliffe, 2008; Shipley and Bixler, 2017), and snakes (Prokop et al., 2009). Thus, focusing solely or even primarily on educational outreach as a way of influencing tolerance of snakes, or other types species that generate perceived problems for people (Krafte Holland et al., 2018), may not be particularly effective. Nevertheless, positive educational experiences involving snakes were typically associated with higher levels of tolerance, especially when the identity of a snake was unknown. This relationship may not stem from factual knowledge gains, but the powerful emotions that are evoked in experiential education (Sponarski et al., 2016; Castillo-Huitrón et al., 2020). Experiences that foster positive and personal affective connections with fear-inducting species can enhance human tolerance for these species (Skupien et al., 2016; Teixeira et al., 2020), and the same may be true for snakes. Thus, creating opportunities for positive interactions with snakes, whether they are direct or indirect (e.g., vicarious experiences through the media), could help to combat negative perceptions, influence choices during human-snake interactions, and ultimately promote snake conservation and stewardship.

4.1 Limitations and future research

Several limitations of our study highlight opportunities for future research. First, our specific sample frame only included undergraduate students from one university in one region of the United States. Perceptions and tolerance of snakes may vary by populations and regions (Keener-Eck, 2020b), highlighting the need for similar research across other geographic areas and cultural contexts (Teel et al., 2007). Our methodology also introduced potential biases. For instance, self-report questionnaires are often subject to social-desirability response bias (Whitehouse-Tedd et al., 2020), which might lead to artificially high estimates of tolerance for snakes. This means that public acceptance of snakes might be even lower than documented in our study. Combining self-report questionnaires with more objective measures of attitudes, emotions, and tolerance, such as implicit association tests or physiological tracking, might yield new insights (Vaughn et al., 2022). Future research could also examine a wider variety of past experiences with snakes, particularly including more than one type of positive interaction. Although we strategically portrayed snakes that represented a range of species native to the region, including some snakes that were easy to identify and some often confused with others, selection of other snake photos (or snakes in different postures) might have yielded different results. Demographic variables were not strongly linked to tolerance in our analysis, but they were associated with different behavioral antecedents. Future research could explore the role of certain demographic variables (e.g., gender, urban vs. rural) as moderators of tolerance for wildlife (Baron and Kenny, 1986; Kleiven et al., 2004). Finally, our study used behavioral intent, as opposed to actual behaviors, to measure tolerance. Furthermore, we only examined behavior intent in one situation (i.e., encountering a snake "right outside your residence"). Assessing responses to snakes across different contexts and situations would yield a more robust and comprehensive measure of tolerance. Future studies could integrate more diverse strategies for assessing tolerance and capacity for coexistence with wildlife (Kansky et al., 2016; Pooley et al., 2021).

4.2 Conclusion

Our findings indicate that most college students had limited knowledge of snakes, and many struggled to distinguish between venomous and non-venomous species. These factors, coupled with a prevailing belief that humans were superior to snakes (i.e., dominionistic WVO) and intense negative emotional reactions to snakes, resulted in relatively low levels of tolerance for all snake species. When identification was in doubt (a very common occurrence), students were more likely to express intolerance by killing or removing a snake. Given these patterns observed in our respondents, wildlife managers and educators might therefore search for strategies to increase public awareness of snakes, including the variety of benefits that snakes provide. But our study also suggests that education alone is not a sufficient response. The best approaches to influencing tolerance of and behavior toward snakes should target multiple behavioral antecedents simultaneously. Programs, messaging, and communication strategies that combat negative stereotypes, foster positive experiences, acknowledge diverse WVOs, and emphasize pleasant emotional responses to all types of snakes (venomous and non-venomous) are likely to be more effective at bolstering tolerance than those that focus on factual knowledge and identification skills, even though enhancing public capacity to accurately distinguish venomous and non-venomous snakes remains important. This comprehensive approach to increasing acceptance and tolerance for snakes could positively impact snake conservation and inform efforts to understand and promote tolerance for other maligned and misunderstood species.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

This human subjects research project was reviewed and approved through the Institutional Review Board of North Carolina State University (IRB#20906). The patients/participants provided their written informed consent to participate in this study.

Author contributions

AV was the principal investigator in the study and oversaw design of the conceptualization of the research and the data collection process, with input from LL, MP, and LP. AV and LL led the data analysis and writing of the manuscript, with MP and LP contributing to drafts. All authors contributed substantially to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcosc.2022.1016514/full#supplementary-material

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