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Research article

Object neophilia in wild herring gulls in urban and rural locations

Emma L. Inzani, Laura A. Kelley and Neeltje J. Boogert

E. L. Inzani (https://orcid.org/0000-0002-3685-7271) ✉ (eli204@exeter.ac.uk), L. A. Kelley and N. J. Boogert, Centre for Ecology and Conservation, Univ. of Exeter, Penryn, UK.

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Living with increasing urbanisation and human populations requires resourcefulness and flexibility in wild animals' behaviour. Animals have to adapt to anthropogenic novelty in habitat structure and resources that may not resemble, or be as beneficial as, natural resources. Herring gulls *Larus argentatus* increasingly reside in towns and cities to breed and forage, yet how gulls are adjusting their behaviour to life in urban areas is not yet fully understood. This study investigated wild herring gulls' responses to novel and common anthropogenic objects in urban and rural locations. We also examined whether gulls' age influenced their object response behaviour. We found that, out of the 126 individual gulls presented with objects, 34% approached them. This suggests that the majority of targeted gulls were wary or lacked interest in the experimental set-up. Of the 43 gulls that approached the objects, we found that those tested in urban locations approached more slowly than their rural counterparts. Overall, gulls showed no preference for either novel or common anthropogenic objects, and age did not influence likelihood of approach, approach speed or object choice. Individuals paid most attention to the object they approached first, potentially indicative of individual preferences. Our findings indicated that most herring gulls are not as attracted to anthropogenic objects as anecdotal reports have suggested. Covering up obvious food rewards may thus help mitigate human–gull conflict over anthropogenic food sources.

Keywords: exploratory behaviour, human–wildlife conflict, risk perception, urban ecology

Introduction

Adapting to urban life is a challenge facing many species. With increasing urbanisation and the resulting loss of natural habitats and resources, animals are under increasing pressure to use anthropogenic resources (McKinney 2006, Sol et al. 2013, Soulsbury and White 2015). A common feature of animal species that successfully colonise urban areas is an apparent inquisitiveness to explore new surroundings and objects (Lowry et al. 2013, Griffin et al. 2017, Barrett et al. 2019).

Neophilia is the attraction to novelty for no reward other than the exploration of novelty itself, which can be an object, place or food (Greenberg et al. 2003, Griffin et al. 2017). In contrast, an individual can also exhibit neophobia when it avoids novelty

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due to perceiving its potential risks as exceeding its potential benefits (Greenberg 2003). Neophilia and neophobia are not mutually exclusive, as individuals can display both behaviours simultaneously depending on the perceived benefit/risk trade-off and context (Greenberg and Mettke-Hofmann 2001). For example, corvids have highly neophobic responses when presented with novelty (Greenberg and Mettke-Hofmann 2001, Emery and Clayton 2004), yet they are also highly innovative and able to take advantage of novel opportunities (Emery and Clayton 2004, Emery 2006, Bird and Emery 2009, Greggor et al. 2016a, Nager and O'Hanlon 2016). The level of neophobia can depend on the environmental context: jackdaws *Corvus monedula* in urban environments have a higher tolerance for urban litter near food sources than their rural counterparts (Miller et al. 2015, Greggor et al. 2016b, Forss et al. 2017). The behavioural flexibility required to habituate to novelty in their environment aids animals' acquisition of resources needed to survive and thrive in human-modified landscapes (Greenberg and Mettke-Hofmann 2001, Greggor et al. 2015).

Avoidance of uncommon anthropogenic objects may be beneficial as they may be of little nutritional value compared to more natural food sources, or could even be harmful to the animal's health (Robertson et al. 2013). For example, plastic litter and discarded netting are well-known 'ecological traps': predators are fatally attracted to fishing nets to get to potential prey already trapped in the netting, while seabirds get entangled in artificial fibres used as nesting material (Croxall et al. 2012, Kühn and Franeker 2020, Lopes et al. 2020). Plastic objects or packaging are frequently ingested accidently or through mis-categorisation as potential food (Sol et al. 2011, Modlinska and Stryjek 2016, Kühn and Franeker 2020, Lopes et al. 2021). Gulls are known to have consumed plastic pieces and microplastics, with negative long-term physiological effects to individuals' health and breeding success (Lopes et al. 2020, 2022). Spending time investigating inedible materials may not only decrease foraging efficiency, but also negatively impact health and survival (Bateman and Fleming 2012, Murray et al. 2015, Modlinska and Stryjek 2016, Kühn and Franeker 2020).

However, exploring novel objects can also create new opportunities. Cavity-nesting birds that investigate and use nest boxes provide a striking example of how exploring novel anthropogenic objects can be hugely beneficial for breeding success, particularly in species that are limited by the abundance of natural nesting cavities (Gahbauer et al. 2015, Cox and Gaston 2018, Reynolds et al. 2019). Approaching anthropogenic objects can also provide access to food sources, such as picnic benches and bird-feeding tables. As neophobic conspecifics and heterospecifics may not approach such food sources, neophilic individuals may increase their food intake through reduced competition for food (Galbraith et al. 2015, Shutt and Lees 2021). For example, common garden bird species like great tits *Parus major*, blue tits *Cyanistes caeruleus*, house sparrows *Passer domesticus* and greenfinches *Chloris chloris* more readily approach a bird table with a novel object in urban areas compared with rural areas (Tryjanowski et al. 2016). Increased exposure to novel anthropogenic items allows for habituation or even attraction to novelty in urban birds compared with rural birds. This demonstrates behavioural plasticity in response to novelty, where the risk of approaching a bird table with an unfamiliar object on it is outweighed by the reward of food. Individuals residing in rural locations are known to be more wary in approaching novelty, or may lack interest because they have not formed an association between anthropogenic novelty and food rewards. As a result, they may miss out on opportunities (Martin and Fitzgerald 2005, Tryjanowski et al. 2016, Galbraith et al. 2017, Jarjour et al. 2020).

While urbanisation explains some of the variation in the extent to which individuals exhibit attraction to or avoidance of novelty, another driver of neophilia and neophobia is age. Young animals are inexperienced and learn about their surroundings through exploratory behaviour, which is a key component of behavioural plasticity (Greenberg and Mettke-Hofmann 2001, Sherratt and Morand-Ferron 2018). Juveniles across a wide range of taxa are more exploratory and faster to approach novel objects than adults (Bergman and Kitchen 2009, Biondi et al. 2010, Benson-Amram and Holekamp 2012, Carter et al. 2018, Sherratt and Morand-Ferron 2018, Greggor et al. 2020).

Herring gulls *Larus argentatus* and other Larids around the world are well-known for taking advantage of anthropogenic food sources, with many species consuming commercial fishing discards (Oro et al. 2013, Real et al. 2017) and human refuse from rubbish dumps (Monaghan 1980, Greig et al. 1986, Pierotti and Annett 2001, Duhem et al. 2008, Blight et al. 2015, Huig et al. 2016, Carmona et al. 2021). Herring gulls are large, long-lived omnivorous seabirds that typically live close to the coast across much of the Northern Hemisphere and have moved into more urbanised areas since the late 20th century (Rock 2005, Coulson 2015, Nager and O'Hanlon 2016). Since the 1960s, however, the population of herring gulls in the UK has declined by 60%, whilst there is an increasing gull presence in urban areas throughout the UK (Rock 2005, Nager and O'Hanlon 2016). This suggests that herring gulls nesting in more natural colonies may be suffering more than those in urban colonies (Soldatini et al. 2008).

Recent studies have shown that gulls coordinate their foraging to follow human schedules. For example, gulls only visit the local rubbish dump when fresh waste has been delivered, and visit towns and schools more frequently at optimal times of day and year for scavenging food from larger numbers of people eating outdoors (Huig et al. 2016, Parra-Torres et al. 2020, Pais de Faria et al. 2021, Spelt et al. 2021). Herring gulls can also use subtle cues like human handling when exploiting anthropogenic food sources: they are more likely to approach a wrapped food item previously handled by a human than an unhandled food item (Goumas et al. 2020b). However, human handling did not increase attraction to a non-food item (Goumas et al. 2020b). This suggests that herring gulls' exploration of anthropogenic objects is often associated with a search for food (Huig et al. 2016, Goumas et al. 2020b).

In addition, herring gull nests have been found to contain anthropogenic debris such as netting fibres and plastic drinking straws (Lopes et al. 2020, Thompson et al. 2020), and anecdotal reports suggest they explore anthropogenic items such as dentures and bottle caps, as well as deterrents such as bird scarers and model owls (Rock 2005). However, it is not known whether 1) herring gulls are generally attracted to anthropogenic objects without a food association, 2) they show a preference for novel over common anthropogenic objects (i.e. neophilia), nor whether 3) gull age and urban/rural location contribute to inter-individual differences in neophilia. To address these questions, we quantified the behaviour of herring gulls when presented with pairs of one novel and one common anthropogenic object.

Given their likely regular exposure to anthropogenic objects and their reputation as 'bold' and 'brazen' (Carr and Reyes-Galindo 2017), we predicted that the majority of herring gulls tested would approach the anthropogenic objects we presented. We expected urban herring gulls to be more inclined to approach than rural gulls, due to the higher likelihood of urban gulls having previously learned to associate anthropogenic objects with food. Similarly, as they had more time to experience human objects, we expected adults to be more likely to approach than juveniles and to approach the presented objects presented more quickly. Alternatively, the opposite prediction could be made, given that juveniles are more exploratory than adults in a range of bird species and might approach the objects faster (Heinrich 1995, Greenberg and Mettke-Hofmann 2001, Greenberg 2003, O'Hara et al. 2017).

With regards to neophilia, we predicted that gulls tested in urban locations would preferentially approach and interact with unfamiliar 'novel' anthropogenic objects over 'common' anthropogenic objects. Urban gulls might recognise common objects, such as tennis balls and watering cans, to not be sources of food, while novel objects could contain food and might thus be worth investigating. Following the same rationale, we predicted that adults would be more inclined to approach and interact with the novel object. Juveniles, in contrast, might not have accumulated sufficient experience with either object category to discriminate between them.

Materials and methods

Study location and subjects

We conducted experimental trials around Cornwall, UK (50.3356847°N, −5.05192972°W) in various urban and rural settlements (Supporting information) in commercial and recreational spaces where gulls are commonly found (e.g. quays, high streets, car parks, beaches). Trials were conducted between 31 August 2020 and 24 November 2020 by the same experimenter (ELI) between 07:00 and 14:00 GMT. A similar study on urban gulls found no effect of time of day on the likelihood that gulls approached the experimental setup (Goumas et al. 2019). We recorded experimental trials using a Panasonic HC-V770 video camera on a tripod and recorded the coordinates of all trial locations with a GPS (Garmin eTrex 30x).

The common objects we presented in the experimental trials were household objects that gulls were likely to have previously experienced in urban areas, such as a tennis ball, watering can and cardboard box (Supporting information). Novel objects were constructed from cardboard, plastic, metal, cloth and children's Big Briks® blocks, in configurations that gulls should not have any prior experience of. Any object resembling food packaging was avoided, because gulls appear to show more interest in these items, probably due to their association with food (Greig et al. 1986, Oro et al. 2013, Caldwell et al. 2020, Yorio et al. 2020). We avoided the colours red and yellow in the appearance of the objects as these have been associated with gull sensory biases (Thompson et al. 1971, Tinbergen et al. 1976).

Experimental protocol

Before the start of each experimental trial, the experimenter used a random number generator to select one object from the 'common' and one from the 'novel' category and to determine whether to present the novel object on the left or right side. Different common and novel objects were used to test the next focal gull in the local population to avoid any potential for social learning by non-focal gulls witnessing the experiment in the same area.

For each trial, the experimenter located a focal gull to test that was either sitting/standing on the ground or perched on structures up to 4 m high. If multiple gulls were participating in the trial (i.e. approached within ca 10 m of the objects), individuals were distinguished by colour rings where available, or plumage and size differences that vary with sex and age (Coulson et al. 1983, Greig et al. 1983, Meissner et al. 2017). Gulls were assigned to one of three age categories based on age-specific plumage traits: 'juvenile' for birds under 1 year old, 'sub-adult' for birds 2–3 years old and 'adult' for birds ≥ 4 years old. Multiple trials were conducted in a location on the same day and over multiple days. Care was taken to avoid revisiting exactly the same areas twice to avoid repeat sampling of the same individuals. Repeated testing of adult herring gulls was unlikely because they were already establishing and defending nesting territory areas, so they would reliably be within a ca 50 m radius of the same discrete area (Hunt and Hunt 1976, Tinbergen 1976, Spelt et al. 2019). Sub-adults and juveniles are more individually distinct owing to their unique plumage patterns and stage of moult. We avoided repeated testing of juveniles and sub-adults by identifying their individual characteristics and by not returning to the exact locations where successful trials had been conducted.

Before starting the experiment, the experimenter placed the video camera approximately 15 m away from the focal gull. When it was not possible to maintain an unobstructed view of the focal gull at this distance, the camera and the experimenter would be as far back as possible to minimise disturbance of the focal gull (distance ranged from 2 to 25 m).

To initiate the experiment, the experimenter approached and presented the focal gull with a common and a novel object placed simultaneously at a median distance of 4 m from the gull. Placement distances between the focal gull and objects ranged from 1 to 15 m with larger distances occurring in more rural locations like beaches, due to gulls' wariness of humans approaching (Feng and Liang 2020). The experimenter placed both objects simultaneously on the ground directly in front of the focal gull, by crouching with arms out to the left and right to place the objects equidistantly from the focal gull to ensure equal opportunity and distance to approach each object. The experimenter was looking down at the ground and facing forward to avoid providing any visual cues or scaring the gull away by staring directly at it (Goumas et al. 2019). Objects were spaced ca 1 m apart.

The trial started as soon as the experimenter took one step away from the objects to retreat to a distance of ca 15 m, next to the tripod, to allow the focal gull to approach the objects. A trial was considered successful if the focal gull remained in the immediate area once the objects were placed on the ground and the experimenter had moved back. If the focal gull left the area within ca 10 m radius around its original location due to the experimenter's approach, this was considered a failed presentation. If the focal gull left due to antagonistic interactions with other gulls or people before it could approach the objects or make a clear choice, this was also considered a failed trial for that focal gull. In the latter scenario, a second trial was attempted with the same focal gull using different objects. Each trial lasted a maximum of 10 min unless the focal gull left the area before then.

Behavioural measures

From the video recordings, the experimenter measured the latency for an individual to approach an object from the start of the trial (i.e. experimenter stepping away) until the gull reached the closest distance to the object. An 'approach' was defined as the focal gull taking steps towards one object with gaze directed towards that object. As quantifying gull gaze was ambiguous at distances larger than 1 m, an approach towards an object was only recorded as such if the gull approached to within 1 m of an object and with the chosen object in the gull's direct gaze, indicating a clear 'object choice'. If the gull did not come to within 1 m and did not display clear direct gaze at the objects (still within 10 m of objects after placement) this was recorded as 'no participation' and was not included in analyses of object choice and latency to approach. If the gull made direct contact with the object, the latency to approach was measured up until the moment that contact with the object was made. If the gull did not touch the object with its bill, the latency to approach was measured as the time taken for the gull to reach its closest distance to the object. The distance travelled by the focal gull to approach an object was estimated by the experimenter by noting the gull's original starting point and the closest distance to the chosen object. The gulls' body length (ca 40 cm) was used as a visual aid to approximate when the gull came to within ca 1 m of an object. We then calculated gulls' approach speed (m s^{-1}) by dividing the distance travelled by each gull (range 0.25–20 m, median 2.6 m, IQR 1.7–4.5 m) by the latency to approach the object within 1 m. If the focal gull failed to gaze directly at the object or approach it within 10 min, the trial was marked as 'no participation'.

If the focal gull did approach or peck one of the objects, this object was marked as the bird's first choice. The duration of a gull's exploration of an object was measured from when the focal gull had made a clear choice to approach one object within 1 m, with focus on one object and not the other. A gull was considered to explore the object when it would continue to gaze at the object, further approached the object, walked around or stood close to the object whilst tilting its head to keep its gaze on the object, or pecked it. The object exploration time was considered to end when the gull appeared to stop exploring the chosen object for more than 2 s, either by averting gaze and/or by turning its back to the object and walking away. If the focal gull approached or pecked an object again (either the same object or the other object presented), this was recorded as a second choice and object exploration was timed. The total duration of object exploration for each object was summed for each gull and trial.

The experimenter also recorded environmental factors that may have affected the focal gull's behaviour, such as time of day, location, weather, the number of gulls within 10 and 50 m, and the number of humans and the presence of dogs (yes/no) within 50 m of the focal gull. As stronger wind speeds have been shown to increase flight initiation distance in gulls (Goumas et al. 2020a), trials were not conducted when average wind speeds exceeded 20 mph. Measurements taken from the video recordings, including gull object choice, latency to approach and exploration duration, were double-scored by an independent observer blind to the hypothesis being tested to assess the inter-observer reliability of the behavioural scores.

Location was categorised as urban or rural following the Office for National Statistics classification that settlements > 10 000 residents are considered 'urban', while settlements with fewer residents are 'rural' (Goumas et al. 2020). The data for residential population size used were from the 2011 census for each location where experimental trials were conducted. The national population is predicted to have increased by approximately 7% since the 2011 census (Office for National Statistics 2019), so we corrected our estimates accordingly for our urban–rural classification. This correction only altered St Ives's classification, as in the 2011 census the local residential population was estimated to be just under the 'urban' threshold (9966). Three locations (Cadgwith, Par and Polzeath) were too small to have localised population data and were thus defined as 'rural'. Gulls in rural settlements are likely to experience fewer interactions with humans and their objects as compared to gulls in urban locations. Although gulls have extensive foraging ranges that may include both urban and rural sites (Rock et al. 2016, Spelt et al. 2019), our previous research shows that gulls tested in rural locations can be approached less closely than gulls tested in urban settings (Goumas et al. 2020a).

Analyses

All statistical analyses were conducted using R ver. 4.0.3 (<www.r-project.org>; Supporting information) and the 'lme4' (Bates et al. 2015) and 'MASS' packages (Venables and Ripley 2002). For each general linear model (GLM), the error structure family was tested and that with the lowest AIC values and smallest residuals was selected.

Inter-observer agreement of behavioural measures and confounding variables

Inter-observer correlation coefficients (IOCCs), calculated using Spearman's rank correlations, were used to compare the two observers' scores for gull object choice, latency to approach an object and object exploration time. Observers agreed on first object choice ($r_s = 0.966$, $n = 43$, $p < 0.001$) and time taken to approach ($r_s = 0.945$, $n = 43$, $p < 0.001$). As there was poor agreement between observers on object exploration times ($r_s = 0.561$, $n = 43$, $p < 0.001$), we created a binary score indicating which object each gull explored most throughout the presentation trial according to each observer's object exploration time measurement. Two gulls that spent equal amounts of time inspecting both objects were excluded from the binary analysis as they could not be assigned a binary object preference score. We found inter-observer agreement for this binary score of gull object exploration to be much higher ($r_s = 0.73$, $n = 41$, $p < 0.001$). We report the results of the object exploration model using the experimenter's (ELI's) scores in the main text, while the qualitatively identical results using the independent observer's scores are presented in the Supporting information.

Chi-squared contingency tables showed no significant differences in gulls' decision to approach across trial IDs (representing the time of day and date; $\chi^2 = 91.526$, $df = 93$, $p = 0.524$), object ID ($\chi^2 = 17.884$, $df = 13$, $p = 0.162$) nor side biases (first object approached being on the left/right; $\chi^2 = 0.209$, $df = 1$, $p = 0.647$). We therefore did not include these variables in our models.

Do herring gulls approach anthropogenic objects and are they neophilic?

We used binomial proportion tests to determine whether gulls were more likely than chance (50%) to approach the objects or not. We then used a binomial GLM to test whether gulls' decision to approach the objects or not was associated with any environmental factors, namely number of gulls within 10 m, number of people within 50 m and dogs present (y/n), as well as the predictor variables of interest: the categorical factors of gull age (juvenile, sub-adult or adult) and test location (urban or rural). For those gulls that did approach the objects, we determined whether they showed neophilia by testing whether they were more likely to approach and/or peck the novel over the common object, using binomial proportion tests.

Are juvenile and urban gulls more neophilic than (sub)adult and rural gulls?

We used generalized linear models (GLMs) to determine if gull age category and urban/rural test location were associated with 1) an individual gull's decision to approach the novel or common object first, using a GLM with binomial error distribution; 2) the gulls' speed to approach their first choice of object, using a GLM with gamma error distribution and 3) the object that the gulls explored most throughout the trial, using a GLM with binomial error distribution and including the object approached first (novel or common) as another predictor. The environmental variables (number of gulls within 10 m, number of people within 50 m and dog presence) were only included in 2) the GLM testing gulls' speed of approach, as we did not have any a priori reasons to expect those variables to influence whether gulls preferred the novel over the common object once they had approached the objects.

Results

Do gulls approach anthropogenic objects?

We conducted 94 object presentation trials where the gull did not leave owing to experimenter's approach when presenting objects. During these trials, we recorded 126 individual herring gulls' responses in 15 different locations in Cornwall, with 84 responses recorded in urban settings and 42 responses in rural settings. We attempted to test a further 113 gulls (60 urban and 53 rural), but the gulls flew upon the experimenter's approach or were disturbed by the public or other animals before objects could be put in place. There was no significant difference between urban and rural test locations in the likelihood of a gull fleeing upon the experimenter's approach (Pearson's Chi-squared test, $\chi^2 = 18$, $df = 14$, $p = 0.207$).

The majority of herring gulls that were presented with two anthropogenic objects and remained in the test area did not approach either object: only 34% of gulls ($n = 43$ out of 126; 32 urban and 11 rural) presented with the objects approached the objects (binomial proportions test: $p < 0.001$). The likelihood of a gull approaching the objects was not associated with the focal gull's age category nor whether the test location was urban or rural (Table 1), and none of the environmental variables included in the model showed a significant association with gulls' decision to approach (Table 1).

Are herring gulls neophilic?

Gulls that approached an object were not significantly more likely to approach a novel than a common object (binomial proportions test, $n = 26$ out of 43 gulls approached the novel object; $p = 0.222$). Only 13 of the 43 gulls that approached an object also pecked it, and those gulls were not more likely to peck the novel than the common object (binomial GLM: Z value $= 0.77$; $n = 13$; $df = 1$; $p = 0.441$).

Table 1. Results of a binomial GLM (link = logit) testing whether environmental variables, gull age and urban–rural categories influenced the likelihood of gulls approaching objects.

	Estimate	SE	Odds ratio	95% CI	Degrees of freedom	Z value	p-value
Intercept	−1.277	0.452	0.279	0.191–0.654			
Number of gulls < 10 m	−0.082	0.068	0.921	0.796–1.046	1	−1.209	0.227
Number of people < 50 m	−0.002	0.011	1.002	0.981–1.024	1	0.176	0.860
Dogs present (yes or no) < 50 m	0.791	0.430	2.205	0.950–5.179	1	1.838	0.066
Focal gull age: juvenile (versus adult)	0.192	0.453	1.211	0.110–2.964	2	0.423	0.672
Focal gull age: sub-adult (versus adult)	−0.112	0.508	0.894	0.324–2.402	2	−0.221	0.825
Urban–rural category	0.5253	0.4395	1.691	0.727–4.122	1	1.195	0.232

Are juvenile and urban gulls more neophilic?

Whether the gull approached the common or novel object was not significantly influenced by gull age category nor test location (approach to common or novel object: binomial GLM: gull age juvenile versus adult, Z value = 1.18, n = 43, df = 2, p = 0.238; sub-adult versus adult, Z value = −0.85, n = 43, df = 2, p = 0.396; urban–rural, Z value = 0.50, n = 43, df = 1, p = 0.616). Speed at which a gull approached was also not significantly influenced by age category (Table 2). However, gulls were faster to approach when their first object choice was the novel rather than the common object, and approach speed was faster in rural than in urban locations (Gamma GLM: first object choice, t test = 2.84, n = 43, df = 1, p = 0.007; urban–rural, t test = −2.57, n = 43, df = 1, p = 0.015; Fig. 1). Neither gull age nor test location influenced the object type that was most explored throughout the trials (Supporting information). However, the object that each gull approached first was also the object that the gull explored the most for the duration of the trial (Supporting information).

Discussion

Do gulls approach anthropogenic objects?

While herring gulls are often portrayed in the media as being 'bold' and 'brazen' (Carr and Reyes-Galindo 2017), only 53% of the targeted herring gulls stayed within the test area when approached to start an experimental trial, and of these 34% actually approached the objects. This replicates previous findings that most gulls are wary of humans approaching them directly (Goumas et al. 2020a). A previous study that presented two common objects, namely sponges, to urban herring gulls found that 32 out of 41 targeted gulls (78%) approached the objects (Goumas et al. 2020b). This higher approach rate compared with our study might be due to the sponges being smaller in size and less complex in shape than some of our common and novel objects, and thus potentially less intimidating. Bird deterrents often have complex shapes or vivid colouration that may move or change in appearance depending on wind or the viewer's perspective, to exploit neophobic and anti-predator behavioural responses (Baker et al. 2005, Rock 2005, 2012). The objects that we used may have been inherently intimidating to gulls because they shared some of these properties.

Are herring gulls neophilic?

Although the majority of gulls that engaged with the experiment (n = 26; 63%) approached the novel object first, the difference with the number of gulls that approached the common object was not significant. At a population level, herring gulls do not appear to be neophilic. The perceived risk of approaching a novel object of unknown benefit (i.e. not a known or obvious source of food) in the presence of humans may have outweighed any perceived rewards associated with its exploration. In contrast, raccoons *Procyon lotor*, often considered a pest due to their exploitation of human resources, will readily approach and solve anthropogenic puzzle boxes for food rewards (Stanton et al. 2017). The gulls in our study might have been more likely to approach the novel objects if these had been associated with a food reward. However, the aim of our study was to quantify object neophilia, i.e. attraction to a novel object for no reward other than the exploration of novelty itself. It seems likely that

Table 2. Results of gamma GLM (link = log) testing whether environmental variables, gull age and urban–rural location influenced the speed (m s^{-1}) of gulls' approach to objects. Significant predictors are in bold.

	Estimate	SE	Back transformed coefficient	95% CI	Degrees of freedom	T value	p-value
Intercept	−2.096	0.348	1.123	0.062–0.260			
Number of gulls < 10 m	0.025	0.045	1.025	0.936–1.141	1	0.553	0.584
Number of people < 50 m	−0.003	0.006	0.997	0.985–1.010	1	−0.573	0.570
Dogs present (yes or no) < 50 m	0.385	0.277	1.469	0.858–2.540	1	1.387	0.174
Focal gull age: juvenile (versus adult)	0.025	0.292	1.025	0.563–1.867	2	0.085	0.933
Focal gull age: sub-adult (versus adult)	0.178	0.338	1.195	0.601–2.422	2	0.527	0.602
Object type (novel or common)	**0.771**	**0.271**	**2.161**	**1.222–3.735**	**1**	**2.840**	**0.007**
Urban–rural category	**−0.795**	**0.309**	**0.452**	**0.236–0.833**	**1**	**−2.570**	**0.015**

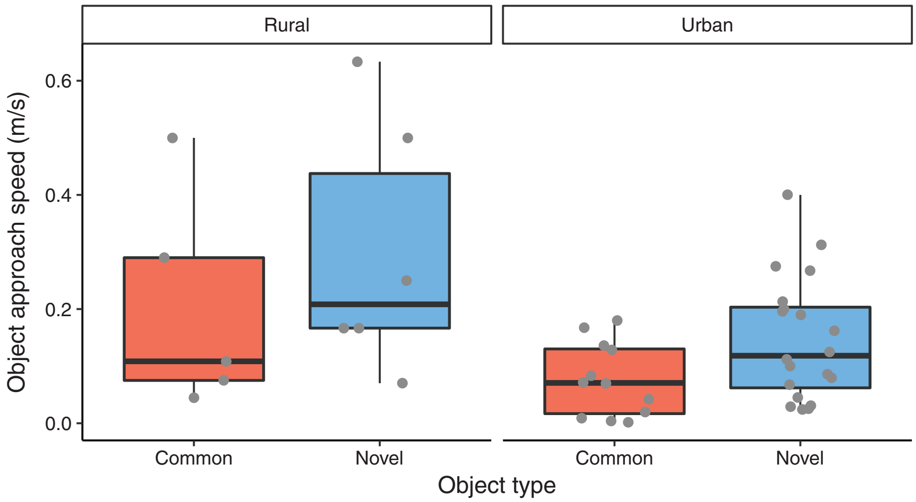

Figure 1. Boxplot showing speed to approach objects (m s⁻1) by urban–rural classification. Bold horizontal lines show the median, and the outer horizontal lines of the boxes indicate the interquartile range of the data. Error bars show the range, and the grey dots overlaying the boxplots show the raw data. .

the presence of food and absence of the experimenter would have increased gulls' exploration of the novel objects. Urban jackdaws, when compared to their more rural counterparts, discriminated between human litter and novel objects, and prioritised inspecting the litter-like objects due to established food associations (Greggor et al. 2016b). Such discrimination and categorisation of human litter items versus novel objects may reduce the risks associated with investigating unfamiliar anthropogenic objects and increase foraging efficiency in urban environments (Greggor et al. 2016b).

It is also possible that gulls may also use senses other than vision to gather information to assess the risks and benefits of approaching novel objects. Seabirds are known to use olfaction when foraging over long distances at sea and locating their nests (Nevitt et al. 1995, Bonadonna et al. 2004, Amo et al. 2013). In other birds, zebra finches *Taeniopygia guttata* and chickens *Gallus domesticus* will accept novel-looking foods if they can recognise it as food via olfactory cues (Marples and Roper 1996, Kelly and Marples 2004). Gulls may assess the potential likelihood of food association with a novel object via olfaction to determine whether a possible food reward is enough to outweigh the risks of coming into close contact with novelty. Future studies could test whether urban herring gulls can categorise anthropogenic objects and investigate how their responses to such objects change with repeated exposure and food association in the absence of humans.

While our test subjects did not show a significant preference for novel objects, our results suggest that gulls approached the novel objects ca 0.1 m s^{-1} faster than they approached the common objects. Latency to approach novelty (which we used to calculate approach speed to control for distance moved) is a common measure of neophilia (Greggor et al. 2014, 2015, Griffin et al. 2017), hence our results may suggest that the 26 out of 43 gulls that approached the novel object could be showing some neophilic behaviour. However, the difference in approach speed between novel and common objects was relatively small and could possibly be explained by the fact that we had to estimate gull distance when the objects were placed. We found no overall population preference for novelty, and further studies are needed to quantify whether individuals' speed to anthropogenic objects is repeatable and indicative of individuals' tendency to explore novel objects.

Although we did not find an overall population-level preference for either the common or novel objects, from our analysis of object choice it did appear that gulls spent most time exploring the object that they chose to look at first; 38 out of 43 gulls that made a first choice also went on to show repeat and continued exploration of the same object. As we tested wild gulls, we have no knowledge of individuals' experiences of anthropogenic objects or whether they have encountered similar objects. For example, gulls may have experienced similar common objects in association with food in the past, even though common objects chosen for this experiment (shoe, tennis ball, watering can, etc.) were not likely to have had any prior food associations. It would be interesting to repeatedly test the same individuals on different days to determine whether object preferences are consistent within individuals and possibly linked to personality traits such as boldness and exploratory behaviour, or instead related to motivational states such as hunger. Future studies could also attempt to habituate the gulls to the presentation of the 'common' objects first, to standardize their familiarity with these and the presentation procedure. One could then present the familiarised object next to an unfamiliar one, to test for neophilia in a more standardized (but more time-consuming) manner.

Are urban gulls more neophilic than rural gulls?

We found that herring gulls approached the objects faster in rural than in urban settlements. Although this finding should be interpreted with caution owing to the small sample size of rural gulls we managed to test, this result is contrary to our prediction that gulls in urban areas would be more neophilic and would approach objects faster than gulls in rural areas. Previous studies show that corvids, chimango caracara *Milvago chimango* and small passerines in urban environments display lower neophobia and approach food near novelty more readily than their rural counterparts (Greggor et al. 2016, Tryjanowski et al. 2016, Biondi et al. 2020, Jarjour et al. 2020). One potential explanation for our findings is that individuals that spend more time in urban areas may appear less exploratory/neophilic than rural individuals because they have a greater prior knowledge of which anthropogenic objects might be associated with food or pose a threat. Rural gulls are likely to have relatively less experience of anthropogenic objects so may have found our presented objects more interesting as a possible new food source. This hypothesis is supported by a study on captive garden warblers *Sylvia borin*, which found that birds that had experienced anthropogenic objects before were slower to approach them compared to birds that had no prior experience of the objects (Mettke-Hofmann et al. 2006). Herring gulls in rural areas may also have been more sensitive to increased risk from human disturbance and/or predation due to being on the ground (Lowry et al. 2013), and therefore may have approached the objects more quickly to minimise risk duration. In contrast, urban herring gulls appear to be more tolerant of disturbance as they have a shorter flight initiation distance when approached by a human compared with rural gulls (Goumas et al. 2020a).

Are juvenile gulls more neophilic than adult gulls?

Gull age did not affect the speed of approach to an object, nor the amount of exploration of either object presented. This result is contrary to our predictions and previous studies' findings that younger individuals are more likely to interact and spend more time interacting with novelty in a variety of species (Greenberg 2003, Biondi et al. 2010, Benson-Amram and Holekamp 2012, Miller et al. 2015). Being able to exploit calorie-dense anthropogenic resources may be particularly useful to immature animals, as they generally have a higher mortality risk compared to adults and are inefficient and inexperienced in their foraging techniques (Chabrzyk and Coulson 1976, Greig et al. 1983, Marchetti and Price 1989, McCleery 2015). There are age differences in the use of anthropogenic foods in Audouin's gulls *Larus audouinii* and yellow-legged gulls *L. michahellis*, where juveniles exploit predictable anthropogenic food subsidies like fishery discards and landfill more than adults (Navarro et al. 2010, Carmona et al. 2021; but see Calado et al. 2021 where adult yellow-legged gulls interacted more with fisheries than immatures). This may increase their energy intake sufficiently to increase their survival (Navarro et al. 2010, Steenweg et al. 2011). However, exploring novel anthropogenic food sources may also carry risks, as such food sources could be toxic or just lacking in beneficial nutrients (Pierotti and Annett 2001, Riotte-Lambert and Weimerskirch 2013, Caldwell et al. 2020), and a high intake could actually increase juveniles' mortality rate (Pierotti and Annett 1991, Riotte-Lambert and Weimerskirch 2013, Sotillo et al. 2019). Juvenile and sub-adult Olrog's gulls *L. atlanticus* are found to be less neophobic than adults when approaching novel anthropogenic objects (García et al. 2019). This suggests that initial neophobic responses to novelty may be dependent on the ecology of the species as well as age and experience of an individual. Olrog's gulls are dietary specialists and do not closely associate with people nor exploit human resources, so it is unlikely that adults would have a strong affinity for anthropogenic objects as they would not be considered as a potential cue for food or other useful resource (Yorio and Giaccardi 2002, Yorio et al. 2013). In contrast, herring gulls are well known for the diversity of their diet and for habitually living in close proximity to people. Herring gulls may therefore be exposed to, and exploit, anthropogenic resources due to learnt associations from early life onwards, which may explain why we did not find any age differences in object neophilia.

Conclusions

This study is the first to test how wild-living herring gulls of varying ages respond to common and novel anthropogenic objects in urban and rural test locations. Although we did not find population-level evidence of neophilic responses to anthropogenic objects, individuals did show variation in their decisions to engage with the objects, which may influence their ability to cope with increasing urbanisation and anthropogenic resources. Further research is required to establish if neophilic, neophobic and exploratory behaviours observed in wild-living animals are repeatable within individuals and how factors such as human proximity and perceived risk could influence individuals' responses. Future studies are also needed to investigate how these behaviours affect individuals' survival and reproductive success in increasingly urbanised areas. Relatively larger species like gulls and mesocarnivores can travel large distances in a day to forage and so can visit both urban and rural habitats regularly (Bateman and Fleming 2012, Van Donk et al. 2020, Pais de Faria et al. 2021, Spelt et al. 2021). Individuals are therefore likely to have some prior experience and knowledge of anthropogenic objects, but they still vary greatly in their exploratory and neophilic behaviours. These observations suggest that behavioural flexibility and personality could be key to individuals' ability to thrive in human-modified habitats (Thompson et al. 2018).

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Author contributions

Emma L. Inzani: Conceptualization (lead); Data curation (lead); Formal analysis (lead); Methodology (equal); Writing – original draft (lead). **Laura A. Kelley**: Conceptualization (supporting); Formal analysis (supporting); Methodology (equal); Supervision (supporting); Writing – review and editing (equal). **Neetje J. Boogert**: Conceptualization (equal); Formal analysis (supporting); Methodology (equal); Supervision (lead); Writing – review and editing (equal).

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Data availability statement

Data are available from the Dryad Digital Repository: <https://datadryad.org/stash/dataset/doi:10.5061/dryad.qrfj6q5kj> (Inzani et al. 2022).

Supporting information

The Supporting information associated with this article is available with the online version.

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