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RESEARCH ARTICLE

Biophobia: A Hidden Dimension of Human-Nature Relationships

Giant anteaters as bad omens: Determinants and implications of wildlife superstitions

Mariana L. Catapani[1,2,3] | Arnaud L. J. Desbiez[2,4,5] | Carla Morsello[1,6]

[1]Graduate Program in Environmental Science, Institute of Energy and Environment, University of São Paulo, São Paulo, Brazil; [2]Wild Animal Conservation Institute (ICAS), Campo Grande, Brazil; [3]Chester Zoo, Chester, UK; [4]Royal Zoological Society of Scotland (RZSS), Edinburgh, UK; [5]Instituto de Pesquisas Ecológicas (IPÊ), São Paulo, Brazil and [6]School of Arts, Sciences and Humanities, University of São Paulo, São Paulo, Brazil

Correspondence
Mariana L. Catapani
Email: macatapani@hotmail.com

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Abstract

1. Superstitious beliefs threaten wildlife species, yet they have received limited attention in the scientific literature.
2. Through a mixed-method approach, including 259 face-to-face interviews, we explored the factors influencing superstitions about giant anteaters in the Brazilian Pantanal and their implications for both people and the species.
3. Our results indicated that bad omen superstitions about giant anteaters could be explained by the psychological discomfort felt from the species' peculiarities, social influence, misconceptions about their biology and behaviour, and the frequency of the species' sightings. Age, gender and schooling did not influence superstitious adherence.
4. Interviewees holding superstitious beliefs of bad luck reported worry, distress and anxiety in trigger situations. Most engage in superstitious behaviours to ward off bad luck. While some acts were harmless, others threatened people and giant anteaters.
5. By explaining misconceptions and demystifying unique species characteristics that evoke psychological discomfort, conservationists might foster better coexistence between people and species historically associated with misfortune.

KEYWORDS
coexistence, cultural beliefs, human–wildlife interactions, misfortune, wildlife persecution

1 | INTRODUCTION

In several cultures, human–wildlife interactions surpass material and utilitarian connections, encompassing broader symbolic realms (Bakels et al., 2016). Such cultural conceptions can have a positive impact on biodiversity conservation. This is especially true when species or natural landscapes hold mythological or symbolic importance that reduces hunting or destruction (Allaby, 2010; Landry Yuan et al., 2020) or when species are culturally protected through taboos, restrictions or dietary avoidance (Jones et al., 2008). However,

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cultural beliefs may also threaten biodiversity when animals or parts of their bodies are subject to religious practices (Waldau, 2006), or when thought to have healing or aphrodisiac properties (Djagoun et al., 2013). Another little addressed, and potentially wildlife-threatening, symbolic dimension relates to when a species is believed to harbour bad omens or, in other words, superstition. Superstitions are conceptualized here as the beliefs and/or practices lacking religious or scientific foundations, leading individuals to associate specific facts or objects with bringing good or bad luck or serving as signs of positive or negative outcomes (Delacroix & Guillard, 2008). This definition excludes beliefs in witchcraft, astrology and supernatural and mythological beings, incorporated by specific authors within this concept (e.g. Jahoda, 1970; Whiting, 2006). Although conceptually superstitions encompass a wide range of beliefs and behaviours, most can be united by a single underlying property: the incorrect establishment of cause and effect (Foster & Kokko, 2009).

Direct persecution (i.e. aggression towards animals or death) motivated by bad omen superstitions has been observed across various taxa, including reptiles (Ceríaco, 2012), owls (Mikkola, 2000), frogs (Tarrant et al., 2016), hyenas (Hadad et al., 2023), crows (Hagemeijer & Blair, 1997) and bats (Prokop & Tunnicliffe, 2008). In some cases, such beliefs can pose a significant threat to the survival of the species, as exemplified by the aye-aye primate in some villages of Madagascar (Randimbiharinirina et al., 2021; Simons & Meyers, 2001) and giant anteaters in Costa Rica (Velázquez & Monroy-Gamboa, 2023).

Dealing with such wildlife superstitions demands a deeper understanding of how they evolve, are assimilated, and disseminated. Thus, this study aimed to compare the significance of sociodemographic, contextual and psychosocial factors in people's adherence to wildlife superstitions. We also examined the implications of these beliefs for both individuals and the species involved. This information can foster insights that contribute to promoting more positive interactions between people and species associated with misfortune. We begin by reviewing theories on the emergence and diffusion of superstitions within a group, followed by a focus on a seemingly ideal study of superstition towards wildlife.

1.1 | Theoretical foundations explaining superstitions

Superstitions exist in probably all human societies (Beck & Forstmeier, 2007; Foster & Kokko, 2009), and can be both personal (e.g. lucky coins or charms) and culturally shared by a group (e.g. unlucky numbers). In fact, the associative process explaining superstitions has long been attributed to other species as well. Conducting an experiment, for example, Skinner (1948) provided food every 15 s to pigeons, irrespective of their actions. Over time, each pigeon developed unique ritualized behaviours (head swinging, turning anticlockwise) as though their actions were causing the food to arrive (Abbott & Sherratt, 2011). Skinner suggested there was a causal connection between food presentation and rituals in pigeons, based on the Contiguity Theory (Guthrie, 1940), which postulates that the only requirement for associating stimuli and response is a close temporal relationship between events. He then concluded that superstitions arise from misinterpretations of accidental contingencies.

The ubiquity of superstitions is puzzling from an evolutionary perspective since it suggests a mismatch between perception and reality. More importantly, since superstitions often involve costs (either from avoiding or doing something), this should lead to lower fitness (Abbott & Sherratt, 2011). Yet, authors argue (Henrich & Henrich, 2010; Singh, 2022), and some empirical (Henrich & Henrich, 2010) and model-based (Abbott & Sherratt, 2011; Beck & Forstmeier, 2007; Foster & Kokko, 2009) theoretical studies suggest, that superstitions, along with taboos and other magical beliefs, may be well-designed practices to address environmental challenges. People adopt ineffective goal-oriented behaviours ('superstitions') because of psychological mechanisms that are products of natural and cultural selection (Singh, 2022). According to this view, superstitions inevitably result from an adaptive causal learning mechanism that reduces the risk of errors. Individuals that seek causal relationships in the environment to inform their behavioural decisions must rely on incomplete information, which may come from natural selection (i.e. instinct), cultural transmission, personal learning, or a combination of all three (Abbott & Sherratt, 2011). Our psychology predisposes us to the optimal use of information and to adopt low-cost options, while evolution crafts those actions to be maximally effective (Singh, 2022).

A low-cost strategy is learning from coincidences, which helps distinguish real patterns from randomness. Associative learning is similar to setting the level of alpha for rejection of a null hypothesis in statistics. The process is governed by risk management, which means individuals have to trade-off the cost of failing to detect a pattern that actually exists (ignorance or type II error), against the cost of concluding there is a pattern where there is randomness (superstition, or type I error; Beck & Forstmeier, 2007). It is impossible to reduce one error without raising the other. If the mechanisms were designed to avoid any superstition, this would increase the likelihood of costly misses, such as failing to avoid rotting pig meat when one is pregnant (a taboo). Human psychological mechanisms are designed to favour less costly errors over more costly ones, sustaining superstitions (Singh, 2022). Thus, superstitions are a by-product of the evolved mechanism of causal thinking and an inevitable consequence of the ability to learn from the observation of coincidences. Although the process is similar in other organisms, humans have evolved strong causal thinking that has allowed us to understand and manipulate environments, in addition to learning quickly (Beck & Forstmeier, 2007).

Three situational characteristics make superstitions more probable. First, they often arise from causal relationships that, while nonexistent, are plausible. While plausibility may derive from understanding (instinctive or learned), cultural traditions are a very influential source of beliefs in humans (Abbott & Sherratt, 2011). Second, they develop when the cost of performing a superstitious behaviour is low, but potential benefits are high. Paraphrasing

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Beck and Forstmeier (2007: 40), to a non-believer, it costs little more than pride to knock three times on wood to avoid bad luck on a plane trip, but the potential benefit of survival is considerable. Third, there is a relationship between the uncertainty of an environment and the level of superstitious beliefs (as uncertainty goes up, so too do superstitions; Shermer & Marshall, 1997). For example, Malinowski (1948) observed in his study with Trobriand islanders that fishermen in areas with lower risk (inner lagoon) and more consistent returns were less superstitious, while those in open, deep and dangerous seas, with higher variability and uncertainty, relied on superstitious rituals. According to Malinowski, uncertainties and risks would leverage the emergence of superstitions.

Three aspects make a novel superstition developed by one individual more likely to spread via cultural transmission. First, the plausibility of the idea. When beliefs appear inconsistent, the concept must be seductive and interesting without extrapolating from what is understandable to the human mind (e.g. believing in flying dolphins; Norenzayan et al., 2006). Second, human cognitive biases play a part. Evolutionary models have depicted how natural and cultural selection may shape the social learning abilities that lead individuals to selectively focus their attention on those people (models) most likely to possess adaptive information (beliefs, skills or practices) (Beck & Forstmeier, 2007). Social ties within one's network, mainly family, are preferred models due to the low cost of information transmission (Henrich & Henrich, 2010). Additionally, when several people hold a belief, new members are more likely to acquire it (Latané, 1981). Finally, transmission depends on people's assimilation processes, which are not always passive. Individuals may selectively retain information according to what they consider trustable evidence about a concept (Norenzayan & Atran, 2004). Thus, by understanding what people consider as evidence for existing superstitious beliefs, conservationists may be able to understand how to avoid bad luck superstitions when needed to protect a threatened species.

1.2 | The giant anteater: An empirical case of superstition towards wildlife

Our model species in this investigation is the giant anteater (*Myrmecophaga tridactyla*; Figure 1) from the rural Brazilian Pantanal. This insectivorous mammal has a broad distribution across South and Central America; however, despite its extensive range, it is categorized as vulnerable on both the IUCN Red List of Threatened Species (Miranda, Bertassoni, & Abba, 2014) and the Brazilian Red List (Miranda, Chiarello, et al., 2014).

Giant anteaters can grow up to 2 m in length and weigh around 39 kg. There is no sexual dimorphism in the species, which mainly presents solitary habits, except during parental care and reproductive periods. In some areas of their distribution, giant anteaters symbolize bad luck (Bertassoni, 2012; Gaudin et al., 2018). Persecution motivated by superstitions has also been argued to threaten the species (Velázquez & Monroy-Gamboa, 2023) and is reported in the Brazilian National Action Plan (Instituto Chico Mendes de Conservação da Biodiversidade, 2019). To date, however, there is no study investigating the determinants and impacts of superstitious beliefs towards giant anteaters.

2 | METHODS

2.1 | Study area and participants

The study was conducted in the southern portion of the Brazilian Pantanal (Mato Grosso do Sul), specifically in three selected municipalities (Corumbá, Aquidauana and Miranda, Figure 2), based on giant anteater occurrence and accessible car routes. The Pantanal is the world's largest wetland, covering ~200,000 km^2 across Brazil, Bolivia and Paraguay (Coutínho et al., 1994). The region is characterized by sandy soils with mosaic vegetation, including semideciduous forests, dispersed shrub vegetation and seasonally flooded fields

FIGURE 1 A giant anteater (*Myrmecophaga tridactyla*) in the Brazilian Pantanal. Photo credit: Wild Animal Conservation Institute.

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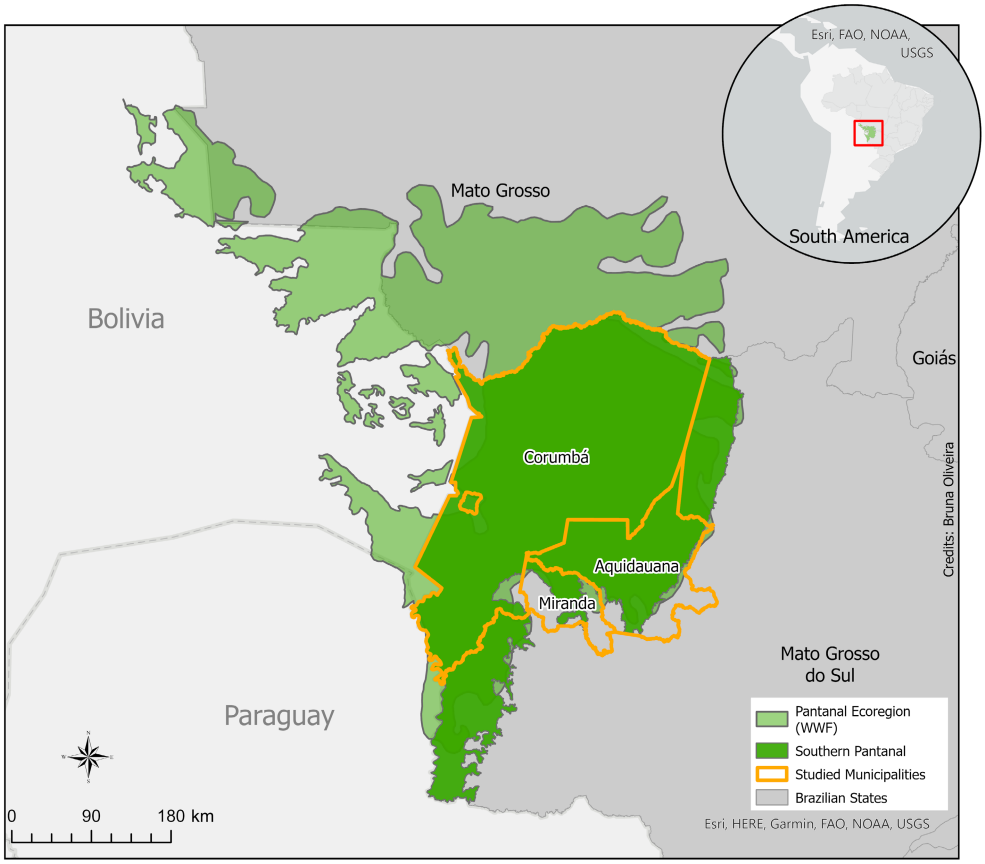

FIGURE 2 Municipalities where data were collected in the Brazilian Pantanal, Mato Grosso do Sul state, based on Olson et al. (2001).

(Rodela, 2006). Many parts of the biome range change every year from terrestrial to aquatic habitats. During the dry season, the flooded areas dry up as water recedes and evaporates.

The study was conducted with rural inhabitants from Pantanal, regionally called *pantaneiros*. The Brazilian Pantanal was settled by cattle ranchers over 200 years ago (Wilcox, 1999) and, historically, was divided into large farms. Cattle ranching remains the most significant activity (Girard, 2012), involving most rural inhabitants. These inhabitants live in low human densities (<2 people per km^2; Swarts, 2000) and are geographically isolated due to the seasonal floods.

2.2 | Research design

We used a mixed-method approach involving qualitative semi-structured interviews and a quantitative survey (Creswell, 2009). The study was approved by the Brazilian National Commission for Research Ethics (CAAE n° 80236317.4.0000.0065). All participants provided their informed consent to participate.

2.2.1 | Semi-structured interviews

From February to April 2017, we conducted 88 semi-structured interviews (Newing, 2010) to explore local superstitious beliefs about giant anteaters and associated variables. The interviews were recorded, transcribed and analysed following template analysis (TA). After identifying repetitions, similarities and differences, we finalized the coding template and then applied it to the entire dataset, following the six-step procedure by King (2012) and Brooks et al. (2015). The results were systematized and used to determine variables for the subsequent quantitative stage. The analysis was conducted using NVivo® v.11 software. Figure 3 summarizes the final coding template, covering superstitious beliefs, the contextual and psychosocial factors associated with them, as well as their implications for both people and animals.

2.2.2 | Survey

From August 2018 to July 2019, structured interviews were conducted using a pre-tested protocol. Due to the low literacy rate of the population, face-to-face interviews were chosen over self-administered questionnaires. We employed a multi-stage probabilistic sampling design to ensure representation across dispersed populations in our study area. Rural properties were chosen by randomly drawing points on satellite images using Google Earth® software. Upon arrival, we explained the research purpose and asked for the names of all residents over 18 y.o. We then drew the names of two residents from the list to be interviewed. When there were only two

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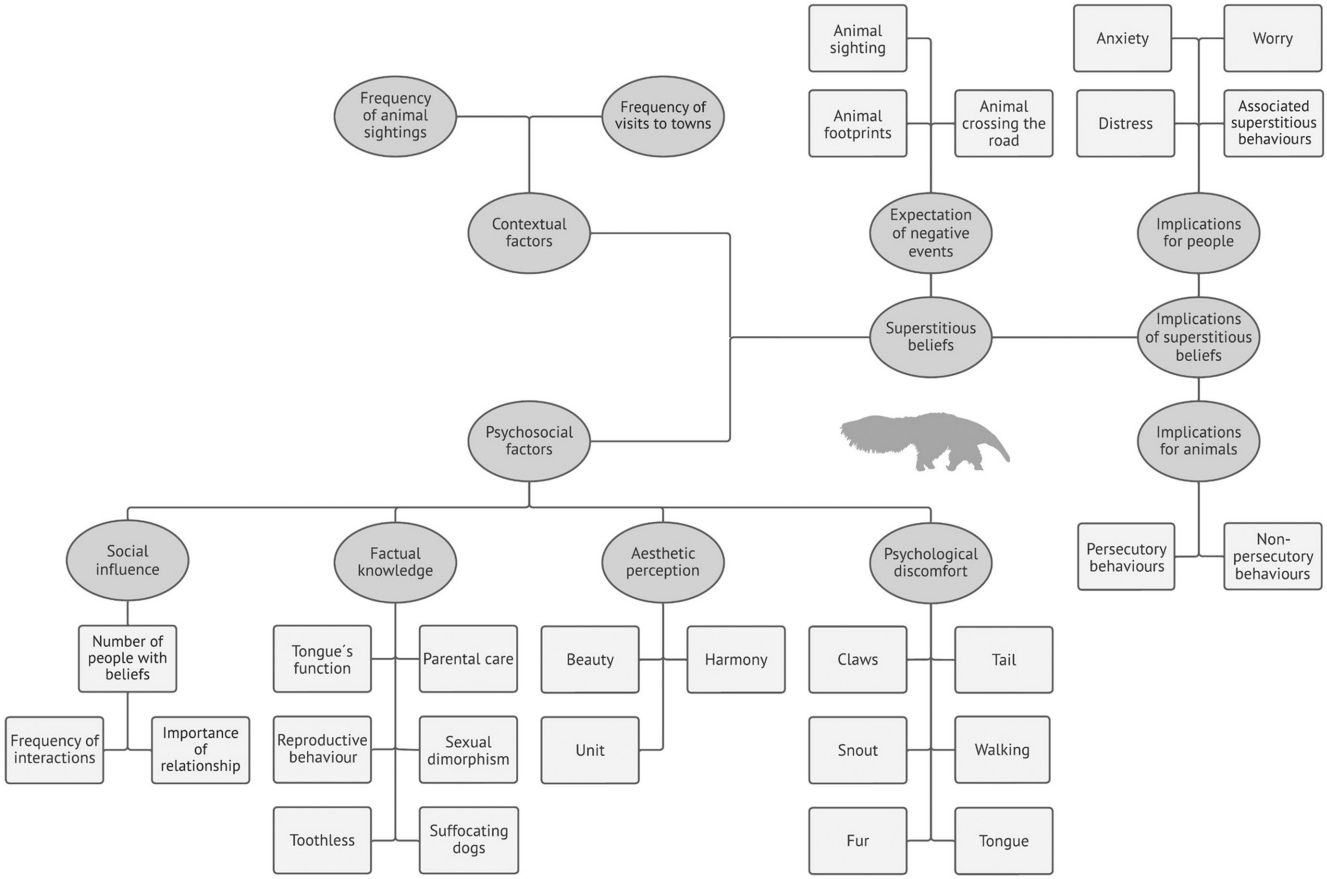

FIGURE 3 Final coding template applied to full set of qualitative data. Ovals represent identified themes, that is, recurring factors in participant accounts characterizing specific perceptions relevant to the study. Rectangles represent existing subthemes. Subthemes share their organizing concepts under the umbrella of the main theme while also focusing on distinct and significant elements.

residents, one name was drawn. To avoid biases (most women being at home and men being in the field during the day), we waited until the end of the day for people's return to interview them. None of those selected refused to participate.

2.2.3 | Variable definition

Each theme identified by the TA resulted in at least one variable included in the structured interview (Supplementary material S1) and hereafter described.

Contextual factors

We identified two factors in qualitative interviews that could be associated with adherence to superstitions about giant anteaters: the frequency of giant anteater sightings within a 12-month period (from none to every day) and the frequency of the interviewee's visits to town in the last 12 months (from none to seven or more times).

Aesthetic perception

This variable assessed people's evaluation of the aesthetic value of giant anteaters. A scale consisting of three semantical differential statements was adopted, which compare two opposite adjectives (e.g. ugly–beautiful, unpleasant–pleasant, uninteresting– interesting). Each statement was rated on a scale from −3 (negative end of the spectrum) to +3 (positive end of the spectrum), including a neutral point rated as zero.

Psychological discomfort

This variable measured the level of discomfort individuals experience with the unique characteristics of giant anteaters. It was calculated based on ratings given by respondents to six questions related to specific anteaters' characteristics (i.e. claws, way of walking, tail, fur, tongue, snout) identified as causing discomfort in the qualitative phase. Ratings were provided on a unipolar 5-point scale from 1 (not weird at all) to 5 (much too weird). The use of a unipolar scale lacks a neutral point and has the potential to inflate results. However, it was selected here to provide a more refined category gradation about the attribute of interest (i.e. weirdness). We also included an option for those who had never see the trait, rating it as zero.

Factual knowledge

We created a knowledge test based on information gathered in the qualitative phase, focusing on the main misinterpretations of certain

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characteristics of the species (e.g. sexual dimorphism, and reproductive behaviour). The test consisted of six statements, half correct and half wrong, with three response options for each statement: Correct (=1), Incorrect (=0), and I do not know (=0). By summing the individual's scores on the test, we analysed their factual knowledge about giant anteaters.

Superstitions

All superstitions associated with giant anteaters identified in the qualitative phase were related to bad luck. Superstitious beliefs about giant anteaters were assessed using a Likert-type scale with four statements representing information gathered from the qualitative phase. Participants rated each statement on a bipolar 7-point agreement scale (e.g. from 'excellent' = −3 to 'terrible' = 3), including a neutral point.

Social influence

The influence of others who held beliefs in superstitions about giant anteaters was assessed measuring three aspects: the number of people with the belief (1 question), the importance of the relationship (1–3 questions) and the interviewee's frequency of interactions with other believers (1–3 questions). Response scales ranged from 0 (none, not important, never) to 7 (many people, very important, always).

Implications for the person

This aspect assessed three psychological consequences identified exclusively in individuals who hold superstitious beliefs: anxiety, distress and worry. They were measured using a unipolar scale ranging from −2 (not worried at all, not distressed at all, and not anxious at all) to +2 (very worried, very distressed and very anxious).

Superstitious behaviours

Refer to the belief in specific actions or rituals to prevent bad luck from giant anteaters, including harmful and non-harmful behaviours identified in the qualitative phase. Frequencies of mentioned behaviours were counted in those with superstitious beliefs.

Intention to harm

We assessed people's intentions to engage in harmful behaviours (e.g. clobber or killing giant anteaters), following the principle of compatibility (Fishbein & Ajzen, 1975). Participants rated three statements on a 5-point scale [from strongly agree (+2) to strongly disagree (−2)]. The frequencies were tallied for each response category.

Individual characteristics

We collected data on gender, age, schooling, religion and place of residence. However, the religion variable was not included in the statistical analyses due to lack of variation. Additionally, the place of residence variable was excluded from the analyses due to inconsistency between the interviewees' perceived place of residence and the administrative territorial delimitation of municipalities.

2.3 | Data analyses

We performed a path analysis to examine the association between independent variables [individual (age, gender and schooling), contextual (the sightings frequency of giant anteaters and the frequency of the interviewee's visits to town) and psychosocial factors (social influence, psychological discomfort, aesthetic perception and factual knowledge)] and the dependent variable (i.e. superstitions about giant anteaters) using partial least squares-structured equation modelling—PLS-SEM (Figure 4). Descriptive statistics were conducted using IBM SPSS Statistics® software (v. 23), while path analysis, including the factor analysis step, was performed using SmartPLS® software (v. 4).

3 | RESULTS

We interviewed 171 individuals aged 18 to 87 (mean 47.4, SD = 15), with the majority being men (82.5%) born in the study area (92.4%) and with low levels of schooling (average years = 3.7 ± 2.8). We did not find any positive superstition towards giant anteaters. Less than half of the participants (40.4%; $n = 69$) held bad luck superstitions about the species. Specific superstitions were commonly associated with negative expectations when encountering giant anteaters and crossing their path (see Table 1). The anticipated negative outcomes varied widely, from failing to fish, hunt, close a deal, and get ill or general misfortune.

3.1 | Determinants of superstitious beliefs about giant anteaters

The first step was evaluating the goodness of the model fit and, thus, checking the validity and reliability of each scale adopted (i.e. aesthetic perception, psychological discomfort, social influence and superstition) to verify if they appropriately represented the latent variables. Table 2 summarizes the metrics of convergent validity (average variance extracted—AVE) and reliability (composite reliability—CR; Cronbach's alpha—a) of the scales, which were considered appropriate (AVE ≥0.5; CR ≥0.7; $\alpha \geq 0.7$) as indicated in the literature (Byrne, 2010; Marôco, 2014).

After these analyses, we evaluated the scales' discriminant validity using cross-loadings, HTMT ratio and Fornell–Larcker criteria. Table 3 shows factor loadings of each phrase (indicator) used in the scales related to the constructs involved in the measurement model. As can be seen, the higher loading of each indicator is related to its respective construct and not any other, showing no cross-loadings and, consequently, discriminant validity (Hair et al., 2011).

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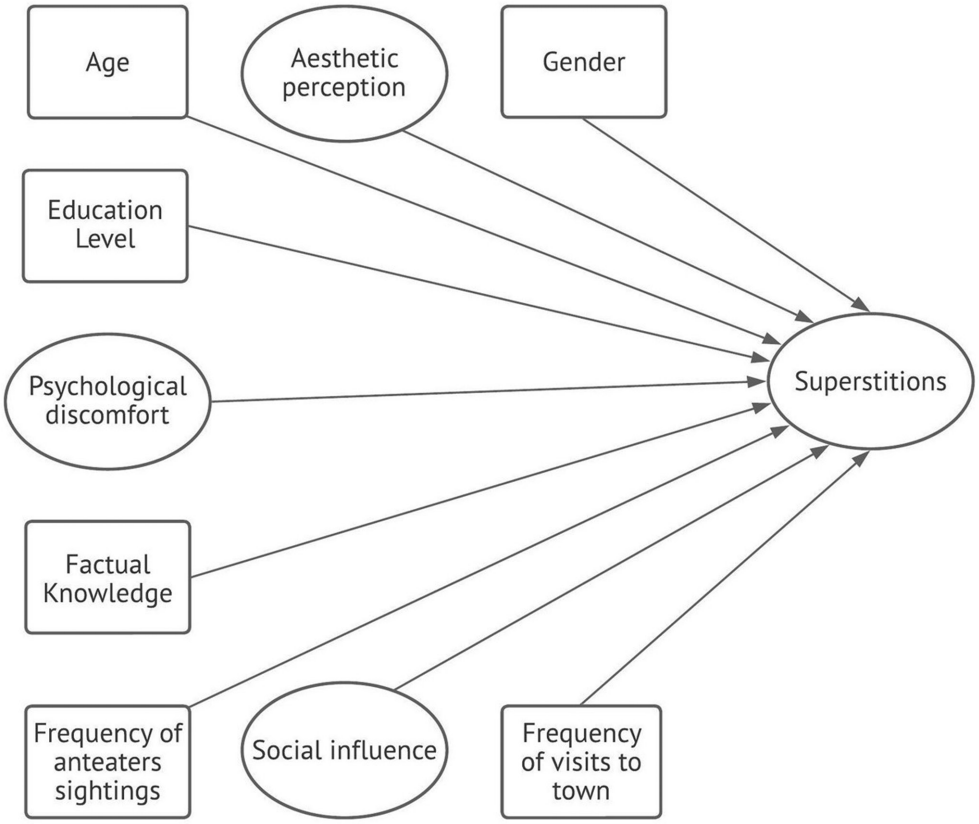

FIGURE 4 Theoretical model. Oval figures represent latent variables, and rectangular figures represent observed variables, following the SEM nomenclature.

TABLE 1 Prevalence of superstitious beliefs about giant anteaters (*Myrmecophaga tridactyla*) across our sample ($n = 171$).

Superstitious beliefs about giant anteaters	*N*	%
The expectation of negative events when seeing a giant anteater	63	37.0
The expectation of negative events when crossing a giant anteater in the path	47	27.5
The expectation of negative events when a giant anteater crosses in front of one's vehicle	43	25.1
The expectation of negative events when coming across a giant anteater's footprints	40	23.3

Note: As participants were allowed to select more than one superstition they believed in, the cumulative count may surpass the total number of participants ($n = 171$).

TABLE 2 Reliability and validity of the scales used.

Variables	Cronbach's alpha (a)	Composite reliability (CR)	Average variance extracted (AVE)
Aesthetic perception	0.853	0.911	0.774
Psychological discomfort	0.895	0.921	0.661
Social influence	0.847	0.884	0.527
Superstition	0.934	0.953	0.836

Additionally, the results (Table 3) showed a good correlation (factor loadings in grey shade) between each latent variable and respective phrases/questions (above 0.5), according to Hair et al. (2009), indicating a so-called factorial validity (Marôco, 2014).

After the cross-loadings analysis, we adopted the procedure recommended by Fornell and Larcker (1981) and compared the square root of the average variance extracted (AVE) of each construct with the Pearson correlation verified between the constructs. If there is

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discriminant validity, the correlations have values smaller than the square root of the AVEs of the scales. As seen in Table 4, the correlation between the constructs was below the square root of the AVE of each construct, indicating the existence of discriminant validity in the scales used. To estimate a final scale's discriminant validity, we adopted the heterotrait–monotrait ratio (HTMT) criterion (Henseler et al., 2015). As displayed in Table 5, all HTMT ratio values met the parameters that guarantee the discriminant validity of the scales (≤0.85).

Once the measurement model was validated, we evaluated the proposed theoretical model (structural model), verifying the statistical significance of the relationships. The bootstrapping technique was used with 5000 resamplings (Hair et al., 2014; Vinzi et al., 2010) to obtain the path coefficients (Table 6).

The path analysis results (Table 6) revealed that psychological discomfort and social influence positively and significantly influenced superstitions about giant anteaters. This finding means that higher levels of psychological discomfort with species peculiarities

TABLE 3 Discriminant validity—Cross-loading criteria.

Indicators	Aesthetic perception	Psychological discomfort	Social influence	Superstition
aesthetic1	0.892	−0.662	−0.362	−0.493
aesthetic2	0.916	−0.628	−0.349	−0.466
aesthetic3	0.830	−0.545	−0.379	−0.456
discomfort1	−0.433	0.647	0.308	0.460
discomfort2	−0.548	0.781	0.384	0.536
discomfort3	−0.562	0.806	0.433	0.562
discomfort4	−0.565	0.853	0.457	0.577
discomfort5	−0.629	0.893	0.513	0.676
discomfort6	−0.638	0.874	0.517	0.659
social1	−0.328	0.341	0.624	0.363
social2	−0.319	0.394	0.688	0.404
social3	−0.288	0.213	0.503	0.303
social4	−0.283	0.373	0.794	0.463
social5	−0.353	0.472	0.772	0.609
social6	−0.308	0.441	0.852	0.618
social7	−0.267	0.453	0.787	0.633
superstition1	−0.499	0.646	0.586	0.872
superstition2	−0.522	0.681	0.613	0.920
superstition3	−0.458	0.639	0.655	0.923
superstition4	−0.486	0.659	0.69	0.942

TABLE 4 Discriminant validity—Fornell–Larcker criterium.

Constructs	Aesthetic perception	Psychological discomfort	Social influence	Superstition
Aesthetic perception	**0.880**			
Psychological discomfort	−0.697	**0.813**		
Social influence	−0.413	0.543	**0.726**	
Superstition	−0.537	0.718	0.696	**0.914**

Note: Values in bold are the square root of AVE of each construct.

TABLE 5 Discriminant validity—HTMT ratio criterium.

Constructs	Aesthetic perception	Psychological discomfort	Social influence	Superstition
Aesthetic perception				
Psychological discomfort	0.794			
Social influence	0.499	0.605		
Superstition	0.602	0.781	0.753	

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TABLE 6 Path coefficients and respective significance, VIF and f^2 parameters.

Variable	Path coefficient	SD	*p*-value	VIF	f^2
Individual characteristics					
Gender	−0.075	0.142	0.561	1.039	0.003
Age	−0.003	0.049	0.978	1.187	0,000
Education level	−0.056	0.049	0.257	1.321	0.008
Contextual					
The frequency of giant anteater sightings	−0.237	0.061	<0.001	2.027	0.099
The frequency of the interviewee's visits to towns	0.047	0.051	0.371	1.639	0.004
Psychosocial					
Aesthetic perception	0.009	0.065	0.876	2.084	0,000
Psychological discomfort	0.345	0.079	<0.001	2.662	0.155
Factual knowledge	−0.137	0.057	0.017	1.569	0.041
Social influence	0.359	0.058	<0.001	1.591	0.282

Note: Path coefficients are in the standardized form.

and greater social influence led to higher levels of superstition. Conversely, the frequency of past sightings of giant anteaters negatively and significantly affected superstitions, suggesting that more frequent sightings were associated with lower superstition levels. In the same direction, factual knowledge about giant anteaters significantly reduced superstitions about them. The more knowledge respondents had about giant anteaters' biology and behaviour, the less superstition they held towards the animal. None of the other variables in the model had a statistically significant influence on the respondents' superstitions.

Comparing the path coefficients of the variables significantly influencing superstitions (Table 6), we observe that psychological discomfort with the species' peculiarities and social influence were the most important, followed by the frequency of sighting giant anteaters and factual knowledge about the species.

We also conducted a multicollinearity test to examine its potential influence on our results. The literature suggests varying collinearity limits of variance inflation factor (VIF), ranging from 10 (Hair et al., 2019) to 5 (Marôco, 2014). None of these values affected our interpretation that multicollinearity is not a significant concern in our study since the highest value observed was 2.662 (Table 6).

In terms of the explanatory power of the model proposed, 69.8% (determination coefficient $R^2_{\text{adjusted}}=0.698$) of the superstitions about giant anteaters is explained by psychological discomfort with the species' peculiarities, social influence, factual knowledge about giant anteaters and frequency of sighting giant anteaters. To assess how each predictor affected the endogenous construct's R^2 value, we calculated the f^2 effect size metric. As can be seen in Table 6, f^2 effect sizes present values fluctuating from small (0,02), medium (0,15) and large (0,35) (Hair et al., 2019), but mainly aligned with the magnitude of significant values of absolute path coefficients. According to the literature, collinearity among sets of independent variables, significance of path coefficients, coefficient of determination (R^2) and effect size (f^2) (Hair et al., 2014, 2019) are ways to demonstrate the goodness of the structural model. The statistical robustness of the test developed was verified using the G*Power® 3.1.9.2 software, obtaining a result >0.99 (post hoc test; Faul et al., 2007, 2009).

3.2 | Implications of superstitious beliefs about giant anteaters

Of those who hold superstitions about the species ($n=69$), when the trigger situations occur, 65.2% ($n=45$) of them declared that they become worried or very worried, 60.9% ($n=42$) distressed or very distressed, and 56.5% ($n=39$) reported feeling anxious or very anxious about the situation. About 94% ($n=65$) of interviewees holding superstitions described performing associated actions to prevent negative events. Of the 69 people who believed in the bad luck of giant anteaters, 69.6% ($n=48$) engaged in non-harmful behaviours (e.g. dodging the animal or its footprints). Harmful behaviours, such as clobbering the animal, were mentioned by 18 interviewees (26.1% of the 69 people who believed). Sixteen respondents, accounting for 9.36% of our sample of 171 participants, reported a moderate to high intention to clobber the animal the next time they encountered it. None have admitted an intention to kill the animal in these situations.

4 | DISCUSSION

Giant anteaters perceived as a harbinger of bad luck is a common but not predominant belief in our study area. Around 60% of respondents did not manifest this belief, though 90% reported knowing someone who did. The specific superstitions related to giant anteaters varied among individuals, from sighting the animal as a bad omen to associating dire consequences with coming across its footprints. Similarly, the consequential superstitious behaviours changed, but low-cost strategies (dodging the animal or its footprints) predominated over high-cost ones (clobbering or killing anteaters), which

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aligns with models that suggest superstitions should be 'cheap' (Abbott & Sherratt, 2011). The existence of superstitious beliefs about anteaters also aligns with contexts whereby theoretical models predict they would develop, that is, uncertain situations with some perceived danger or low level of perceived control (Foster & Kokko, 2009).

Accordingly, the rural Pantanal is home to other wildlife-related superstitions. Sighting an American barn owl, hearing the plaintive chant of the nocturnal common potoo or dreaming about snakes are all considered signs of misfortune. The process of seeking signs in nature is likely a component of adaptative processes of decision-making which enable predictions and coping with landscape adversities (Nyong et al., 2007). For example, insect-eating birds flying low soon before the rain and ants building anthills with higher, steeper sides are considered indicators of an intense flood in the Pantanal. This observation does not imply that rural contexts favour the development of superstitions. Superstitious beliefs and behaviours are multiple and a universal phenomenon, with prevalence in urban environments as well (George & Sreedhar, 2006).

Even though superstitions are widespread, little is known about which factors explain people's adherence to them. Our study indicates that gender, age and schooling do not drive superstitions towards giant anteaters. For gender, previous research shows conflicting findings, with studies showing no gender differences in superstition levels (Buhrmann & Zaugg, 1981; Tobacyk & Milford, 1983), while others suggest women are more superstitious (Irwin, 1993). Research investigating the relationship between age and superstitions has also found conflicting results, with studies suggesting higher superstition levels among young people (Corrigan et al., 1980), while others propose the opposite (Epstein, 1993). Although superstitions have been considered, historically, as cognitive deficits, the association between education and superstitions also diverges across studies (Musch & Ehrenberg, 2002; Salter & Routledge, 1971). Overall, the relationship between individual characteristics and superstitions remains undefined and requires further investigation.

Our empirical results about people's exposure to giant anteaters on their adherence to superstitions suggest that encountering these animals more often makes a person less likely to hold superstitions. At first glance, this result contradicts what a model about superstition development indicates (Abbott & Sherratt, 2011), that is, that the number of opportunities to evaluate the consequences (here, anteater sightings) may increase the likelihood of developing a superstition. Yet, the model shows the outcome depends on previous beliefs: with more exposure and prior superstitious beliefs, the chances of developing superstitions rise, whereas previous disbelief leads to the opposite. Suppose you live in the rural Pantanal, believe giant anteaters bring misfortune, and you see one followed by an adverse event. That might be enough for you to connect the two unrelated occurrences and adopt the superstition due to confirmatory bias (seeking evidence that confirms our beliefs; Klayman & Ha, 1987). If you believe, the more times you see the animal, the more likely you are to experience a negative occurrence and, hence, to develop a superstition. In contrast, if you disbelieve, frequent encounters with giant anteaters without negative consequences can further disprove this belief, leading to its rejection. Wherever disbelieving predominates in a context, the tendency is likely to increase the number of disbelievers with more exposure.

Three significant findings emerged when we correlated psychosocial factors with superstitions. First, social influence matters. If superstitions are part of the culture itself or a descriptive social norm (what most people think, feel, or do; Cialdini et al., 1991), the chances that an individual will acquire superstitions through oral communication increase (Madden et al., 2006). Knowing individuals with superstitions about giant anteaters (mainly close relatives) and having frequent interactions with them increased the likelihood of adopting those beliefs. These results also corroborate expectations from the social impact theory (Latané, 1981) about the influence of relationship strength, immediate interactions and the number of individuals sharing a belief on said beliefs. This also align with empirical findings, which suggest these transmission paths are favoured due to their low cost, at least in taboos (Henrich & Henrich, 2010).

Our second psychosocial finding is that low factual knowledge about giant anteaters (misunderstandings) predicts people's adherence to superstitions. This aligns with the theoretical prediction that, despite cultural transmission, ideas should not be passively acquired but incorporated depending on the quality of the evidence supporting them (Norenzayan & Atran, 2004). Accordingly, research with Slovak students showed that greater scientific knowledge about bats correlated with fewer superstitions (Prokop & Tunnicliffe, 2008). Similarly, misinterpretations of species' behaviours can lead to superstitions, as observed with owls in Malawi (Clark et al., 1978), where their presence in cemeteries is mistakenly associated with evil when it may simply indicate their preference for wooded areas. Nevertheless, there is also evidence showing the contrary. A study on the aye-aye in Madagascar found that, despite their scientific knowledge, forestry agents still held superstitious beliefs (Simons & Meyers, 2001).

The third psychosocial finding indicates that an individual's belief associating giant anteaters with unluckiness is significantly influenced by their psychological discomfort towards the animal's attributes. Anteaters possess unique physical characteristics that contrast with other species: an elongated skull with small ears and eyes; a long snout with a tiny tubular mouth without teeth; a dense body coat and a long-fringed tail, along with front legs ending in three large claws. Their lack of sexual dimorphism and intra-abdominal testicles can lead to misinterpretations, as people attribute other functions to these organs or structures. These unique characteristics and misunderstandings contribute to giant anteaters' mysterious and uncertain reputation. People might embrace superstitious beliefs towards wildlife when faced with unfamiliar and uncommon creatures, aligning with Malinowski's (Malinowski, 1948) and others' (Shermer & Marshall, 1997) observations on uncertain situations and model predictions (Abbott & Sherratt, 2011). These findings shed light on the persistence of superstitions regarding other animals with unique traits, like crows' vocalizations, owls' unusual behaviours (e.g.

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head rotation) or the aye-aye's distinctive fingers. Superstitions are probably more likely to develop when animals' traits and behaviours are unfamiliar.

Research on personality assessment indicates that uncertain situations can threaten our sense of control (Amoura et al., 2014), leading to psychological discomfort and anxiety (Archer, 1979). Our results on the implications of superstitions corroborate this view, as individuals who held these beliefs about giant anteaters reported feeling worried, distressed and anxious when trigger situations occurred. This aligns with cognitive psychologists' perspective that people seek to understand, predict and control their environments to maximize positive outcomes and minimize negative ones (Case et al., 2004). The motivation for control has adaptive value, and many individuals engage in specific behaviours or rituals to ward off bad luck and reduce anxiety levels with a sense of control over uncertain situations (Keinan, 2002). This may explain why most interviewees who held superstitious beliefs also exhibited superstitious behaviours. While some acts were harmless, such as avoiding the animal or its footprints, others were more costly and threatened both people and giant anteaters.

While none of the interviewees intended to kill giant anteaters, certain aspects require attention. First, note that admitting to killing these animals is likely a sensitive issue due to potential punishment (due to illegality) or judgement (Fisher, 1993). Thus, our 'intention to kill' estimates probably are underestimated. For a reliable quantitative assessment of the direct threat of superstitions upon giant anteaters, further studies may benefit from using indirect questioning techniques (e.g. Bean Method; Lau et al., 2011; Unmatched Count Technique; Hinsley et al., 2018) developed to increase response accuracy.

Second, approximately one-tenth of our interviewees intended to clobber giant anteaters' snouts to ward off bad luck. The frontal area of the giant anteater is anatomically and physiologically delicate, serving vital functions for the animal (Naples, 1985, 1999). Veterinary experts have emphasized that trauma to this area can cause irreparable damage, particularly affecting the digestive tract, tongue, salivary glands and mandibular musculature. Such injuries can lead to the animal's inability to feed, ultimately resulting in starvation (D. Kluyber, personal communication, May 21, 2021).

Third, although giant anteaters generally avoid human contact, they can defend themselves with their powerful forelimb claws when threatened. While human deaths caused by giant anteaters are rare, they have been reported due to severe tissue lacerations from the animal's sharp claws. Therefore, superstitions about anteaters can also have negative consequences for people, causing anxiety and distress while potentially putting individuals at risk.

Fourth, superstitions and other cultural practices are not inherently and directly harmful to the species. Some of these practices, such as food taboos, can even reduce the impact on threatened species (Colding & Folke, 1997). The predominant superstitious behaviour observed was avoiding anteaters, which could, hypothetically, even reduce the negative effects on the animal. However, a non-neglectable 9.36% of our sample admitted that would clobber the animal the next time it was seen, and this percentage is most likely undersized. Additionally, ad hoc evidence shows that anteaters were extinct in parts of their range in other countries due to such beliefs (Velázquez & Monroy-Gamboa, 2023). Lastly, bad omen superstitions differ from taboos since even when deleterious behaviours are absent, the former affect people's views about the species involved, probably leading to less support for their conservation in the region. Therefore, from a conservation perspective, local bad omen superstitions are indeed directly or indirectly detrimental.

5 | CONCLUSIONS AND IMPLICATIONS

Given the negative consequences of bad luck superstitions for both people and giant anteaters, we argue that diminishing their strength can enhance human coexistence with giant anteaters and other wildlife species associated with misfortune. Here we share some insights about how to proceed.

First, diminishing bad luck superstitions by explicitly bringing them up in interventions is not a good solution. Generally, people memorize information, which may be retrieved when exposed to negative occurrences involving target species. Recalling information may be sufficient for the assimilation of a superstition, with extensive effort required to later refute the belief.

Second, the findings indicated problematic behaviour towards anteaters (clobbering) was not the predominant superstitious strategy. This could direct us to a potential, but highly controversial approach (and to us unethical), that is, to publicize the low-cost superstitious behaviour (avoidance). Hence, it predominates and substitutes the harmful behaviour, such as predicted with some models (Beck & Forstmeier, 2007). This strategy could be supported by people who consider it more ethical to keep such cultural beliefs of a specific population. However, we strongly refute this option because it has drawbacks to species conservation and human safety. As just argued, mentioning the problem makes it more accessible in people's minds, leading to greater chances of superstition assimilation.

Third, conservationists could focus on approaches to raise the importance of anteaters so that the local population comes to value them. They could do so by debunking misconceptions and addressing factors that elicit psychological discomfort with the species' traits. In the long term, child-oriented interventions may be the most appropriate strategy to connect with students, their families and communities (Ballantyne et al., 2001; Marchini & Macdonald, 2020). A school-based approach is, in fact ongoing, based on an illustrated booklet (Supplementary material S2) and a teacher's guide (Supplementary material S3), which address misunderstandings and demystifies key anteater characteristics. The booklet was distributed to rural school children and integrated into teachers' training, but further research is required to assess the effectiveness of this approach. Securing a future for wildlife will demand from conservationists a nuanced understanding of the interactions between species and cultural belief systems.

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AUTHOR CONTRIBUTIONS

Mariana L. Catapani and Carla Morsello conceived the ideas and designed the methodology. Data collection and data analysis were performed by Mariana L. Catapani, who led the writing of the manuscript. Arnaud L. J. Desbiez coordinates the Wild Animal Conservation Institute, providing crucial logistical and financial support for the fieldwork. Both Carla Morsello and Arnaud L. J. Desbiez revised the article making substantial contributions to the manuscript, providing critical input during drafting and giving final approval for publication.

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CONFLICT OF INTEREST STATEMENT

Although Carla Morsello is an Associate Editor for People and Nature, she was not involved in the peer review or publishing process.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in Figshare at https://doi.org/10.6084/m9.figshare.24486847.

ORCID

Mariana L. Catapani https://orcid.org/0000-0002-4784-6631

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Supplementary S1. Questionnaire utilized in the structured interviews.

Supplementary S2. Illustrated booklet 'The Incredible Giant Anteater' addressing misunderstandings and demystifying key giant anteater characteristics.

Supplementary S3. Teacher's guide, crafted to provide context for the illustrated booklet within the classroom setting.

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