

RESEARCH ARTICLE

Examining the multi-disciplinary origins of biophobia towards threatening and non-threatening wildlife in a highly urbanised city in China

Sam S. S. Lau^{1,2}  | Jason W. L. Fong¹ | Andras N. Zsido^{3,4}  |
Matthew H. E. M. Browning⁵

¹Research Centre for Environment and Human Health, School of Continuing Education, Hong Kong Baptist University, Hong Kong, China

²College of International Education, School of Continuing Education, Hong Kong Baptist University, Hong Kong, China

³Faculty of Humanities and Social Sciences, Institute of Psychology, University of Pécs, Pécs, Hungary

⁴Contemporary Challenges Research Centre, University of Pécs, Pécs, Hungary

⁵Department of Parks, Recreation and Tourism Management, Clemson University, Clemson, South Carolina, USA

Correspondence

Sam S. S. Lau

Email: samlau@hkbu.edu.hk

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Abstract

1. Urbanisation is reshaping how people experience wildlife, reducing our shared spaces with local biodiversity. Fewer opportunities for human–wildlife interactions weaken our emotional attachments to nature and precipitate a loss of species knowledge and familiarity. However, we still know little about why modern city residents have become increasingly fearful of both threatening and non-threatening animals.
2. To address this gap, we surveyed 1430 adults in Hong Kong, a highly urbanised city in China, to examine how nature connectedness, disgust sensitivity and experiences with wildlife interact to predict biophobia across threatening animals (snakes and spiders) and non-threatening animals (small harmless animals, such as mice, bats and worms).
3. Using structural equation modelling, we found that behavioural nature connectedness—how often people physically engage with nature—is the strongest protective factor against biophobia. In contrast, psychological nature connectedness only buffered threatening animal fears, revealing a critical role of engagement with natural environments in reducing fears for a multitude of small animals.
4. Distinct disgust pathways also shaped biophobia: animal reminder disgust predicted fear of threatening animals, whereas blood–injection–injury fear was the strongest predictor of the fear of non-threatening animals. Most strikingly, fears of threatening animals (especially spiders) spilled over to fears of non-threatening animals, even after accounting for disgust, nature connectedness and gender, suggesting a previously underexplored generalisation process in biophobia.
5. Contrary to the ‘vicious cycle of biophobia’ model, sociocultural pathways—parental fears and personal experiences with animals—did not meaningfully explain this fear generalisation, implying that social transmissions of knowledge did not generalise biophobic responses between threatening and non-threatening animals.

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6. Our findings highlight the significant, opposing effects of disgust and physically engaging with nature on biophobia. Interventions that strengthen opportunities for direct nature experiences may be more effective than traditional, information-based approaches in reducing disgust and cultivating behavioural nature connectedness. This is important for reducing public fears, fostering coexistence and removing barriers for conservation efforts that benefit a broader spectrum of local species.

KEYWORDS

biophobia, disgust, fear of small animals, fear of snakes, fear of spiders, nature connectedness

1 | INTRODUCTION

1.1 | Urbanisation and the 'Extinction of Experience'

Urbanisation changes how people experience the natural world. City dwellers, having less contact with wildlife, are less familiar with local species and natural environments, a phenomenon called the 'extinction of experience' (Pyle, 1978, 1993). This reduced contact weakens emotional bonds with nature (Soga & Gaston, 2016) and can foster biophobia, an aversive or fearful reaction towards living organisms or natural environments (Simaika & Samways, 2010; Ulrich, 1993). The challenges of rapid urbanisation often create densely populated cities with insufficient means of supporting biodiversity in its urban green spaces, such as in Asia and Australia (Haaland & van den Bosch, 2015). Understanding the roots of biophobia is crucial for underpinning its influence on the human–nature relationship and to promote biodiversity-friendly urban management (Soga & Evans, 2024).

1.2 | Catalysts of biophobia

Animal phobias date back to prehistory when our ancestors developed autonomous behavioural responses to evolutionary threats, which persist today in modern human brains according to the modularity of the mind (Coelho et al., 2019). Today, animal phobias are the most prevalent form of specific phobias for adults with the highest lifetime prevalence of nearly 4% in 22 countries (Wardenaar et al., 2017), of which snake (*Ophidiophobia*) and spider (*Arachnophobia*) phobias were among the most common types (Correia & Mammola, 2023; Polák, Rádlová, et al., 2020). Snakes and spiders are feared worldwide in nonclinical populations (Isbell, 2009; Mammola et al., 2022), and studies suggest our brains detect snake and spider images more rapidly and subconsciously compared to other stimuli (Hoehl et al., 2017; LoBue & DeLoache, 2011). An alternative theory to fear perceptions is the disease-avoidance model (Davey, 2011; Matchett & Davey, 1991), which suggests that many animal phobias emerge from our evolutionary predisposition to avoid pathogens (see also Coelho et al., 2023). Indeed, many studies link both fear and disgust as key negative emotions in common phobic reactions to spiders

with potent or non-potent venom and to predatory snakes (de Jong & Peters, 2007; Rádlová et al., 2020; Stankova et al., 2021), due to their movements, appearance and the difficulty in distinguishing venomous from venomous species without expert knowledge (Grassini et al., 2019; LoBue & DeLoache, 2011).

As urbanisation transforms natural environments, wildlife increasingly seeks food and shelter in cities, potentially leading to human–wildlife conflicts depending on public perceptions and tolerance (Puri et al., 2024). The prevalence of animal phobias has risen with urban population growth and declining human–nature interactions (Correia & Mammola, 2023). Phobic animals are perceived as the most threatening in urban spaces because our fear responses act as survival mechanisms aimed at detecting and avoiding biological threats (Ulrich, 1993). Unlike larger feared predators, snakes, spiders and small animals (e.g. mice, bats and worms) are widespread globally and also evoke intense fears in people (Zeller et al., 2025). These animals share anxiety-evoking characteristics, such as small sizes, stealth and sudden movements (Bennett-Levy & Marteau, 1984; Merkelbach et al., 1987). Many species have adapted to urban environments, occupying small, enclosed spaces within human dwellings. Urban populations may overestimate the likelihood and severity of involuntary physical contact with animals due to exaggerated beliefs about their ubiquity, aggressive nature and dangerousness (de Jong & Muris, 2002; Hengen & Alpers, 2019). The urbanisation-disgust hypothesis (Fukano & Soga, 2021) posits that urban residents exhibit increased disgust when encountering insects indoors compared with similar outdoor encounters. This pattern is attributed to residents' higher perceived risks of contamination in spaces intended for eating and sleeping, even when insects are unlikely to transmit diseases, and to their unfamiliarity with different insect species compared with rural residents.

Soga et al. (2023) proposed the vicious cycle of biophobia, illustrating how sociocultural pathways amplify and internalise biophobic attitudes in urban populations. This model integrates behaviourist theories through key pathways (Askew et al., 2014; Correia & Mammola, 2023): direct negative experiences trigger learnt fear responses and subsequent avoidance or hostile behaviours via classical conditioning, reinforced by continued avoidance of animals and their habitats (i.e. negative reinforcement). This reliance on indirect knowledge from vicarious experiences from online media, peers or

social learning channels compensates for their unfamiliarity with threatening or non-threatening animals (Olsson et al., 2007), which in turn diminishes emotional connections with nature and wildlife (Bashan et al., 2021; Zhang et al., 2014), thereby increasing hostile actions towards them (Williams et al., 2021).

We distinguish between 'threatening' (e.g. snakes and spiders) and 'non-threatening' (small animals such as mice, bats and worms) animals (Arrindell et al., 1984; Tasto, 1977), based on the predominant emotional responses: fear of animals with threatening features (predatory or venomous), versus disgust-driven avoidance of non-threatening animals linked to contamination. Despite some overlap between categories, this distinction clarifies how different negative emotions contribute to biophobia. Whether harmless or not, the context of encounters with animals also matters. Anxiety (strong anticipatory and generalised sensitivity to threat) often mediates the transition from transient fear or disgust to long-term animal-related anxiety disorders (Norberg et al., 2023). Therefore, we conceptualise biophobia as a multidimensional construct shaped by the interaction of fear, disgust and anxiety (Soga & Evans, 2024; Zsido et al., 2022).

In contrast to biophobia, nature connectedness is a psychological measure of the extent to which a person's sense of self overlaps with nature. It develops from childhood experiences and remains stable throughout adulthood as a trait-like characteristic (Mayer & Frantz, 2004; Nisbet et al., 2009). It can be assessed at the affective level (how emotionally connected people feel to nature), cognitive level (how they perceive humans as part of ecosystems or hold pro-environmental values) and behavioural level (how much time they spend in nature and how comfortable they feel there). Studies have suggested that the novelty of new nature experiences support high levels of nature connectedness (Santori et al., 2021; Warber et al., 2015), while lifelong experiences with nature throughout adulthood foster pro-nature conservation behaviours (Aota & Soga, 2024). Zsido et al. (2022) observed that nature connectedness mitigates the fear of snakes and spiders through psychological and behavioural dimensions. The psychological dimension encompasses moral concern for nature and wildlife, while the behavioural dimension indicates a willingness to seek out natural environments for positive experiences. Furthermore, successive experiences can desensitise people to fearful stimuli, demystifying their perception of animals as 'dangerous', 'unpredictable' or 'disgusting' (Coelho et al., 2021; Sugiyama et al., 2021) and potentially mitigating biophobic attitudes (Soga & Gaston, 2020; Zhang et al., 2014). Controlling for reduced disgust sensitivity, we hypothesise that the psychological and behavioural dimensions of nature connectedness mitigate the fear of threatening and non-threatening animals within a highly urbanised population (Hypothesis 1).

1.3 | Extending biophobic attitudes to unfamiliar species

Given the multifaceted aetiology of phobias towards snakes and spiders, few studies have examined whether fear of these animals can predict generalised effects of biophobia. One exception is a study of Australian university students using electroencephalogram data, which

found that a higher self-rated fear of snakes and spiders predicted increased attentional bias towards harmless worms and beetles (Mallan & Lipp, 2011). Conversely, Stankova et al. (2021) found that fear and disgust ratings were intercorrelated only for snakes and spiders, while no association was found for taxonomically distinct species with typical fear- or disgust-evoking traits. Lack of species knowledge could be a key risk factor for disgust responses to various insects, potentially linking fear of animals with similar invasive behaviours in human dwellings (Fukano & Soga, 2021). Widespread misconceptions about biophobic species are difficult to distinguish from their sociocultural or symbolic meanings. Examples include the persecution of bats after the outbreak of the novel coronavirus (SARS-CoV-2) in China (Lu et al., 2021) and the reputation of rats as 'disease carriers' (rather than fleas) during the 14th-century bubonic plague. Accurate identification and species knowledge is essential to evaluate whether they pose a threat (e.g. venomous, disease-carrying or biting or stinging). Low species knowledge may even cause unintentional provocations of animal attacks (González-Crespo et al., 2023; van der Meer et al., 2019). However, many species have developed mimicry strategies, adopting features of feared animals, such as the false stinger of wasps in hoverflies or the colouration pattern of venomous snakes in milk snakes. This can lead to misidentification based on physical features or taxonomy, with fears of animals transmitted intergenerationally, through parents' descriptions, fear responses and facial expressions to their children, or through parental control of exposure to nature and wildlife (Conrad et al., 2021; Dunne & Askew, 2013; Muris et al., 2010).

We hypothesise that, beyond the effects of disgust sensitivity and nature connectedness, the fear of non-threatening animals shares some degree of visceral fear with the widely feared threatening snakes and spiders (Hypothesis 2). Furthermore, we hypothesise that this relationship is positively moderated by (i) a lack of direct experience, (ii) negative vicarious experiences due to parental fear of snakes and spiders and (iii) socio-demographic background (Hypothesis 3).

1.4 | Research objectives

We examined whether nature connectedness, beyond its effect on disgust sensitivity, can mitigate biophobic perspectives when distinguishing between threatening animals (e.g. snakes and spiders) and non-threatening but fear-inducing animals (e.g. small animals). Our hypotheses are summarised in the model shown in Figure 1.

2 | METHODS

2.1 | Study site

Hong Kong was selected to represent a highly urbanised Chinese city. As shown in Figure 2, its urban development loosely follows a concentric zone pattern interspersed with countryside. Urban green spaces (turquoise zones) are integrated as ancillary

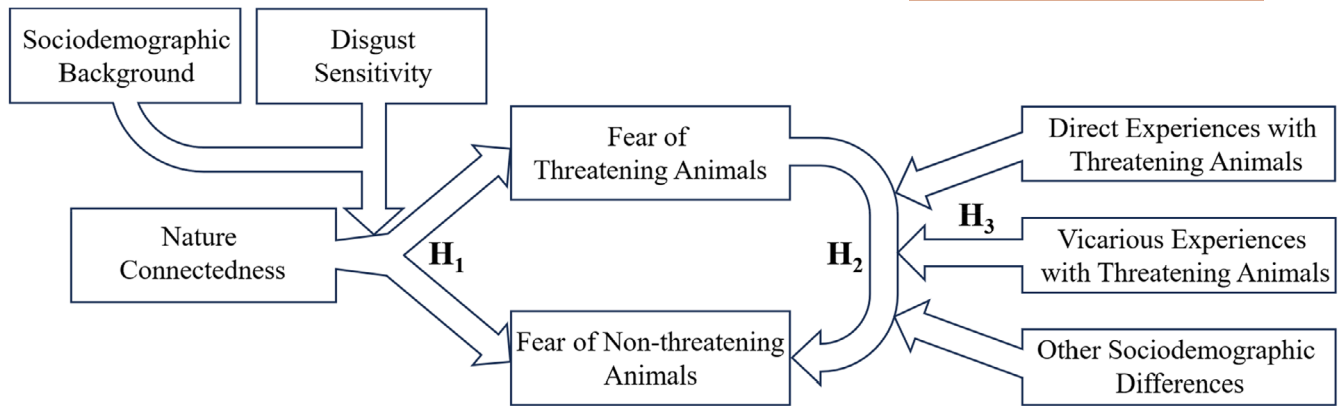


FIGURE 1 Conceptual model illustrating the hypothesised correlation between nature connectedness and biophobia, controlling for the effects of disgust sensitivity and socio-demographic background (H_1). We also expect fear of threatening animals to explain additional variance in fear of non-threatening animals (H_2), an effect moderated by direct and vicarious experiences with threatening animals or other socio-demographic differences (H_3).

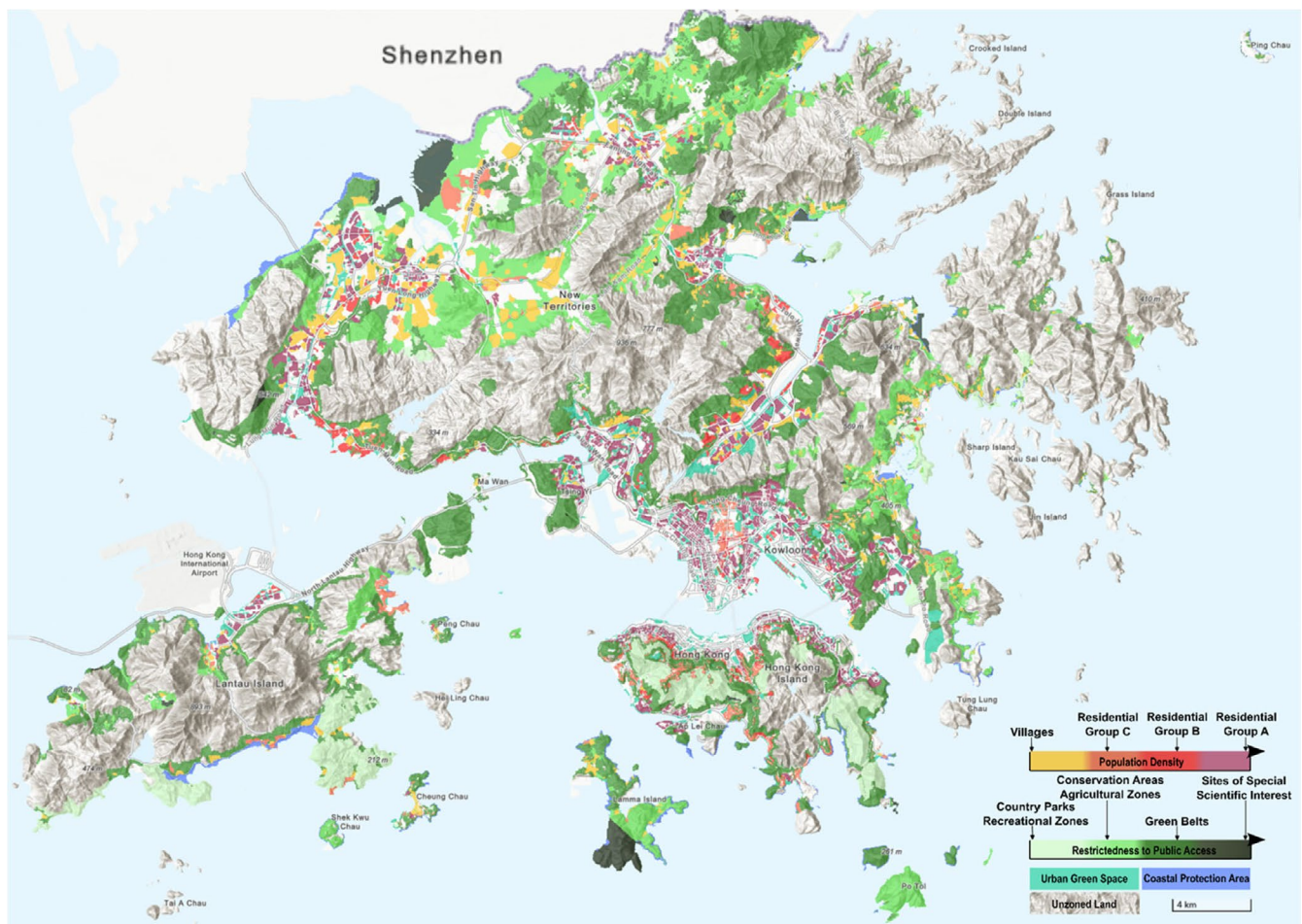


FIGURE 2 Hong Kong's topography and land use zoning, showing (1) residential areas by their population density and (2) green spaces by their accessibility to the public, from country parks and recreational zones (publicly accessible) to sites of special scientific interest (limited access to protect biodiversity). The outline zoning plan data are adapted from Wong (2022).

provisions in higher density residential zones (e.g. purple or red zones). Hong Kong is fully urbanised, with approximately 7% of its land designated for residential use. By mid-2023, it was among the

world's most densely populated cities, with 7.54 million residents in 1115 km² (Hong Kong Census and Statistics Department, 2024). Adjusted for usable urban land, the population density reaches

25,719 inhabitants per km² (Filipowicz, 2018). Three quarters of Hong Kong's land area consists of grasslands, woodlands or scrublands, largely unzoned hilly terrain unsuitable for urban development (i.e. mountains in greyscale). Hong Kong ranks third among Asian cities for vegetation cover per person (Hong Kong Planning Department, 2016, 2023) and has 25 country parks and 22 special areas covering 40% of its area (Environmental Bureau, 2016). Hong Kong has exceptional biodiversity, including 3300 species of flora (2100 endemic), 55 species of terrestrial mammals, 115 species of amphibians or reptiles, 240 species of butterflies and 130 species of dragonflies. It is also a central stopover for over 570 species of migratory birds and is home to over 1000 recorded marine fish species in the South China Sea. Hong Kong's rich history as a rural fishing village is overshadowed by its transformation into one of the few fully urbanised cities in the world (World Population Review, 2024). In Hong Kong, public perception is influenced by the presence of a few venomous species, although most local species are not dangerous, which is enough to generalise threat-related fear across taxa (Coelho et al., 2019). This raises questions about whether the population faces an extinction of experience and whether greater wildlife unfamiliarity fosters biophobic attitudes or whether other factors mitigate human–wildlife relationships.

2.2 | Study design

Our results were obtained as part of a larger study entitled 'Animal Phobia and Nature Conservation' using a cross-sectional study conducted among the general Chinese population of Hong Kong, China. The questionnaires were distributed through the Qualtrics platform using convenience and snowball sampling across diverse distribution channels, including social media (i.e. Facebook, Instagram, Snapchat), community centres, district offices, NGOs and student associations in universities between August and September 2022. The inclusion criteria required that participants be Hong Kong residents aged 18 or older and able to read Chinese. Informed consent was obtained from all participants prior to their involvement, and the study was conducted on an anonymous basis to ensure confidentiality and protect participants' privacy. Our study was in accordance with the Declaration of Helsinki and was approved by the research ethics committee of Hong Kong Baptist University (REC/21-22/0551). An attention check question was included midway through the questionnaire to ensure participant engagement, asking them to select option 3 from a multiple-choice scale from 1 to 5.

2.3 | Measures

We used validated psychological scales to assess several domains of biophobia. The constructs are defined in the sequence aligned with our hypotheses.

For H_1 , nature connectedness was assessed using the Nature Relatedness Scale (NR-21), which distinguishes affective (Self), cognitive (Perspective) and experiential (Experience) orientations towards nature. Disgust sensitivity was assessed using the Disgust Scale-Revised (DS-R), which captures three subdimensions: core disgust (DS-R-Core), animal reminder disgust (DS-R-AR) and contamination disgust (DS-R-Contamination).

For H_2 , fear of snakes and spiders was assessed using the Snake Questionnaire (SNAQ) and the Spider Questionnaire (SPQ), respectively, while fear of small animals was assessed using the Fear of Small Animals (FSS-ANI) subscale of the Fear Survey Schedule III (FSS-III). Blood-injection-injury (BII) fears are aversive reactions to injuries, illnesses or medical procedures (e.g. seeing blood or injections) and were assessed using the Injury (FSS-INJ) subscale of the FSS-III. This construct is widely recognised as a subtype of disgust-centric anxiety disorder.

For H_3 , we assessed demographic background and experience with snakes and spiders using our own questions.

2.3.1 | Nature connectedness and disgust sensitivity (H_1)

We measured individuals' cognitive, affective and experiential dimensions of nature connectedness using the NR-21 (Nisbet et al., 2009), a multidimensional measure containing 21 items rated on a 5-point Likert-type scale ranging from 1 (disagree strongly) to 5 (agree strongly), organised into three subscales: Self (eight items), Perspective (seven items) and Experience (six items). The Self subscale measures internalised identification with nature, focused on feelings of personal connection with natural environments. The Perspective subscale measures external, nature-related worldviews, encompassing human responsibility towards nature, extinction ethics, animal rights and our right to use natural resources. The Experience subscale measures physical familiarity with the natural world, including affection and comfort felt in the physical natural environment. The Self and Perspective subscales measure psychological orientations of nature connectedness, while the Experience subscale measures behavioural orientation (Dean et al., 2018). The scale has been validated in Chinese populations without revision (Zuo et al., 2023), but the internal reliability of the subscales in our study varied greatly: Self ($\alpha=0.78$, $\omega=0.80$), Perspective ($\alpha=0.38$, $\omega=0.39$) and Experience ($\alpha=0.73$, $\omega=0.73$). We excluded the Perspective subscale from further analyses due to its low internal reliability. The remaining subscales each had a total score ranging from 1 to 5, calculated as the average of each item score. The higher the score, the stronger the connection to nature in the respective dimensions.

We measured disgust levels using the DS-R (Olatunji et al., 2007, 2008), a two-part scale based on three subscales: the DS-R-Core (12 items), measuring disgust due to oral offence and revulsion to physical stimuli (e.g. animals carrying diseases or bodily waste) and chemical stimuli (e.g. the stench of urine or rotten food); the DS-R-AR (eight items), based on morbid stimuli that blur the boundaries between

humans and animals, eliciting disgust at reminders of our mortality (e.g. corpses) and of animal nature (e.g. mutilated organs); and the DS-R-Contamination (five items), measuring disgust felt towards pathogenic stimuli spread by other people (e.g. contact with a toilet seat or drinking from the same cup as an acquaintance), which differs from the pathogenic objects central to core disgust. Part 1 uses true/false statements about disgusting situations (13 items) and part 2 (12 items) uses a 3-point Likert-type for these disgusting situations (0 = not disgusted, 0.5 = slightly disgusted, 1 = very disgusted). van Overveld et al. (2011) cautioned against using the full DS-R because each dimension of disgust is distinct. The unmodified scale yielded unacceptable internal reliability, which justified a factor analysis to correct for low (<0.3) and negative factor loadings. We revised and validated a shortened DS-R for our sample, retaining the three-factor structure, represented by five core disgust items (0–5), six animal reminder items (0–6) and three contamination disgust items (0–3) (Table S1). The internal reliability of the revised subscales was acceptable (DS-R-Core: $\alpha=0.60$, $\omega=0.60$; DS-R-AR: $\alpha=0.70$, $\omega=0.70$; DS-R-Contamination: $\alpha=0.59$, $\omega=0.59$). Higher scores were interpreted as greater disgust sensitivity in the respective dimensions.

2.3.2 | Fear of snakes and spiders, harmless animals and BII (H_2)

We used the 30-item SNAQ and the 31-item SPQ to measure self-reported fears and screen for potential phobias of snakes and spiders, respectively (Klorman et al., 1974). Both scales are single-factor instruments consisting of true/false statements. The higher the score, the greater the fear of snakes and spiders. The internal validity of both scales was excellent in our study (SNAQ: $\alpha=0.92$, $\omega=0.92$; SPQ: $\alpha=0.92$, $\omega=0.92$).

Furthermore, within the FSS-III (Wolpe & Lang, 1964), we used the FSS-ANI subscale, which focuses on small animals (e.g. mice, bats and worms) that do not pose a direct threat but can still elicit aversive reactions, including disgust consistent with the disease-avoidance model (Davey, 2011; Fukano & Soga, 2021; Matchett & Davey, 1991). According to Arrindell et al. (1984), the FSS-ANI score is more informative than the total score, measuring the degree of disturbed reactions associated with stimuli (six items relating to worms, bats, flying insects, crawling insects, mice and harmless snakes) using a 5-point Likert scale ranging from 1 (not at all) to 5 (very much). The total score ranged from 6 to 36, with higher scores indicating higher levels of fear.

We also used the FSS-INJ subscale (Wolpe & Lang, 1964) to measure BII fears (Sánchez-Navarro et al., 2018). The literature strongly supports the classification of BII phobias as disgust-centric anxiety disorders (Kiss et al., 2022; Sánchez-Navarro et al., 2018), presented as an independent disgust dimension in this paper. The FSS-INJ includes 12 items measuring disturbed reactions to witnessing or experiencing bodily injury and illness, particularly in medical settings. Total scores were halved for a range of 6–36. The higher the score, the greater the fear responses associated with the category. Both subscales had good-to-excellent internal validity (FSS-ANI: $\alpha=0.85$;

$\omega=0.85$; FSS-INJ: $\alpha=0.87$, $\omega=0.87$), and all items had adequate factor loadings (>0.3). Harman's one-factor test confirmed the absence of common method bias between the FSS-ANI and FSS-INJ subscales, as the total variance extracted by one factor in all items did not exceed the 50% threshold ($\sigma^2=37.19\%$).

2.3.3 | Socio-demographic background and experiences with threatening animals (H_3)

We assessed socio-demographic background by collecting the participants' sex at birth, age, highest level of education, income bracket and current housing situation. Direct experiences with snakes and spiders were measured using Yes/No questions: 'Have you ever seen a [snake/spider] in your home?' and 'Have you ever been bitten by a [snake/spider]?' Vicarious experiences with snakes and spiders were operationalised as parental fears of snakes and spiders, assessed using the following Yes/No question: 'Is your [father/mother] afraid of [snakes/spiders]?'.

2.4 | Statistical analysis

Data analysis was performed using IBM SPSS Statistics and Amos for Windows, version 29.0 (IBM Corporation, Armonk, New York, USA) and R for Windows, version 4.4.1 (R Foundation for Statistical Computing, Vienna, Austria). The assumptions of all statistical tests used were met, and significance levels were conducted as two-tailed tests for $p < 0.05$. For H_1 , we performed a feature selection for structural equation modelling (SEM). We used a redundancy analysis (RDA) to plot and extract an underlying set of explanatory factors that explained biophobia in our sample, and our forward variable selection method retained all scale measures and gender. For H_2 , we examined fear of snakes and spiders to predict fear of small animals through a mediation model using Hayes' (2013) PROCESS macro in SPSS, with all SEM variables as covariates. For H_3 , we used a moderated mediation model to test the moderating effects of the interaction between direct experiences with threatening animals, vicarious experiences of threatening animals through parental fears and individual differences in socio-demographic background on the relationship between fear of snakes/spiders and fear of small animals. The effect sizes of the moderators were calculated using the change in explained variance between the null model (R_a^2) and the moderation model (R_b^2) as f^2 according to the formula (Hair et al., 2021):

$$f^2 = \frac{R_b^2 - R_a^2}{1 - R_b^2}$$

Because we analysed the additional explanatory effects of moderators over the mediation model in H_2 , we interpreted these effect sizes as improvements in the mediation model's explanatory power, with an f^2 value of 0.005, 0.01 and 0.025 representing small, medium and large moderation effect sizes (Kenny, 2018).

3 | RESULTS

We obtained 2120 preliminary responses. Data cleaning was performed on invalid questionnaires ($n=609$), duplicate questionnaires ($n=19$), speeders ($n=40$) and participants who failed the attention check question ($n=22$). We retained 1430 participants, of whom 64 were reinvited within 70 days of completing their questionnaire for test-retest reliability. Biophobia measures demonstrated good-to-excellent test-retest reliability ($ICC > 0.75$), while disgust measures achieved moderate-to-good test-retest reliability ($0.5-0.9$), and nature connectedness had moderate test-retest reliability (Table S4). Most of our participants were women (72.0%) with a mean age of 26.90 years (range = 18–65). Most lived in private housing (56.7%), followed by public housing (33.8%), village-type housing (6.5%) and temporary housing (<3%). The majority were highly educated, with 78.0% holding a bachelor's degree or higher. The income distribution was not informative due to the young age of the participants (58.8% were aged 18–24), with 42.9% reporting no personal income, largely because they were still students.

3.1 | Redundancy analysis

The Pearson correlations of our measures presented in a correlation matrix (Table S5) indicated that the nature connectedness subscales and all disgust dimensions were associated with biophobia and that strong correlations were found between threatening and non-threatening animals. Analyses of variance (ANOVA) of socio-demographic factors underscored the need to control for the large effects of gender as a covariate between each biophobia measure and our predictors (Table S6). To reduce our model's dimensionality, we performed an RDA using nature connectedness, disgust sensitivity and gender as explanatory variables for fear of snakes, spiders and small animals (Figure 3). These variables explained 34.1% of the variation in biophobia levels, with two significant canonical axes (RDA 1: $R^2=0.323$, $p<0.001$; RDA 2: $R^2=0.015$, $p<0.001$). A forward selection approach was applied using the criteria of change of R^2 and reduction of AIC (Table 1), which retained all factors in the

model. Our biplots indicate two main quadrants: the top right for fear of snakes and spiders and the bottom right for fear of small animals. This reveals a stronger relationship between animal reminder disgust and contamination disgust for threatening animals and a negative relationship with psychological nature connectedness. Fear of small animals was more closely related to BII fears, core disgust and gender differences, and fear of both threatening and non-threatening animals had a negative relationship with behavioural nature connectedness.

3.2 | Structural Equation Modelling

As shown in Figure 4, SEM showed that common biophobic factors simultaneously predicted fear of small animals, snakes and spiders ($\chi^2(5529)=24,363.34$, $\chi^2/df=4.41$, $p<0.001$, SRMR=0.070, RMSEA=0.049 [0.048, 0.049], CFI=0.687, TLI=0.679). The low CFI and TLI values (<0.9) were caused by adequate fitting only to the null model (RMSEA=0.086), removing the interpretability of our incremental fit indices when the approximation error is not sufficiently high (RMSEA >0.158 ; Kenny, 2020). Our biophobia model had a greater predictive power for fear of small animals ($R^2=0.613$) than fear of snakes ($R^2=0.333$) or spiders ($R^2=0.242$). Behavioural nature connectedness was a better preventive factor of biophobia than psychological nature connectedness, where it solely predicted reduced fear of small animals ($\beta_{Exp.}=-0.363$) and had a stronger effect on fear of snakes ($\beta_{Exp.}=-0.185$ vs. $\beta_{Self}=-0.060$) and spiders ($\beta_{Exp.}=-0.241$ vs. $\beta_{Self}=-0.092$). The only disgust dimension that predicted all three fears was BII fears, but it was not the strongest dimension for each animal fear. In order, animal reminder disgust ($\beta=0.249$), contamination disgust ($\beta=0.204$) and BII fears ($\beta=0.174$) predicted fear of snakes; animal reminder disgust ($\beta=0.224$), core disgust ($\beta=0.124$) and BII fears ($\beta=0.119$) predicted fear of spiders; and BII fears ($\beta=0.498$) and core disgust ($\beta=0.333$) predicted fear of small animals. Women were more afraid of small animals ($\beta=0.109$), snakes ($\beta=0.098$) and spiders ($\beta=0.094$) than men. Furthermore, gender had significant positive covariances with the disgust dimensions and nature connectedness (Self), with women showing greater

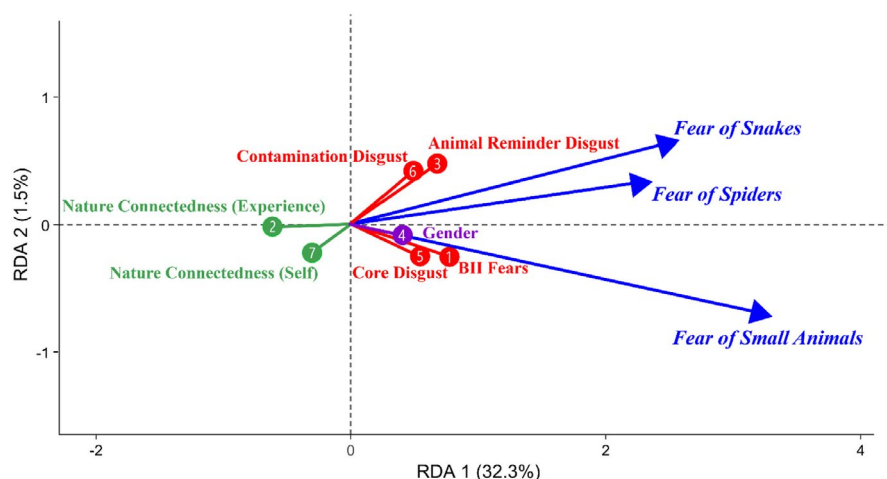


FIGURE 3 Redundancy analysis (RDA) ordination plot illustrating the relationship between nature connectedness, disgust dimensions and gender in explaining the variance of biophobia. The length of the arrow indicates the strength of the factor in the overall model.

TABLE 1 Forward selection of explanatory factors for biophobia.

Factor	Adjusted R^2	Adjusted ΔR^2	df	AIC	ΔAIC	F	p value ^a
1. BII Fears	0.194	-	1	1265	-	344.05	0.007
2. Nature Connectedness (Experience)	0.273	0.079	1	1119	-146	156.30	0.007
3. Animal Reminder Disgust	0.298	0.025	1	1069	-50	52.36	0.007
4. Gender	0.316	0.018	1	1033	-36	38.34	0.007
5. Core Disgust	0.327	0.011	1	1009	-24	25.49	0.007
6. Contamination Disgust	0.335	0.008	1	994	-15	18.04	0.007
7. Nature Connectedness (Self)	0.338	0.003	1	989	-5	6.55	0.007

Note: The variables were ranked in order of importance based on the variance explained (R^2) and predictive accuracy (AIC), according to a forward selection approach.

Abbreviations: AIC, Akaike information criterion; df, degrees of freedom.

^ap values adjusted using the Holm–Bonferroni method for multiple hypothesis testing.

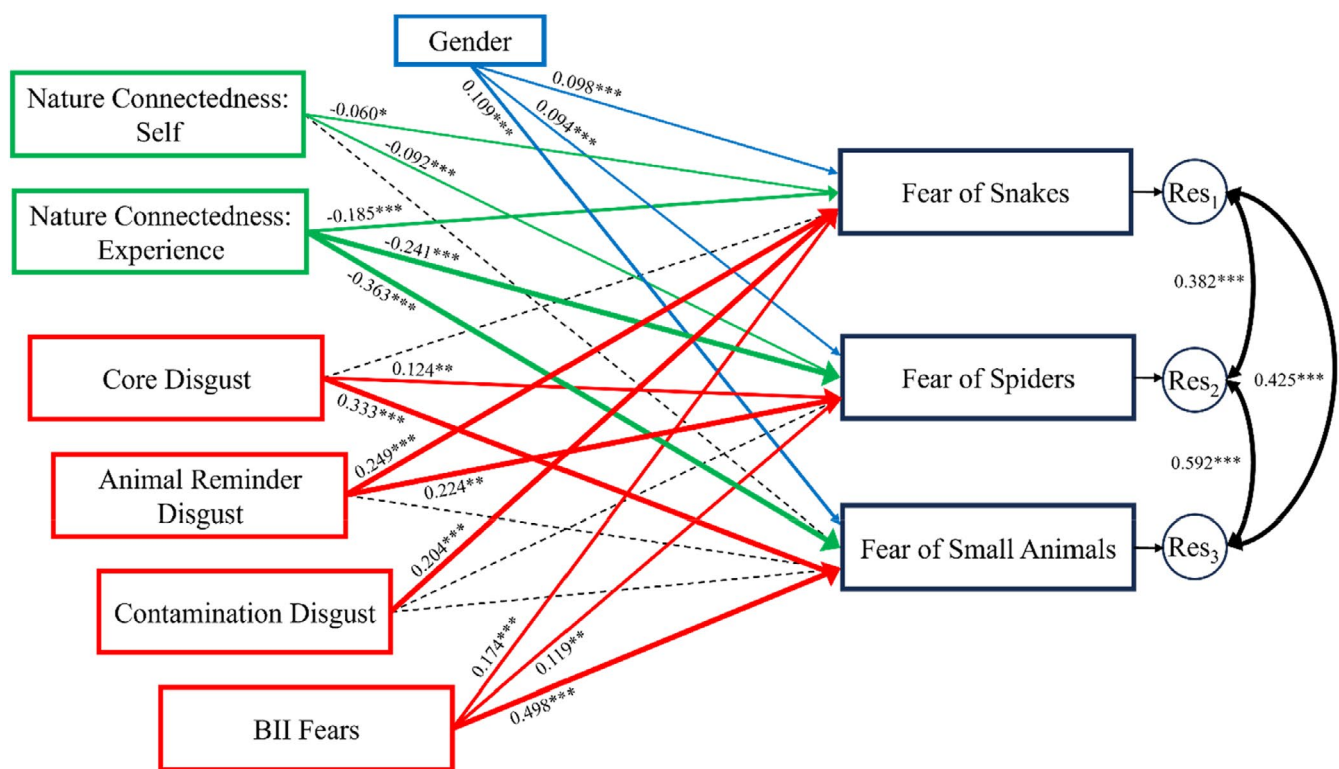


FIGURE 4 Standardised SEM path coefficients for biophobia, after removing non-significant paths. Blue arrows represent significant direct effects of gender. Green arrows represent significant direct effects of nature connectedness variables. Red arrows represent significant direct effects of disgust sensitivity. Arrow thickness indicates path coefficient magnitude. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

disgust and nature-oriented self-identities. The negative covariances with nature connectedness (Experience) indicated that men experienced greater positive affect towards natural environments.

3.3 | Mediation and moderated mediation analyses

To clarify the relationship between fear of snakes and spiders and fear of small animals, we conducted another forward variable selection with fear of small animals as the sole outcome variable, which

indicated that fear of snakes and spiders contributed unique variances to the model (Table 2). Fear of spiders was selected as the most important variable for predicting fear of small animals and 36.2% of their variances were shared (Adjusted $R^2 = 0.362$). Fear of snakes explained an additional 2.5% of the variance (Adjusted $\Delta R^2 = 0.025$) as the fourth selected variable after fear of spiders, BII fears and behavioural nature connectedness. Next, we verified that fear of spiders and fear of snakes partially mediated each other in predicting fear of small animals (Figure 5a), controlling for other predictors as covariates. Again, the direct effect of fear of

spiders was greater ($\beta = 0.299$, $p < 0.01$) than that of fear of snakes ($\beta = 0.203$, $p < 0.01$) in predicting fear of small animals. The mediation model explained 62% of the variance in fear of small animals ($R_a^2 = 0.620$). Next, we examined whether direct experiences with threatening animals, vicarious experiences with threatening animals, or socio-demographic variables other than gender moderated the strength of associations between types of animal fears in a mediated moderation model (Figure 5b), controlling for the same covariates. Table 3 shows the moderating effect at each path of our mediation model with the explained variances of the moderated mediation models under each moderator (R_b^2). The sociocultural

pathways showed some moderation, with low significance levels ($p > 0.010$) and small effect sizes or less ($f^2 < 0.01$). For instance, experiencing a spider bite at home had a negligible negative moderating effect on the relationship between fear of spiders and fear of small animals ($Mb = -0.182$, $p = 0.049$, $f^2 = 0.004$). Surprisingly, fear of snakes in mothers was a negative moderator of the relationship between fear of snakes and fear of small animals, with a small effect ($Mc = -0.071$, $p = 0.032$, $f^2 = 0.006$). Regarding threatening animals, fear of spiders in both parents (Father: $Ma = 0.214$, $p = 0.012$, $f^2 = 0.006$; Mother: $Ma = 0.108$, $p = 0.015$, $f^2 = 0.001$) positively moderated the relationship between fear of snakes and fear of spiders,

TABLE 2 Forward selection of explanatory variables for fear of small animals.

Factor	Adjusted R^2	Adjusted ΔR^2	df	AIC	ΔAIC	F	p value ^a
1. Fear of Spiders	0.362	—	1	-640	—	811.36	<0.001
2. BII Fears	0.520	0.158	1	-1047	-407	472.31	<0.001
3. Nature Connectedness (Experience)	0.557	0.037	1	-1159	-112	118.41	<0.001
4. Fear of Snakes	0.582	0.025	1	-1243	-84	88.45	<0.001
5. Core Disgust	0.601	0.019	1	-1307	-64	67.32	<0.001
6. Gender	0.612	0.011	1	-1345	-38	40.08	<0.001
7. Animal Reminder Disgust	0.617	0.005	1	-1365	-20	21.54	<0.001
All variables ^b	0.618	0.001					

Note: The variables were ranked in order of importance based on the variance explained (R^2) and predictive accuracy (AIC), according to a forward selection approach.

Abbreviations: AIC, Akaike information criterion; df, degrees of freedom.

^ap values adjusted using the Holm–Bonferroni method for multiple hypothesis testing.

^bNature Connectedness (Self) and Contamination Disgust did not significantly explain additional variances in the model.

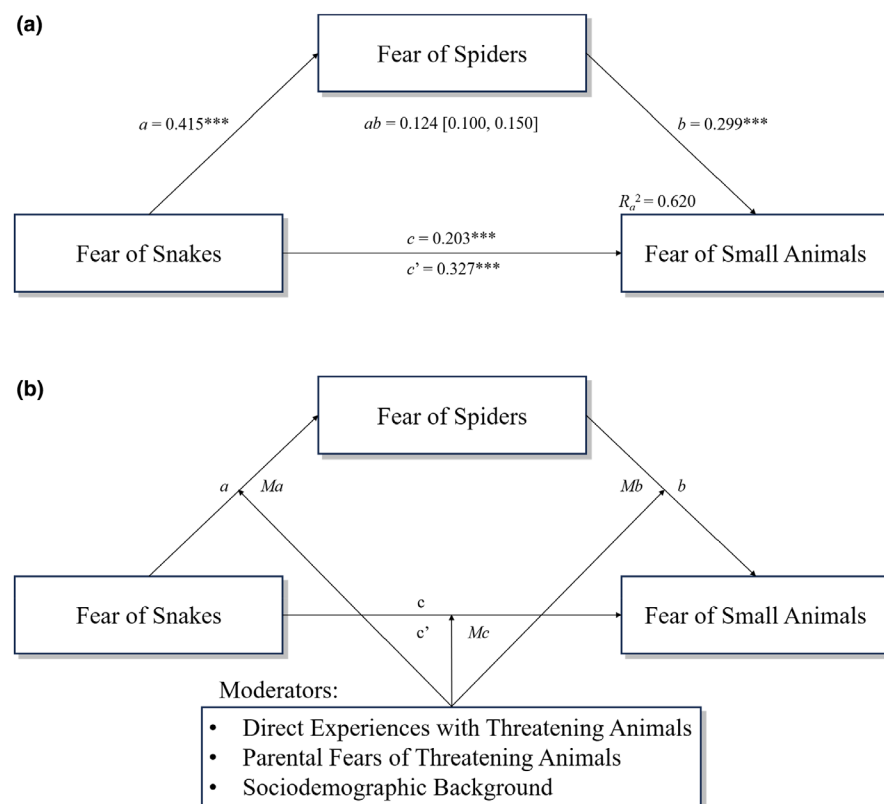


FIGURE 5 Baseline partial mediation model (a) and conceptual moderated mediation model (b) between fear of snakes, fear of spiders and fear of small animals. All coefficients are standardised. *** $p < 0.001$.

TABLE 3 Interaction effects of direct experiences with threatening animals, vicarious experiences with threatening animals and socio-demographic background on mediation pathways between animal fears.

	Unstandardised coefficients (B)			$\Delta R^2 (R_b^2 - R_a^2)$	f^2
Moderator	SNAQ → SPQ (Ma)	SPQ → small animals (Mb)	SNAQ → small animals (Mc)		
Direct experiences					
Seen a Snake at Home	−0.042	−0.030	−0.059	0.000	0.002
Bitten by a Snake	0.144	−0.105	0.093	0.000	0.005
Seen a Spider at Home	−0.077	0.056	−0.059	0.001	0.002
Bitten by a Spider	0.130	−0.182*	0.117	0.001	0.004
Vicarious experiences					
Fear of Snakes, Father	0.058	0.004	−0.016	0.000	0.001
Fear of Spiders, Father	0.214*	−0.010	−0.021	0.000	0.006
Fear of Snakes, Mother	−0.009	−0.015	−0.071*	0.001	0.006
Fear of Spiders, Mother	0.108*	0.035	−0.044	0.000	0.001
Socio-demographic background					
Age	−0.001	−0.001	0.001	0.000	0.001
Education Level	−0.003	0.044	0.013	0.001	0.007

Note: Gender, Nature Connectedness (Self), Nature Connectedness (Experience), DS-R Core, DS-R Animal Reminder, DS-R Contamination and FSS-INJ were included as covariates. ΔR^2 = Change in R^2 between the mediation model (R_a^2) and the moderated mediation model (R_b^2). Effect sizes: small: $f^2 = 0.005$; medium: $f^2 = 0.01$; large: $f^2 = 0.025$.

* $p < 0.05$.

but did not strongly predict fear of small animals. Although other moderators (e.g. education level and having been bitten by a snake) had no significant interaction effects on the mediation pathways, the model showed small effect sizes, suggesting that the effects of other moderators might be due to overfitting of multiple small interaction effects.

4 | DISCUSSION

4.1 | H_1 : Protective effects of nature connectedness and risk factors for disgust sensitivity

The reduction of biophobia was mainly associated with behavioural nature connectedness and, to a lesser extent, psychological nature connectedness, which confirmed H_1 and reflected previous findings regarding snakes and spiders (Zsido et al., 2022). These dimensions presuppose different mental conceptualisations of human–wildlife connections. The weaker psychological orientation of the Self dimension (i.e., identification with nature, feelings towards natural environments) suggests that individuals conceptualise a limited number of emotionally evocative animals. For example, animals with anthropomorphic traits (expressive facial features) may be perceived as more emotionally evocative than small animals. In contrast, behavioural orientations within the Experience dimension (i.e. physical familiarity, affection and comfort with the natural environment) are a more robust factor, motivating individuals to actively seek positive experiences in nature (Oh et al., 2021). Direct exposure to nature helps overcome animal-related fears (Coelho et al., 2021), while interventions aimed at

improving attitudes through psychological guidance do not necessarily mitigate visceral fear responses (Kelly et al., 2023). Frequent experiences with nature have been shown to diffuse positive attitudes for a diverse number of unfavourable animals (Ngo et al., 2019, 2022). Such experiences can simultaneously increase tolerance to disgust-evoking stimuli and decrease fear of engaging in natural habitats (Sugiyama et al., 2021). Individuals with a strong Experience dimension also have better incidental experiences with nature, both passively (being more attuned to their sensory perceptions) and actively (noticing aspects of nature) (Richardson et al., 2022). Overall, the behavioural orientations of nature connectedness are strongly associated with opportunities for direct human–wildlife experiences, potentially reducing fear of both threatening and non-threatening animals.

Although disgust is an important underlying factor in biophobia, neither the core disgust, animal reminder disgust, contamination disgust nor BII fears were identified as the largest risk factor for overall biophobia. Davey (2011) suggested that fear of small animals, BII fears and contamination disgust are interrelated in the disease-avoidance paradigm. Our findings partially support the strong relationship between fear of non-threatening small animals and BII fears, although we found that core disgust was related to small animals and not to contamination disgust. Indeed, studies on individuals with BII phobia have demonstrated fears of stimuli outside their usual domain, akin to a generalised propensity to experience disgust (de Jong & Merckelbach, 1998). BII phobics react to disgust-evoking insects in the same way as individuals with high levels of animal reminder disgust (Viar-Paxton et al., 2014). In our study, animal reminder disgust was only associated with threatening animals. The difference in association between small, non-threatening animals and BII fears

(versus animal reminder disgust) may be related to the unique element of invasiveness (e.g. fear of injections) as a pathogenic threat. Meanwhile, threatening animals pose a direct threat to our survival and evoke animal reminder disgust by reminding us of our mortality (Çavusoglu & Dirik, 2011; Sánchez-Navarro et al., 2018).

Nevertheless, spiders remained weakly associated with core disgust, reflecting their perceived role as potential disease carriers. Although some studies have treated fear of spiders as a subset of small animal phobias (e.g. the disease-avoidance model), other studies have argued that reactions to spiders differ from those to other arthropods in terms of the degree of fear and disgust evoked (Gerdes et al., 2009; Landová et al., 2021). This suggests that spiders elicit a different kind of disgust than other insects perceived as 'non-threatening'. Contamination disgust contributed the lowest variance to our biophobia model, which unexpectedly included snakes. Some species, such as the blind snakes native to Hong Kong, primarily evoke disgust rather than fear due to their earthworm-like appearance and might evoke contamination disgust from its physical similarities to human endoparasites, such as tapeworms or roundworms (Rádllová et al., 2019; Stankova et al., 2021). However, it is difficult to determine which species of snake frightened our participants. In general, the dimensions of disgust are specific to animal fears, reflecting how animals can elicit disgust through involuntary contact, food contamination or injury. Finally, consistent with the literature, the inclusion of gender in our biophobia model had a consistently positive effect on women's reported fears, while the effects of age and education level were mixed or contradictory depending on the animal fears (Notaro & Grilli, 2022; Polák, Sedláčková, et al., 2020; Zsido et al., 2022).

4.2 | H₂: Contribution of fear of snakes and spiders to the prediction of fear of small animals

Controlling for disgust sensitivity, nature connectedness and gender, our findings supported H₂ that fear of non-threatening animals is predicted by fear of threatening animals. This effect was stronger for fear of spiders than for fear of snakes. This may be explained by a greater similarity of non-predatory behaviours with other small animals or by the fact that fear of spiders may be triggered by media misinformation (Mammola et al., 2020, 2022), thus sharing similar pathways in their formation. Studies have also reported correlated levels of fear between different subtypes of phobias linked by generalisable negative experiences. Polák, Rádllová, et al. (2020) discovered that prior experiences of dog bites decreased the average self-reported fear of 25 different animals. The severity of the bite (i.e. the negative nature of the experience) also accounted for greater reductions in the average level of disgust. Coelho et al. (2021) also found that snake encounters and bites uniquely predicted lower levels of fear of other animals, including small animals, birds, dogs and cats. To some extent, the positive effects of bite experiences observed in these studies could be construed as part of the behavioural orientation of nature connectedness, potentially leading to an accumulation of positive or negative human-wildlife

experiences. However, it remains unclear why fear of snakes and fear of spiders uniquely contribute to a generalised increase in fear of small animals, beyond the effects of disgust sensitivity, nature connectedness and gender.

4.3 | H₃: Moderation of the relationship between threatening and non-threatening animals

Based on the vicious cycle of biophobia (Soga et al., 2023), we found little evidence that sociocultural pathways replace direct experience in explaining how biophobia extends to threatening and non-threatening animals, through vicarious experiences of parents, education level or age. Therefore, H₃ was not supported. Although some pathways between snakes, spiders and small animals were statistically significant in the moderated mediation model, we could not determine whether the improved predictive power was due to moderation because of the small effect sizes and potential overfitting caused by simultaneously testing three interaction effects.

5 | LIMITATIONS AND CONCLUSIONS

The cross-sectional survey design limited our study to simple self-reported constructs, which may have obfuscated the true effects of the determinants of biophobia, such as parental fears, representing vicarious experiences through the parent-child social learning pathway. By focusing on disgust sensitivity, we compared key dimensions of disgust between animal fears, but disgust propensity (the tendency to respond to stimuli with disgust) was not measured as a separate variable. This may have moderated the association between fear of threatening and non-threatening animals. Self-reported fear of animals and disgust can be problematic for reasons other than subjectivity and social desirability bias, as there is an inherent risk of unintentionally conflating questions about fear responses with disgust-based aversion (LeDoux, 2013). Physiological changes in response to stimuli (i.e. activation of the sympathetic nervous system in response to fear versus activation of the parasympathetic nervous system in response to disgust) could identify the primary emotions involved. As less resource-intensive options, subjective scoring using visual phobic stimuli and behavioural testing with live specimens are generally consistent with physiological measures (Landová et al., 2023). We justified the fit of our SEM using small incremental fit indices because the RMSEA of the null model was already approaching an acceptable range (Kenny, 2020). Although our proposed model is unlikely to achieve a satisfactory improvement over the null model (CFI/TLI < 0.9), this should not invalidate the model fit. However, the low RMSEA of the null model could indicate that the model does not accurately capture the true relationships in the data. The underlying assumption that a generalised biophobia, represented by multiple animal phobias, should be predicted by a single set of predictors may

have reduced the validity of our model, as opposed to selecting variables for each animal phobia and conducting three SEM analyses, especially given the strong specificity between disgust dimensions and animal phobias. Finally, testing the vicious cycle of biophobia may require more specific measures of the sociocultural pathways of the model. For example, we could track the evolution of biophobic attitudes and behaviours when people are exposed to negative vicarious experiences or negative framing of threatening and non-threatening animals. These sociocultural effects may also vary across cultures, as the number of harmless snakes and spiders could influence people's perception of threat, leading to less distinction between these animals and other small animals. A longitudinal study design could clarify the direction of causality of fears transferred or extinguished between threatening and non-threatening animals.

To determine the origins of biophobic attitudes, it is necessary to understand the channels of knowledge and experience used by urbanised populations to construct their understanding of unfamiliar animals. The profound consequences of biophobia pose a pervasive threat to the conservation of local species and could lead to a loss of nature's benefits for human health. Studies have shown that creating opportunities for direct nature experiences may simultaneously reduce disgust and foster behavioural nature connections, reducing biophobia towards both threatening and non-threatening animals. This approach of revitalising the human–nature interaction holds more promise than traditional, information-based campaigns as physically engaging with nature targets a broader range of fears and cultivates tolerance for many local and often unfamiliar species.

AUTHOR CONTRIBUTIONS

Sam Lau: conceptualisation, methodology, investigation, formal analysis, resources, writing—original draft, writing—review and editing, project administration, funding acquisition. Jason Fong: formal analysis, data curation, visualisation, writing—original draft, writing—review and editing. Andras Zsido: writing—review and editing. Matthew Browning: writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

The data used in this study are available from <https://doi.org/10.17605/OSF.IO/UVE45>.

STATEMENT ON INCLUSION

Our study brings together authors from three countries, including scientists, Sam Lau and Jason Fong, based in China where the study was carried out. All authors were engaged with the research and manuscript writing to ensure that the diverse sets of perspectives they represent were considered. Whenever relevant, the literature published by scientists from the region was cited; efforts were made to consider relevant work published in the local language.

ORCID

Sam S. S. Lau  <https://orcid.org/0000-0002-8806-031X>

Andras N. Zsido  <https://orcid.org/0000-0003-0506-6861>

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SUPPORTING INFORMATION

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

Data S1. PN questionnaire transcript.

Figure S1. Confirmatory factor analysis (CFA) of the DS-R scale.

Figure S2. Scree plot of DS-R with 8 eigenvalues above 1.

Text S1. Justification and methodology of revising the DS-R Scale.

Table S1. Comparing the model fit indices of single, bi-factor and tri-factor DS-R models.

Figure S3. Comparing the model fit indices of single, bi-factor and tri-factor DS-R model.

Table S2. Internal validity and correlations between new and old DS-R subscale.

Table S3. Comparison of items retained in revised DS-R scale.

Table S4. Internal reliability and test-retest reliability our scale measures.

Table S5. Correlation between scale measures.

Table S6. Test of variances for large effect sizes between socio-demographic groups on scale measures.

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