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Anthropogenic noise interacts with the predation risk assessment in a free-ranging bird

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Abstract

Anthropogenic noise can affect a number of behavioral, physiological, and ecological aspects of animals from major taxonomic groups, raising serious conservation concerns. For example, noise pollution impacts communicative behavior and perception of signals, movements and distribution, as well as predator–prey interactions, such as hunting success or predator detection and predation risk assessment. We have carried out an experimental playback study, in which we investigated whether exposure to anthropogenic noise (sound of a tractor) distracts free-ranging barn swallows *Hirundo rustica* from paying attention to an approaching human "predator" (the "cognitive distraction" hypothesis), or whether noise leads to increased responsiveness to this "predator" (the "increased threat" hypothesis). The subjects were male barn swallows attending their breeding territories during the time when the females were incubating. We found that barn swallow males initiated flight at significantly greater distances to the approaching human "predator" in the noise treatment than during the quiet control trials. These results suggest that anthropogenic noise causes increased vigilance and reactivity rather than a distraction, enabling birds to avoid the "predator" more quickly. We further discuss the mechanism behind the increased alertness in response to noise and contrast the "increased threat" mechanism, usually tested in previous studies, with an alternative "cognitive sensitization" mechanism.

Key words: anthropogenic noise, barn Swallow, cognitive distraction, flight initiation distance, *Hirundo rustica*, predation risk assessment.

The development of transportation networks, urban land cover, and intensive farming are all associated with the introduction of novel and increasingly influential sources of acoustic disturbance into terrestrial and aquatic habitats, including remote wilderness sites (Barber et al. 2011; Buxton et al. 2017). Anthropogenic noise has been shown to negatively affect a range of species from major taxonomic groups (Shannon et al. 2016a; Erbe et al. 2022). Noise pollution is known to impact behavior (e.g., hampered communicative behavior, perception of signals; Francis et al. 2011; Halfwerk et al. 2011; Derryberry et al. 2020; or altered habitat selection; Rheindt 2003; Goodwin and Shriver 2011), physiology (e.g., noise stress; Raap et al. 2017; Injaian et al. 2018; Kleist et al. 2018), and fitness of individuals (e.g., impaired survival or fecundity; Schroeder et al. 2012; Simpson et al. 2016; Senzaki et al. 2020). Impacts on individuals can have cascading effects on communities by disrupting species interactions and can ultimately lead to animal declines and reduced species richness (Francis et al. 2009, 2012; Siemers and Schaub 2011; Mason et al. 2016), raising serious conservation concerns (Francis and Barber 2013; Shannon et al. 2016a).

Predator–prey relationships are among the ecological phenomena where the impact of anthropogenic noise may be of major importance (Francis et al. 2009; Courter et al. 2020; Shannon et al. 2020). The ability of animals to detect predators and recognize the threat they pose can reduce the risk of death or minimize the cost of losing benefits (e.g., food, territory, mate, or nest with young; Ydenberg and Dill 1986; Lima and Dill 1990). Anti-predator behavior is, therefore, directly related to individual fitness. Noise can interfere with signals and cues that mediate predator detection, predation risk assessment, and decisions about whether and when to flee. If the effectiveness of anti-predator behavior is compromised, it can directly expose animals to a greater risk of death (Simpson et al. 2016). The effect of noise on anti-predator behavior measures, such as vigilance or escape behavior, is among the recommended directions in research on the impact of noise pollution on wildlife (Ortega 2012).

Noise can interfere with predator detection and escape response in 3 ways, including distracting animals from detecting and/or monitoring an approaching predator (the "cognitive distraction" hypothesis), being directly perceived as a threat (the "increased threat" hypothesis), or by acoustic masking (the "acoustic masking" hypothesis). Masking is the most commonly invoked mechanism to explain how noise affects the detection of cues and signals (Barber et al. 2010; Francis and Barber 2013; Dominoni et al. 2020). According to this mechanism, noise, as a result of the similarity of acoustic frequencies and amplitudes, compromises the discrimination or detection of auditory cues from the predators themselves (Grade and Sieving 2016; Jung et al. 2020; Merrall and Evans 2020) or alarm calls communicating danger (McIntyre et al.

2014; Templeton et al. 2016; Tilgar et al. 2022). By definition, masking occurs within a single sensory modality. Noise-exposed animals can be expected to respond later by fleeing, allowing a predator to approach closer, compared to those not exposed to the noise.

Noise-induced cognitive distraction occurs when anthropogenic sound reallocates an animal's finite attention and information processing capability effectively preventing it from responding to those cues or signals that convey biologically relevant information (Chan et al. 2010a; Grade and Sieving 2016). Noise may interfere with attentional processes and information use in other sensory modalities (Chan and Blumstein 2011). For example, auditory distractors can affect the escape response to visual (Chan et al. 2010a, 2010b) or olfactory (Morris-Drake et al. 2016) threats. As with acoustic masking, distraction can be expected to delay the escape response in animals. Under the "increased threat" mechanism, noise is functionally analogous to the threat of predation, prompting animals to increase their alertness (Frid and Dill 2002; Quinn et al. 2006). Increased vigilance in the presence of background noise can enable animals to detect and flee predators sooner (Meillère et al. 2015; Shannon et al. 2016b; Petrelli et al. 2017). The early escape, in this case, is largely explained by the flush early and avoid the rush (FEAR) hypothesis (Blumstein 2010), which proposes that prey will flee the approaching predators soon after they detect and identify them as a threat, to reduce or minimize ongoing attentional costs of monitoring approaching predators. Noise-exposed animals are therefore expected to initiate an escape response earlier than non-noise-exposed animals. However, chronic noise can have a detrimental effect on fitness as it can be perceived by animals as a stressor (Injaian et al. 2018). Most previous research on the "cognitive distraction" and "increased threat" mechanisms has been carried out in laboratory or field settings, where the acoustic stressor was introduced as a novel and acute stimulus (but see Hubbard et al. 2015 and Petrelli et al. 2017). Further research is needed to assess the generalizability of these 2 mechanisms to free-living animals inhabiting environments containing familiar human-induced acoustic stimuli.

We investigated whether the noise accompanying farming operations affects the flight response to approaching predators in the barn swallow *Hirundo rustica*. Barn swallows are mainly associated with farmland, where they find suitable habitats for foraging and nesting (Turner 2006). They often nests on farms, usually inside farm buildings (such as horse stables, barns, and pigsties), where they are constantly exposed to the noise of agricultural machinery operating in farmyards and even inside buildings in the care of livestock. We used flight initiation distance (hereafter FID, the predator–prey distance when escape begins), a measure that is commonly used as a proxy for animals' tolerance of predators as well as the presence of humans (Cooper and Blumstein 2015). The approaching "predator" in this study was a human, as humans can also be considered a form of predation risk (Frid and Dill 2002; Stankowich and Blumstein 2005). Because we used a looming visual stimulus rather than an auditory component as a cue to indicate the approach of a predator, we were able to eliminate the masking mechanism. Therefore, we focused on distinguishing between "cognitive distraction" and "increased threat" mechanisms. If noise distracts the finite attention of barn swallows, making it difficult for them to monitor and assess approaching predators (the "cognitive distraction" hypothesis), we predict that noise-exposed birds should exhibit closer FID compared to controls. Alternatively, if noise prompts barn swallows to increase their alertness, so they are better able to monitor approaching predators and identify them as a threat (the "increased threat" hypothesis), we predict that noise-exposed birds should exhibit longer FID than controls.

Materials and Methods

Study area

We studied the flight initiation distance in 2 breeding colonies of barn swallows located near Warsaw (Poland: 52°22′N, 20°52′E). The surrounding area is an extensive agricultural landscape of the wide valley of the Vistula River, with 2 large oxbow lakes, arable fields, scattered orchards, vast hay meadows with groups of shrubs and trees, and remnants of riparian forests. The nearest expressway or railway line is more than 2 km from the study site. The main sources of anthropogenic noise are locally moving cars and tractors performing agricultural tasks within the farmyards and in adjacent fields.

The breeding colonies are located in horse stables lying 1,200 m apart. In 2021 they numbered 25 and 38 breeding pairs. The study population has been extensively ringed by frequent mist-netting as part of a long-term study (Matyjasiak et al. 2013). All birds were individually color marked with a combination of numbered metal and color leg rings, allowing for individual recognition. On both farms, tractors are used to haul manure and provide feed for horses. On 1 farm, 2 to 3 times a day in the morning, a tractor runs along a corridor inside the stable. In the other, it operates only in the initial sections of the corridors at both entrances to the stable. Tractors Ursus C-360 model, which is common in Polish agriculture, are used for this purpose. Barn swallows in the study area are therefore accustomed to various forms of human-induced disturbance.

Experimental design

The trials were performed in the morning and midday hours (between 07:00 am and 02:00 pm) on days without precipitation or strong winds, from 20 May to 20 June 2021. Mated male barn swallows whose female partners were incubating their first brood clutches were selected for the experiment. A corridor (4 m wide) runs along the buildings of the 2 stables where the study was conducted, with horse box stalls (4 × 4 m) on either side. One horse stall usually houses 1 territory of swallows, rarely 2 or 3. All nests were located behind exposed ceiling beams, which meant that incubating females could not see an approaching human "predator."

Three tests, the order of which was randomized, were conducted on each male barn swallow (n = 43) for 3 consecutive days (or after a day or 2 off in case of inclement weather). All 3 treatments for each male were performed at the same time of day. We tested at most 1 or 2 males per hour. We made sure that successive test males were not adjacent to each other. Experimental treatment ("noise-exposed birds") included the playback of noise (the sound of a tractor) and the approaching human "predator." The playback of noise was initiated 5 s before the human "predator" approach was initiated and turned off when the bird flew away. We increased the playback volume in about 3 s—this way we wanted to mimic the noise of a tractor driving into the stable. Control tests ("controls") included only the approaching human "predator." The

additional third test ("noise-only controls") involved only tractor noise playback (10 s, equivalent to the approach time in experimental trials) and was intended to check whether exposure to tractor noise alone would trigger an escape response in barn swallows. The experimenter (PM), who also acted as the human "predator," was the same person who captured the swallows for biometric measurements and ringing but who did not inspect the swallow nests. The experimenter, walking down the corridor of the stable, selected males that were sitting in their preferred posts in their territories and were not obviously alarmed or involved in interactions with their neighbors but were roosting or preening.

A schematic of the experimental set-up is shown in Supplementary Figure S1. A remote-controlled loudspeaker Harman Kardon Onyx Studio 5 (Harman Kardon Inc., Northbridge, CA, USA; 50 W, frequency response 50–20,000 Hz) was placed in the corridor at a distance of 5 m from the target bird, perpendicular to the path of the human "predator." The experimenter immediately moved away, then returned 5 min later (at the time, the loudspeaker was off). In case the target male was present on his favorite perch, the experimenter moved toward the target bird at a consistent speed of 0.6 m/s (step length 0.5 m) while gazing directly at it. A first sandbag was dropped at the starting point and a second was dropped when the target bird took flight. Flight initiation distance (FID-direct) was measured as the distance between the second sandbag and the focal male's perch. Starting distance (5–10 m) was measured as the distance between the first sandbag and the focal male's perch. The distances were measured with a Bosh GLM 50 Pro laser rangefinder (Bosh Power Tools GmbH, Stuttgart, Germany, range 0.05–50 m, accuracy 1.5 mm). The rangefinder emits a beam of red light, which facilitated precise measurement of the distance to where the focal male was sitting. Starting distances in the "noise-exposed birds" tests and "control" tests performed on the same individual were the same. They averaged (mean ± SE) 7.8 ± 0.2 m (n = 43) and 7.8 ± 0.1 m (n = 43), respectively. Barn swallows are small birds (~18 g) that when perched remain in head-up positions and so we found it difficult to confidently record alert distance and instead, we used trial starting distance as a proxy of alert distance (Samia and Blumstein 2014). Alert distance is the predator-prey distance when the prey becomes aware of and begins to monitor the predator.

We recorded individually 7 tractors Ursus C-360 model that are used daily for work on the farms under study. The recordings were made from a distance of 4 m from the vehicle, which was not in motion but its engine was running at high speed. We used a Clippy XLR EM172 Mono microphone connected to a Marantz PMD661 MKII recorder. We received 7 4-min recordings, which we used in the noise exposure trials. The noise exposure treatment ("noise-only controls" and "noise-exposed birds" trials) involved the broadcast of tractor noise from the loudspeaker (77 dB L_{Aeq} at 5 m, SVAN 958 sound level meter and analyzer, Svantek Ltd, Warsaw, Poland). Measurements of ambient sound levels inside the stables (no tractor was operating nearby at the time) averaged 43 (range 29–61) dB L_{Aeq}.

Flight initiation distances (FID) were transformed using the phi FID index (Φ FID; Samia and Blumstein 2014) to overcome the issue of statistical and mathematical constraints, such as the constrain envelope in the starting distance-FID relationship (starting distance ≥ FID). The Φ FID index is a standardized goodness-of-fit metric (range 0–1) that allows us to estimate how close flight initiation distance is to start distance without being biased by the inevitable methodological effect that the first is always smaller or equal to the second. Tshe Φ FID index for a given flight initiation distance measurement, i, was calculated as follows:

$$\Phi FID_i = 1 - \frac{(e_i - o_i)}{e_i}$$

where e_i represents the starting distance and o_i is the FID for a focal male. The higher the Φ FID value, the closer the FID is to the starting distance, indicating earlier escape (for a given starting distance).

Statistical analyses

Our main hypotheses were tested by investigating how the escape response differed between barn swallow males subjected to noise ("noise-exposed birds") and those not subjected to noise ("controls"). For this purpose, we analyzed the Φ FID index as the response variable. We relied on generalized linear mixed-effect models (normal errors and identity link function) with the above index as the dependent variable. We defined a set of candidate models in which the predictor terms were "Exposure" as a binary variable ("noise-exposed birds" = 1, "controls" = 0), "Colony" as a binary variable (stable no 1 = 1, stable no 2 = 2), and 2-way interaction term between "Exposure" and "Colony." We also included in the models "Incubation stage" as a discrete numeric variable. The identity of males was included as a random intercept to control for the non-independence of trials repeatedly performed on the same individuals. The set of candidate models totaled 10 models (the structure of the models is shown in Supplementary Table S1). We standardized the predictor variables by centering their means and scaling (dividing by 2 SD) prior to analysis to place them on the same scale and thus facilitate the interpretation and comparison of effect sizes based on parameter estimates (Gelman 2008). Numeric variables were rescaled to have a mean of zero and an SD of 0.5. Binary variables were rescaled to have a mean of 0 and a difference of 1 between the 2 categories.

We used the Akaike information criterion with a correction for a small sample size (AICc; Burnham and Anderson 2002) to evaluate and rank the 10 candidate models for the predictors described above. For each candidate model i, we calculated Akaike weight (ω_i) that can be interpreted as the relative likelihood of a model, and thus indicate the probability that the model is the best model, given the data and the set of candidate models. Parameter estimates (effect sizes) and their standard errors for the final model were obtained by averaging a subset of top candidate models (n = 6; Supplementary Table S1) selected with a cut-off criterion of ΔAICc<6.0 in relation to the best model with the lowest AICc (Richards 2005). The summed weight of this "top model set" was 0.99. The confidence intervals (95% CIs) for the final model were calculated using the parameter estimates and the associated standard deviations obtained by model averaging. Estimates of predictor terms were considered to have support for an effect on the Φ FID index whenever their 95% CI did not overlap zero (Grueber et al. 2011). Models were fitted using IBM SPSS Statistics v.27 software.

Results

We conducted the research procedure involving 3 trials with 43 male barn swallows. The total number of trials was

therefore 129 (*n* = 43 for "noise-only control," *n* = 43 for "controls" and *n* = 43 for "noise-exposed birds" trials).

None of the tested birds escaped during "noise-only control" trials (involving only noise playbacks). Entirely opposite results were obtained in experimental "noise-exposed birds" trials (involving both noise playback and an approaching human "predator") and during quieter "controls" (involving only an approaching human "predator"), during which all the males responded by flying (Figure 1). This suggests that any flight by males in response to trials was due to an approaching human "predator," not noise.
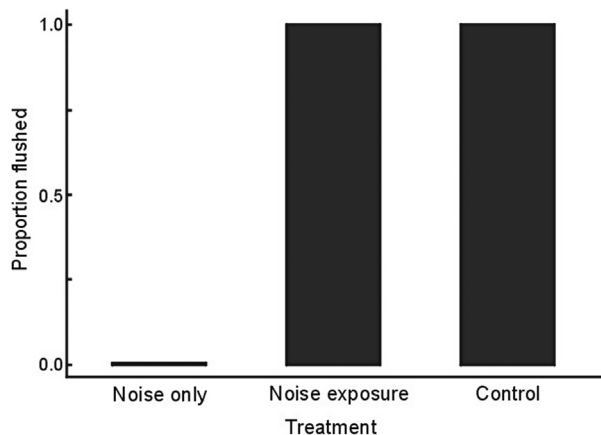

Figure 1. Proportion of male barn swallows *Hirundo rustica* that responded by fleeing to "noise-only controls" trials (involving only noise playback; *n* = 43), "noise-exposed birds" experimental trials (involving both noise playback and an approaching human "predator"; *n* = 43), and "controls" trials (including only an approaching human "predator"; *n* = 43).

Flight initiation distances were greater in the "noise-exposed birds" trials compared to quieter "controls," with averages (mean ± SE) of 5.2 ± 0.2 m (*n* = 43) and 4.0 ± 0.2 m (*n* = 43), respectively. FIDs and starting distances are shown graphically as a box plot in Figure 2A. Model averaging revealed that exposure to noise was a key predictive variable (Table 1), with Φ FID indices being greater during "noise-exposed birds" trials, as shown by the exclusion of zero from the 95% CI of the estimate for the main factor "Exposure." This means that male barn swallows took flight sooner in the presence of an approaching human "predator" during the noise treatment than during the control (Figure 2B).

Discussion

Our goal was to investigate whether farm tractor noise affects the response to an approaching human "predator" in male barn swallows. We found that the studied birds took flight sooner in the presence of an approaching human "predator" during the noise trials compared to quieter control conditions. Second, we found that the noise stimulus alone did not induce escape in male barn swallows.

The results we obtained contradict the "cognitive distraction" and "masking" hypotheses, which coincidentally predict a slower response to an approaching predator in noise-exposed birds compared to a control group. Instead, the results support the "increased threat" hypothesis, according to which animals are faster to respond to a predator when noise is broadcast during its approach (Hubbard et al. 2015; Meillère et al. 2015; Shannon et al. 2016b; Kelligrew et al. 2021). The faster response to a predator is explained by the higher alertness of animals in the presence of acoustic stimuli that may increase the perceived level of threat, and consequently earlier detection of the intruder (Frid and Dill 2002; Quinn et al. 2006). Flee soon after spotting a predator, unless
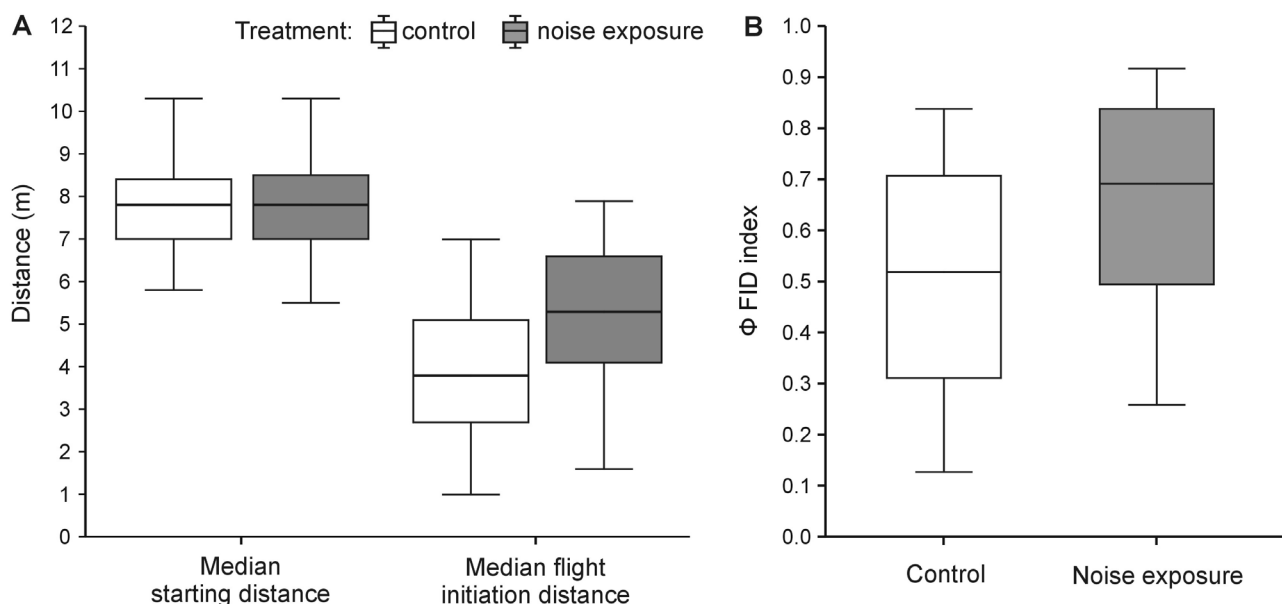

Figure 2. Behavioral response of male barn swallows *Hirundo rustica* to human "predator" approach. White box plots refer to males' response to "controls" trials (*n* = 43), which only included an approaching human "predator." Grey box plots refer to the response of males to "noise-exposed birds" experimental trials (*n* = 43), which involved both noise playback and an approaching human "predator." The horizontal midlines within the boxes represent the median value of (A) the starting distance and flight initiation distance (FID), and (B) the Φ FID index (the higher the Φ FID value, the closer the FID is to the starting distance, indicating earlier escape). Boxes depict the first (Q1) to second quartile (Q3) range of the data, and the whiskers extend 1.5 times beyond the interquartile range (IQR).

Table 1 Model-averaged parameter estimates ± SE and 95% CI for the selected subset of top generalized linear models analyzing the effect of noise exposure (Exposure) on flight initiation distance in male barn swallows *Hirundo rustica* in Poland

Effects	Estimate	SE	95% CI	
Intercept	0.000	0.395	–0.809	0.809
Exposure	**0.360**	**0.052**	**0.255**	**0.466**
Colony	–0.190	0.110	–0.400	0.020
Incubation stage	–0.043	0.044	–0.126	0.041
Exposure * Colony	–0.034	0.031	–0.094	0.025

Bold text indicates the estimate with 95% CI that does not overlap zero.

threat detection is delayed or otherwise compromised by interfering circumstances, coincides with the FEAR hypothesis (Blumstein 2010). The novelty of our work is that we conducted our experiment not in a natural or semi-natural environment, but in a man-made environment with inherent human-induced noise (with which the animals living there are well acquainted) and the constant presence of humans. In earlier field studies, experimentally applied noise was a stimulus new to the environment of the animals studied (e.g., Quinn et al. 2006; Chan et al. 2010a, 2010b; Meillère et al. 2015; Shannon et al. 2016b; Kelligrew et al. 2021; but see Hubbard et al. 2015 and Petrelli et al. 2017).

We found that the noise of agricultural tractors alone does not elicit a fleeing response in male barn swallows (Figure 1). Birds and other animals typically tend to avoid areas where anthropogenic noise has a strong impact, such as the vicinity of main roads or the surroundings of industrial operation areas (Francis et al. 2009; McClure et al. 2013; Mason et al. 2016; Liu et al. 2020). Barn swallows regularly breed on buildings or other man-made structures, in places where the presence of anthropogenic noise and humans is unavoidable, such as farms, under bridges on busy highways or even along busy streets of urban settlements (Turner 2006). It is conceivable that barn swallows quickly learn that the noise generated by agricultural machinery working in the farmyard and the presence of humans is not life-threatening or threatening to their broods, and hence they become tolerant of these human-mediated stressors. Such tolerance has been observed in another species of small songbirds—the white-eyed vireo *Vireo griseus* (Bisson et al. 2009). On the other hand, it has been shown that black-tailed prairie dogs *Cynomys ludovicianus* and tree swallows *Tachycineta bicolor* living in built-up areas can become habituated to the constant presence of humans or moving vehicles, but nevertheless remain sensitive to human-induced noise (Magle and Angeloni 2011; Shannon et al. 2014; Injaian et al. 2018). It has also been shown that the impact of noise stress on physiology in tree swallows can worsen over the course of the breeding season (Injaian et al. 2018). We do not know to what extent the noise of tractors (or other kinds of human-induced noise) causes stress in barn swallows; this issue requires further investigation. We have shown that sound of a tractor alone does not induce an aversive response in male barn swallows from the study population. However, as we have also demonstrated, these males exhibit plasticity in their fleeing response to an approaching human "predator" depending on the presence of the noise of a tractor (Figure 2A,B).

According to the "increased threat" hypothesis, noise is functionally analogous to the threat of a predation, prompting potential prey to increase their vigilance and reactiveness (Frid and Dill 2002; Quinn et al. 2006). Barn swallows from our study population hear the noise of the tractors every day when these vehicles are working in farmyards or driving into stables 2–3 times a day. This begs the question, why do these birds react to approaching humans more quickly in the presence of tractor noise—a sound that is familiar to the birds and should not be associated by them with an increased risk of death or brood loss (see, e.g., Bisson et al. 2009)? The explanation may lie in the methodology of the experiment we performed. We imitated an event in which a tractor drives into the nesting habitat of barn swallows, and immediately afterward we tested how the accompanying noise would affect the swallows' assessment of the risk associated with the approach of a human "predator." The experiment planned in this way corresponds to natural events, when a tractor enters a stable to deliver horse feed or haul away manure and soon leaves. In this situation, the time interval between the start of noise playback and the approach of the human "predator" was a short 5 s. In earlier studies, this time interval was usually longer—for example, 30 s in Kelligrew et al. (2021) or 2 min in Shannon et al. (2016b). Second, in our experiment, we only used an audio stimulus (the sound of a tractor) without a visual stimulus (there was no tractor). Barn swallows usually hear the sound of a tractor at the same time they see the vehicle itself. In our study, the noise occurred, but the tractor did not come—this unusual situation may have caused the males to become more alert (at least initially) and thus react faster to the sight of an approaching human "predator." Future studies could test whether this initially increased vigilance persists in birds after a longer exposure to noise such as the sound of a tractor. Furthermore, we propose to modify the scheme of future noise playback experiments, in which, in addition to the emission of human-induced noise, the visual stimulus (the source of sound) should also be presented, where applicable.

Moving forward, we would now like to consider the cognitive mechanism behind the increased reactivity we observed in the barn swallows in this study. As mentioned above, in line with the widely recognized "increased threat" hypothesis, noise is associated by animals with an increased risk of predation (Frid and Dill 2002; Quinn et al. 2006). However, in the case of noise that has no obvious connotation of "threat" but is loud, repetitive, and familiar to animals, we propose a different explanation—that increased vigilance and reactivity may be a consequence of a sensitization mechanism. According to this mechanism, repeated stimulation can increase the response to a stimulus, especially when the stimulus is moderately strong or aversive (Shettleworth 2010; Blumstein 2016). The sound of a passing tractor is loud and can be sudden, so it can be considered strong and/or aversive. As with the "increased threat" mechanism, increased alertness and hence faster response to an approaching predator in animals would also be expected here. We will call the proposed mechanism the "cognitive sensitization" mechanism. Among the studies to date, this mechanism may have worked where loud and familiar noise was used as the experimental stimulus. An example is the Hubbard et al. (2015) study, where the sound of motorbike engines, known to the birds they studied, was used as an experimental stimulus. In contrast, the "increased threat" mechanism is more likely in studies using novel sounds as experimental stimuli. Examples include the

Quinn et al. (2006) and Kelligrew et al. (2021) studies, which used traffic noise, unfamiliar to the birds studied, or white noise, respectively.

As part of the current study, we cannot resolve which of these 2 mechanisms worked in barn swallows. However, using our study system as an example, we would like to propose future research to distinguish whether the increased reactivity of animals in noise trials is the result of the "increased threat" mechanism or the "cognitive sensitization" mechanism. We expect, as we mentioned above, that our barn swallows may associate the sound of a tractor (auditory stimulus) with the sight of a tractor (visual stimulus). The ability of animals to associate such acoustic and visual stimuli is well known (Shettleworth 2010). A future experiment should include noise alone as an experimental stimulus and careful observations of the behavior of the target animals. If the "cognitive sensitization" mechanism is at work, we would expect the target animal to look preferentially towards the sound source (e.g., the swallows we study should look for a tractor near the loudspeaker). On the other hand, if the "increased threat" mechanism is in operation, focal animals should look around for a suspected "predator." Still referring to the issue of the impact of noise on physiology—the mechanism of "cognitive sensitization" discussed here does not exclude the possibility that noise, which has no connotation of "threat," can be perceived by animals as a stressor (Grunst et al. 2021).

Anthropogenic noise is among the significant sources of human-induced disturbance to wildlife and is becoming a growing concern for conservation biology (Barber et al. 2010; Shannon et al. 2016a; Buxton et al. 2017; Erbe et al. 2022). We have found that male barn swallows flee more quickly in the presence of an approaching human "predator" when the noise of a farm tractor is broadcast during its approach. This means that human-induced noise causes increased alertness and reactivity, rather than distraction, allowing birds to avoid the "predator" more quickly. Noise, therefore, influences the predator assessment process in animals for which these acoustic stimuli are heard daily and are familiar. In this work, we asked how anthropogenic noise affects antipredator behavior in animals. However, it is worth bearing in mind that natural sounds of abiotic origin can also have an analogous effect on behavior.

Ethical standards

The experiment conducted in this study complied with the animal welfare laws of Poland (license no. 231/2001 issued by the Regional Directorate of Environmental Protection in Warsaw).

Conflict of interest

The authors declare that they have no conflict of interest.

Supplementary Material

Supplementary material can be found at https://academic.oup.com/cz.

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