

## Perspective

# Uncovering the full potential of attitude measures in navigating human-wolf coexistence

Svenja Capitain<sup>a,\*</sup>, Claus Lamm<sup>b</sup>, Sarah Marshall-Pescini<sup>a,1</sup>, Friederike Range<sup>a,1</sup>

<sup>a</sup> Domestication Lab, Konrad Lorenz Institute of Ethology, University of Veterinary Medicine Vienna, Veterinärplatz 1, 1210 Vienna, Austria

<sup>b</sup> Department of Cognition, Emotion, and Methods in Psychology, Faculty of Psychology, University of Vienna, Liebiggasse 5, 1010 Vienna, Austria

## ABSTRACT

Attitudes towards wolves are important indicators of what wolf presence means to people and whether they lean towards support or opposition. Over the past 50 years, attitude surveys and interviews have uncovered that the polarisation between social groups is not only driven by tangible impacts. Moreover, uneven distribution of intangible costs fostered feelings of marginalisation, and socio-cultural divides create different perceptions of wolves and their management. Despite these revelations, little emphasis has been placed on the intricate psychological mechanisms underlying attitude polarisation and behavioural implications. This Perspective drafts a framework around the roles of attitude strength, accessibility, and ambivalence in attitude and behaviour formation, and emphasizes the potential role of unconscious, implicit attitudes beyond explicit self-report in how humans perceive and react to wolves. It explores how these factors may explain polarisation, sudden attitude shifts, mismatches between reported attitudes and behaviours, and the unexpected ineffectiveness of some interventions. Under the assumption of this framework, approaches are discussed that could help navigate attitude shifts amid expanding wolf populations and emotional conflicts between groups and species. Though speculative for now, we hope that this bottom-up approach will guide and inspire research to further explore the proposed mechanisms and improve our understanding about how latent attitudes, ambivalence, and experiences may shape attitudes towards wolves. Rather than advocating for nationwide shifts towards positive views of wolves, we stress the importance of recognizing the full spectrum of attitudes, contexts, and social group settings in managing conflict sustainably, particularly considering expanding and increasingly urbanized wolf populations.

## 1. Introduction

Once widely distributed, wolf populations were hunted close to extinction in many parts of Europe and North America in the past centuries (Linnell et al., 2002; Musiani and Paquet, 2004). With the modification from pest to protected species, they have been steadily returning to their former ranges, with European wolf number increasing by over 40 % in the last decade alone (Blanco and Sundseth, 2023; Boitani et al., 2015; Boitani et al., 2022). This development exemplifies how the distribution of wildlife, and large charismatic species in particular, is often shaped by human perception and behaviour, in some cases more so than ecological factors (Behr et al., 2017; Cimatti et al., 2021; Mech, 2017). Conservation's initial focus on species' ecology and habitat management has hence been joined by the discipline of human dimensions of wildlife, to examine how social, political, and cultural factors influence humans' interaction with the environment (Bath, 1998; Bennett et al., 2017b; Bennett et al., 2017a). Since clashes between behaviour and needs of wildlife and people are inevitable on shared land, the goal of conservation is to foster coexistence by reducing human-wildlife conflicts

(Conover, 2001; though see Peterson et al., 2010 for alternative terms) to a sustainable level for both sides (Carter and Linnell, 2016; IUCN, 2023).

The study of human attitudes has become a key approach in this field (Vaske et al., 2006). Attitudes are defined as an individual's favourable or unfavourable evaluation of an attitude object (here: a species) and is thus expected to precede supportive or aversive behaviour towards that species (Ajzen and Fishbein, 1977). Studying attitudes towards wolves has likewise become a prominent approach to gauge what the presence of wolves means for people, how they cope with it, and how it may reflect future behaviours relevant for coexistence such as voting (Niemic et al., 2022), compliance with regulations, or illegal hunting (Treves and Bruskotter, 2014; Treves et al., 2013).

While the return of wolves was initially facilitated by pro-wolf policies, their reappearance in the human landscape has provoked marked negative reactions and polarised attitudes in people (Breitenmoser, 1998; Drenthen, 2015; Dressel et al., 2015; Mech, 2017; Williams et al., 2002), including backlash against conservation measures (Madden and McQuinn, 2014), contributions to increased far-right voting (Clemm von

\* Corresponding author.

E-mail addresses: [svenja.capitain@vetmeduni.ac.at](mailto:svenja.capitain@vetmeduni.ac.at) (S. Capitain), [claus.lamm@univie.at](mailto:claus.lamm@univie.at) (C. Lamm), [sarah.marshall@vetmeduni.ac.at](mailto:sarah.marshall@vetmeduni.ac.at) (S. Marshall-Pescini), [friederike.range@vetmeduni.ac.at](mailto:friederike.range@vetmeduni.ac.at) (F. Range).

<sup>1</sup> Shared last authorship.

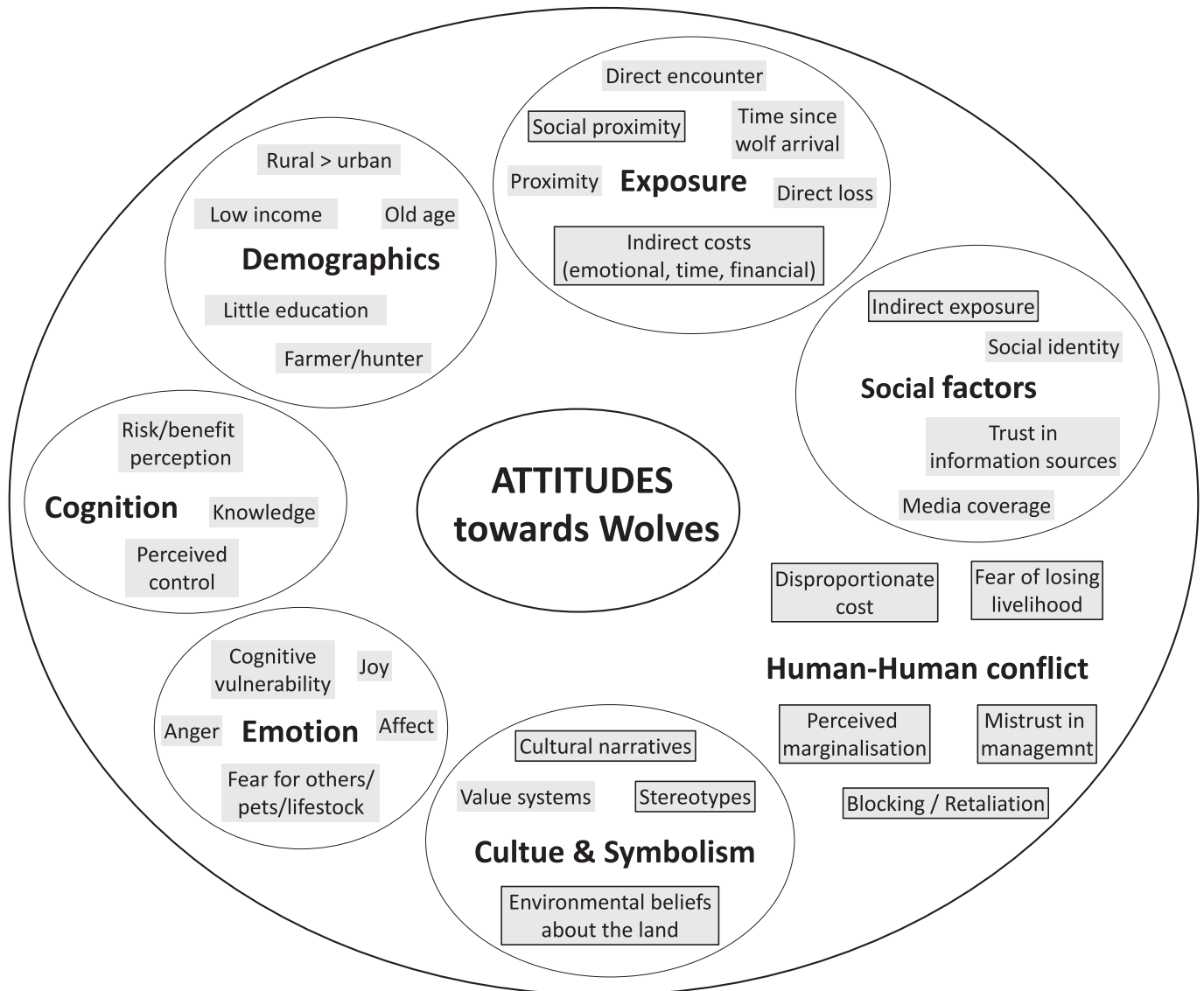
Hohenberg and Hager, 2022), and personal attacks between pro-wolf activists and wolf sceptics (Larsson et al., 2022). Since large-scale studies suggest that wolves have a negligible impact on the national farming output (Linnell and Cretois, 2018), human-dominated ecosystems (Kuijper et al., 2024), and human safety (Linnell et al., 2002; Linnell et al., 2021), these heavily polarised attitudes in parts of the population have been described as seemingly enigmatic, disproportional, or even irrational (as cited by Jürgens and Hackett, 2017; Madden and McQuinn, 2014; Zimmermann et al., 2020). Regardless, these polarisations complicate human-wolf coexistence, especially as attitudes shift with increasing wolf proximity (Ericsson and Heberlein, 2003; Zimmermann et al., 2001), which is exemplified by the controversy around the EU member states' recent vote to downgrade wolf protection status (Ordiz et al., 2024).

To support sustainable human-wolf coexistence, this Perspective explores the mechanisms underlying attitude formation to better understand polarisation, attitude shifts, and seemingly enigmatic reactions in the wolf context. We focus mainly on attitudes, as they present a mirror for what wolf presence means for people (Lehnen et al., 2022; Treves, 2012), and may play a central role in how people behave in the

human-wolf context (Ajzen and Fishbein, 1977; Ajzen et al., 2018; Vaske et al., 2021). We start by shortly delineating what current wolf-attitude approaches have revealed so far to learn where they fall short and where more investigation is needed. From there, we integrate isolated psychological attitude constructs into a more holistic, sociopsychological framework that explores how different attitudes might emerge, which psycho- and sociological factors modulate them, and how these translate into behaviour. Finally, we consider the possible implications these constructs might have for current and future dynamics on sustainable coexistence and propose how they could be measured and applied.

## 2. Attitudes towards wolves: what current study approaches have told us so far

In the past two decades alone, hundreds of studies have identified factors linked to favourable or unfavourable attitudes towards wolves (e.g., Barmoen et al., 2024; Dressel et al., 2015) (Fig. 1, for a detailed summary of each factor see Supplement A). These studies can be roughly divided into two approaches: quantitative surveys and qualitative interviews.



**Fig. 1.** Common factors identified as correlates with attitudes towards wolves in quantitative and qualitative attitude studies. Factors mainly added through qualitative interview studies are framed in black. The socio-spatio-cultural divide driving human-human conflict about wolves reflects in many of these factors. Details and references for each factor can be found in Supplement A.

## 2.1. Quantitative measures

Quantitative surveys use questions with predetermined answering options (e.g., response scales) to assess attitudes in often (though not always) large, representative samples. Thereby, attitude patterns across (study) populations and their correlation with participant characteristics can be evaluated. Although surveys vary in the questions they use to measure attitudes, they reveal that in the majority of cases the attitudes towards wolves are polarised (for detailed reviews see [Barmoen et al., 2024](#); [Dressel et al., 2015](#); [Williams et al., 2002](#)). Negative attitudes are consistently found in rural populations, in populations living in wolf habitats, in farmers and/or hunters, and in people who have experienced damages by wolves ([Arbieu et al., 2019](#); [Barmoen et al., 2024](#); [Dressel et al., 2015](#); [Stauder et al., 2020](#); [Suryawanshi et al., 2014](#)). Such findings led to the assumption that implementing financial support schemes for protection and damages would improve attitudes ([Johansson et al., 2016a](#); [Treves and Bruskotter, 2014](#)). However, while compensation schemes are seen as imperative by all stakeholders, negative attitudes frequently prevail despite their implementation ([Bisi et al., 2007](#); [Majić and Bath, 2010](#); [Naughton-Treves et al., 2003](#); [Pettersson et al., 2021](#); [Røskaft et al., 2007](#); [Treves and Bruskotter, 2014](#)). Evidence that more knowledge ([Glikman et al., 2012](#); [Gosling et al., 2019](#); [Randler et al., 2020](#)) and a higher perceived benefit-risk ratio for wolves ([Bruskotter and Wilson, 2014](#); [Marino et al., 2021](#)) correlated with positive attitudes provided grounds for the extensive use of information campaigns as a tool to shift attitudes and reduce conflict ([Johansson et al., 2016a](#); [Pooley, and o'Connor, M., 2000](#)). But again, while these form the backbone of most public conservation tools, their application as an intervention to change attitudes towards predators frequently fell short of their expected effects ([Ericsson and Heberlein, 2003](#); [Meadow et al., 2005](#); [Morton et al., 2024](#)), and in some cases they have even been reported to lead to increasing negative attitudes ([Johansson et al., 2016a](#)). Meanwhile, affect and emotion-based factors emerged as more influential on attitudes than knowledge, risk-perception, or monetary damages by wolves ([Bruskotter and Wilson, 2014](#); [Glikman et al., 2012](#); [Slagle et al., 2012](#); [Vaske et al., 2021](#)), with anger and joy predicting attitudes better than fear ([Arbieu et al., 2024](#)).

This illustrates how quantitative surveys can be excellent tools to identify *what* the correlative patterns are in large populations, but their reliance on correlation rather than causality may be misleading and overlook more complex attitude drivers. Furthermore, simplifying the measurements to a comparison of group means on a unidimensional scale (favourable to unfavourable) ignores the variability and nuance necessary to understand shifts and reactions ([Arbieu et al., 2023](#); [Van Harreveld et al., 2009](#)). And finally, their wolf-focus neglects the social conflicts that might be at the core of wolf-related conflicts.

## 2.2. Qualitative measures

In qualitative approaches, participants share their reasoning and concerns in (semi-)structured interviews, which are then mapped out to associate attitude and circumstances. In relation to negative attitudes and rural living, these interviews revealed that the perceived damages of (imminent) wolf presence extend beyond predation and fear for oneself ([Larsson et al., 2022](#); [Pettersson et al., 2021](#); [Sjölander-Lindqvist et al., 2021](#)). In a “landscape of stress” and emotional burden with cognitive, physiological, and behavioural implications ([Flykt et al., 2022](#)), such intangible costs include a constant fear of losing one’s beloved animals, and having to change farming methods, lifestyles, and leisure activities ([Crombag, 2022](#); [Kojola et al., 2018](#); [Larsson et al., 2022](#)). Locals worried that these mostly uncompensated costs in time, effort, and money might accelerate farmland abandonment, the loss of the rural way of life, and rural identity ([Donfrancesco, 2024](#); [Pettersson et al., 2021](#); [Sjölander-Lindqvist, 2008](#)).

Spurred by the frustration of unfairly distributed costs of wolf-presence between urban and rural populations, locals report feeling

marginalised by urban decision makers with their needs coming second to wolves ([Almarcha et al., 2022](#); [Jordan et al., 2020](#)). With increasing anger and distrust in management, wolf-attitudes become closely tied to social proximity and group identity. The resulting reliance on local sources and negativity bias ([Behr et al., 2017](#); [Mech, 2017](#); [Sjölander-Lindqvist, 2008](#); [Sjölander-Lindqvist et al., 2020](#); [Skogen and Thrane, 2007](#)) can extend the perceived threat of the wolf to the entire community rather than only the affected individuals ([Suryawanshi et al., 2014](#)). The divergence of beliefs and perceptions of wolves between various stakeholder groups are further accelerated by group-inherent value systems, philosophies about wilderness vs. man, cultural symbolisms, and prejudices ([Boitani, 1995](#); [Caluori and Hunziker, 2001](#); [Drenthen, 2015](#); [Fritts et al., 2003](#); [Jürgens and Hackett, 2021](#); [Linnell and Alleau, 2016](#)) (for detail see Supplement A). Political alienation, conspiracy theories about reintroduced wolves, decreasing trust in science, and illegal killings are just some of the consequences ([Barmoen et al., 2021](#); [Clemm von Hohenberg and Hager, 2022](#); [Olson et al., 2015](#); [Zscheischler and Friedrich, 2022](#)).

This reflects a central but often neglected driver of human-wildlife conflicts: conflicts commonly ensue not only with the animal but more often between human groups that disagree on how the animal is to be perceived and managed ([Caluori and Hunziker, 2001](#); [IUCN, 2023](#); [Peterson et al., 2010](#); [Redpath et al., 2015](#); [Slagle et al., 2019](#); [Young et al., 2010](#)). Wolf-attitudes diverge along a spatio-cultural divide, shaped by social proximity and identity, direct exposure, and cultural symbolism ([Fig. 1](#)). Various models have described how these human-human conflicts can range from simple disagreements about possible solutions all the way to deeply-rooted contempt between groups that threatens identities ([Glikman et al., 2022](#); [Young et al., 2010](#); [Zimmermann et al., 2020](#)). Attempts to shift attitudes then fall short, as the wolf has come to symbolize much more than just an ecological species and its impact, on either end of the attitude spectrum ([Drenthen, 2015](#); [Meadow et al., 2005](#)).

Qualitative interviews have complemented the quantitative structure and made advances in unravelling *why* the polarisation in attitudes occurs. This facilitated valuable yet resource-intensive tools on the local scale (e.g., Conservation conflict transformation ([Madden and McQuinn, 2014](#)), stakeholder focus groups, empathetic advocacy ([Jordan et al., 2020](#); [Redpath et al., 2013](#))). However, qualitative measures moved beyond wolf attitudes by incorporating values, motivations, and social spheres to understand these tensions. This raised concerns that the assessment of attitudes as a first step to shift attitudes and approximate behaviour would be of limited use in applied conservation ([IUCN, 2023](#); [Zimmermann et al., 2020](#)). Moreover, qualitative studies and the abovementioned tools are resource-intensive and limited by small sample sizes. While methodological triangulation, i.e., combining different methods like qualitative and quantitative approaches in the same population, can somewhat alleviate this restriction ([Bennett et al., 2017a](#); [Thurmond, 2001](#)), they are also limited to subjective interpretations of what interviewees are willing and able to share. Moreover, [Cracco et al. \(2024\)](#) recently discovered that participants staying silent on the wolf issue due to perceived taboos, conflicts, or fatigue might be a considerable issue in research and public discourse. Without knowing how people actually perceive the wolf, inference about future attitude dynamics and their connection to behaviour – which attitudes are supposed to be a proxy for – remains limited, especially on a larger scale.

## 2.3. Moving beyond the current approaches

A significant issue raised by both quantitative and qualitative approaches is the tendency for wolf policies and research to come from a wolf-protectionism standpoint ([Mech, 2012](#); [Pettersson et al., 2023](#)). Consequently, attitude research has often focussed on the causes of negative attitudes to shift the wolf into a positive evaluation for easier implementation of conservation measures ([Bruskotter and Wilson, 2014](#);

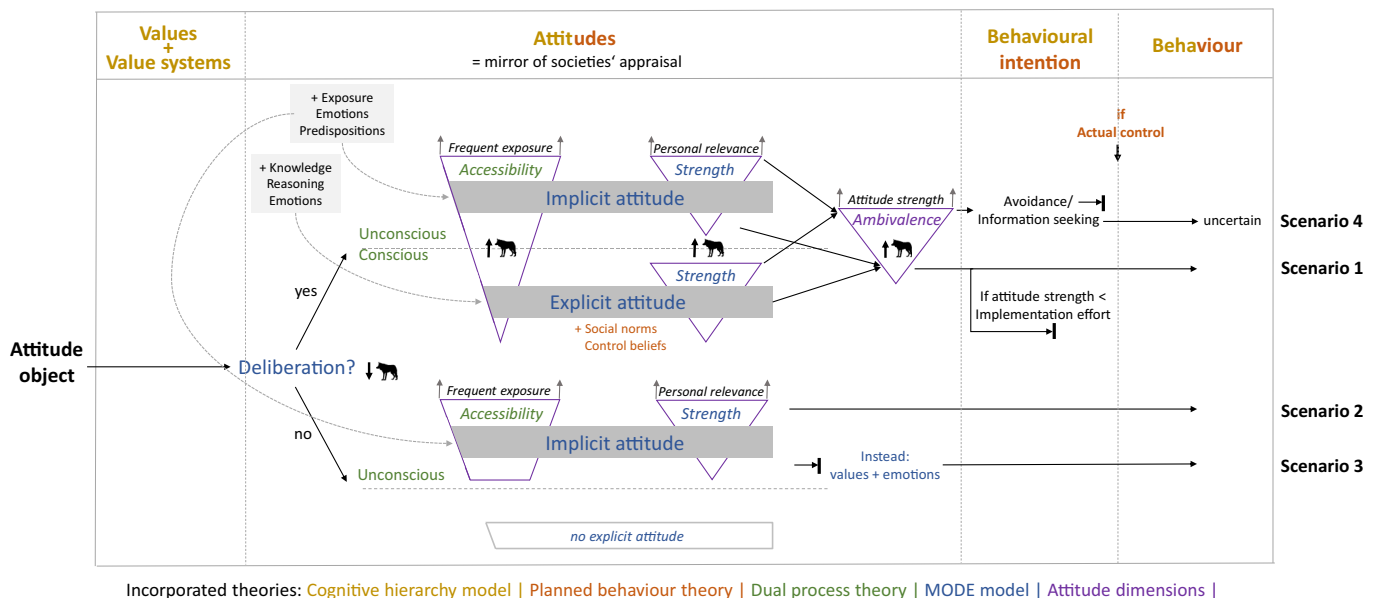
Johansson et al., 2016a; Pooley et al., 2017; Treves and Bruskotter, 2014). This approach frequently backfired, creating a backlash against targeted interventions (Carter et al., 2020; Crombag, 2022; Johansson et al., 2016a; Krangle and Skogen, 2011). Overly pro-wolf attitudes can likewise lack compromise and deliberation needed to manage problematic wolves. Scholars are increasingly recognizing that we should aim at using attitude measures to gauge the situation and then focus on resolving the cause of the conflict, to allow *both* sides to ultimately move towards a (perhaps more neutral) stance built on the wolf as ecological species rather than its symbolism (Drenthen, 2015; Jürgens et al., 2023; Majić and Bath, 2010; Pettersson et al., 2023). Importantly, this movement needs to be achieved through inclusive conflict resolution rather than targeted attitude change or defeat (as reported by locals in some study areas that were classified as coexisting well (Opdam, 2022; Pettersson et al., 2021)).

To move towards such approaches, it is essential to understand where people are coming from, how they perceive the situation, and why they react the way they do. Exploring concepts like values, motivations, and norms (for more detailed ideas see IUCN (2023) Human-Wildlife conflict guidelines) will be essential, but we argue that attitude measures have significant, evidence-based potential that has yet to be fully taken advantage of. To understand current polarisation, attitude shifts, and attitude-behaviour predictability – and expand that to a population-wide scale – we need to acknowledge the underlying psychological mechanisms in the human-wolf conflict from the bottom-up (Barmoen et al., 2024; Lehnen et al., 2022; Pettersson et al., 2023). Hence, we propose that the next step should focus on *how* polarised attitudes emerge and operate on an individual level, how circumstantial factors play into it, how we can measure attitudes appropriately given these circumstances, and how they connect to behaviour. Against this background, sophisticated large- and small-scale approaches can be developed to navigate polarisation and conflict towards coexistence and

attitude shifts during the return of the wolf (Pettersson et al., 2023). In the following sections, we draft a framework by bringing together isolated, established attitude theories to enable understanding of the underlying mechanisms of current and future conflicts, within and between species, on all sides of the attitude spectrum. To aid this process, we subsequently apply these highly interlinked concepts to the human-wolf context by describing in more detail how the interplay between these processes can lead to (mis-)alignment between reported attitudes and behaviour, as well as rapid attitude shifts.

### 3. Integrating the hidden potential in attitude theory

Starting with where attitudes initially come from, the *cognitive hierarchy model* suggests that they are based on the person’s values, defined as one’s generally desired modes of conduct and qualities for life, and their resulting core beliefs about the world (i.e., value orientations). This process could be described as follows (Fig. 2, bold top): Values are the filter through which the (behaviour towards an) object (in our case: wolves) is cognitively (belief-based) and affectively (feelings-based) evaluated as more or less favourable or unfavourable – i.e., the attitude is formed (Ajzen et al., 2018; Eagly and Chaiken, 1993). The initially formed attitude solidifies through further encounters with that attitude object over time. Following the *theory of planned behaviour* (Ajzen, 1991; Ajzen and Fishbein, 2000), the integration of this attitude with beliefs about social norms and one’s control over the situation then generates a behavioural intention – what one would like to do towards that object (Ajzen, 1991; Vaske and Manfredro, 2012). However, actual behaviour only follows if control over that action is available. These are the theories frequently used as base assumptions to study human attitudes towards wolves. The fact that value systems, social identity (as reflection of social norms), and perceived control have emerged as strong correlates for wolf-attitudes (Bruskotter and Wilson, 2014; Carter et al., 2020;



**Fig. 2.** A combined framework depicting how the different psychological attitude theories (namely the cognitive hierarchy model (Vaske and Manfredro, 2012) and theory of planned behaviour (Ajzen, 1991), attitude dimensions (Krosnick and Petty, 1995), and the MODE model (Fazio, 1990) and dual process theory (Smith and DeCoster, 2000)) could be integrated for a more nuanced understanding of how attitudes (e.g., towards wolves, a specific behaviour towards wolves, other stakeholders) could be formed, shift, and translate to behaviour in the human-wolf context. The colour-coding of how the different sub-parts relate to the different models (legend below) is a rough depiction as they overlap on different factors. The flowchart depicts how explicit (conscious) and implicit (unconscious) attitudes relate to each other depending on whether deliberation occurs or not, what factors they are based on beyond values (grey box), and what different attitude-behaviour scenarios this might result in depending on how the arising attitudes’ accessibility, strength, and ambiguity relate to each other. The extent of these attitude dimensions is represented through the triangular shape, with a high extent of accessibility/strength/ambiguity presented as the wide part of the triangle, and a low extent as the narrow end of the triangle. What their extent depends on is displayed with directional arrows right above each triangle. The arrow next to the wolf symbols indicate how the variables change with increasing wolf presence, assuming more direct or indirect exposure (influencing accessibility), more relevance to one’s life (influencing strength and hence ambiguity), and demanding/emotional/stressful (influencing deliberation) interactions.

Figari and Skogen, 2011; Hamilton et al., 2020; Manfredi and Manfredi, 2008), underlines the validity of these processes in the wolf context.

However, this conceptualisation ignores the fact that different evaluations and hence different attitudes towards the attitude-object can coexist within the same person. Repeated encounters mean that each time we interact with the attitude object anew, we draw from a blend of different memories, information, and interactions tied to that attitude object (Ajzen et al., 2018; Conner and Sparks, 2002; Krosnick and Petty, 1995). For example, seeing a wolf play with her pups in a documentary might generate a positive evaluation based on familial values, while the same value system generates a negative evaluation of wolves when they prey on your cousin's sheep. Which attitude a person holds, reports, or acts upon in each moment is therefore highly context dependent and necessitates a more nuanced and dynamic approach.

Decades of attitude research support a *dual processing theory*, suggesting two distinct pathways for forming and expressing attitudes: a fast, automatic system and a slow, deliberate system (Smith and DeCoster, 2000). *Explicit attitudes*, the latter of the two systems, rely on logical reasoning, social expectations, and accessible feelings (Gawronski and Bodenhausen, 2006). Since they are conscious and verbally accessible, they have been predominantly studied in this field. Contrarily, *implicit attitudes*, resulting from the fast and automatic system, are defined as associative reactions, formed through innate predispositions or associative learning with emotional experiences or exposure to repeated information (Gawronski and Bodenhausen, 2006; Wilson et al., 2000). As inconspicuous, mostly unconscious biases in behaviour and physiological reactions, they are more difficult to assess, and have hence been largely ignored in the human-wolf context (Manfredi and Manfredi, 2008). A person can hold differing implicit and explicit attitudes towards the same attitude object, for example by consciously rejecting certain beliefs that remain as unconscious biases (e.g., stereotypes), adherence to social or relational norms, or habitual responses (Ajzen et al., 2018; Gawronski and Bodenhausen, 2006; Lehnen et al., 2022; Nosek et al., 2007; Slagle et al., 2019). For example, one's endorsement of egalitarian interactions while retaining implicit preferences for one social group over another (Ajzen et al., 2018).

Which process takes over any given moment depends on internal and external factors, as well as the three attitude dimensions, commonly conceptualised as attitude accessibility, strength, and ambivalence (Krosnick et al., 2005; Krosnick and Petty, 1995): The *MODE model* ('motivation and opportunity as determinants'-model) posits that, while implicit attitudes arise automatically, conscious deliberation is necessary to access an explicit attitude (Fazio et al., 1982; Fazio et al., 1995). Whether this conscious deliberation takes place relies on a person's motivation and cognitive ability to do so in the moment (e.g., alert vs. tired, level-headed vs. emotional, safe vs. threatened) (Fazio et al., 1982; Fazio et al., 1995). This is in part due to a faster accessibility of implicit attitudes. *Attitude accessibility* describes how quickly an evaluation is retrieved from memory, which depends on how frequently that association has been made (Krosnick and Petty, 1995). While easily accessed attitudes can quickly influence reactions, it does not mean that this attitude overpowers others. *Attitude strength* describes to how durable (i. e., resistant to change) and behaviourally influential an attitude is (Krosnick and Petty, 1995). Importantly, strength does not refer to how close an attitude is to the extremes of an evaluation scale, but rather how personally relevant it is (e.g. personal experience, deeply held values, emotional significance). Consequently, strong attitudes are more likely to impact behaviour than weak ones if both are accessed in the moment (Fazio et al., 1982; Fazio et al., 1995; Krosnick and Petty, 1995). Conversely, someone with moderate dispositions is prone to 'literal inconsistencies', where they perform the easy behaviour (e.g., expressing an intention to act) but fail to follow through if the behaviour is effortful (Campbell, 1963).

This means that even though implicit attitudes tend to arise first and guide behaviour by default, they can be overridden by deliberately

(explicitly) recalled, stronger attitudes (Ajzen et al., 2018; Gawronski and Bodenhausen, 2006; Wilson et al., 2000). If the motivation and ability to deliberate are given, the process follows the *theory of planned behaviour*: the attitude object is deliberately evaluated based on beliefs about societal norms and one's control about the behaviour, resulting in an attitude that can be vocally accessed and predicts (current) behavioural intentions and, if implementable, behaviour (Fig. 2, Scenario 1). The implicit attitude still coexists in this scenario, but is generally suppressed in its influence on behaviour by the explicit deliberation. If deliberation does not occur, the most accessible attitude unconsciously (implicitly) biases the information processing and behaviour formation without any deliberate evaluation, and under exclusion of social and control beliefs (Fazio et al., 1982; Fazio et al., 1995) (Fig. 2, Scenario 2). Notably, this automatic overtaking is only expected to occur if the relevant implicit attitude is strong enough, based on the importance for one's life or direct exposure (Fazio et al., 1982). Accordingly, dissociations between reported intentions and actual behaviour are more likely when implicit and explicit attitudes towards that attitude object are opposed, and motivation and cognitive ability are low. If an attitude is weak, associated with low-emotion or second-hand information, and cannot be accessed deliberately, it is unlikely to activate automatically, let alone result in behaviour (Fig. 2, Scenario 3). In such cases, undeliberate behaviour is expected to be influenced by current emotions and values (Fazio et al., 1982; Fazio et al., 1995; Vaske and Manfredi, 2012). Finally, if implicit and explicit attitudes of similar strength clash in a person, attitude ambivalence may arise (Conner and Sparks, 2002; Krosnick and Petty, 1995) (Fig. 2, Scenario 4). *Attitude ambivalence* occurs when conflicting evaluations of similar strength are retrieved to form an attitude, creating discomfort and uncertainty in behaviour (Conner and Sparks, 2002; Krosnick and Petty, 1995; Van Harreveld et al., 2009). If possible, individuals may procrastinate or avoid such situations. If that is not possible, ambivalent individuals are likely to engage in information seeking and systematic processing, either in a biased (e.g., conforming with the majority) or, if the situation is particularly sensitive, unbiased (i.e., seeking outside information) manner which then shifts the attitude and guides the resulting behaviour (Van Harreveld et al., 2009).

To better understand these scenarios, consider two concrete examples in the human-wolf context. A teenager in central Europe, experiencing Scenario 1: Growing up with fairytales of villainous wolves created a frequently reinforced aversion to wolves that might be (implicitly) immediate but weak, lacking personal relevance as an urban citizen. During an excursion abroad, they personally witness wolves socializing heart-warmingly, creating a strong, positive emotional experience. When asked later to support wolf conservation, the initially arising, unconscious attitude is still adverse due to its frequent reinforcement. Given the chance to deliberate on the topic, however, they recall the recent positive, highly emotional, personal encounter. Reasoning how amicable the wolves were, outweighs the weak negative association in that moment, leading them to endorse and, if given the chance, act on supportive conservation actions (Scenario 1). If the negative association had been stronger (e.g., hearing frightening reports from family members), they might feel conflicted, reacting either way or seeking more information to resolve their ambivalence (Scenario 4). If the personal positive encounter had not occurred, the weak implicit negativity might not have been strong enough to translate into action, leaving their reaction subject to current emotions (Scenario 3).

As a different example, consider a parent living in a newly recolonized wolf habitat, experiencing Scenario 2. As a committed conservationist, they spent their life consciously advocating for wolves as harmless, majestic, and vital components of the ecosystem, drawing from their ecological knowledge and ecocentric beliefs (Scenario 1). One day, they witness wolves killing the neighbour's dog. Though they still consciously support wolf conservation, their implicit attitudes – shaped by the personal, emotional experience – shift towards fear and frustration. Now, when they hear wolves howl in the forest, they may

experience a negative automatic response, causing them to grab their children and flee the forest immediately (Scenario 2). Even though they may consciously maintain their explicit belief in wolf protection, this stress- and emotion-filled personal encounter and increasing exposure to negative laments about the wolf from their neighbour may strengthen their negative implicit attitude, creating ambivalence in future discussions about wolves (Scenario 4).

Understanding how strongly held (and hence unlikely to change) an attitude is across a population, under which circumstances attitudes are more or less accessible, and how individuals cope with ambivalence around the wolf topic would hence be prime target mechanisms to explore. Moreover, depending on the relation of attitude strength, accessibility, and ambivalence, implicit attitudes may play a key role in shaping people's current and future reactions in the human-wolf context.

#### 4. Attitude theory in the larger human-(human-)wolf context

While the two previous examples illustrated how this nuanced framework could help us understand people's behaviour in specific situations, these concepts could also be applied to interpret the attitude-behaviour dynamics and attitude shifts in the human-wolf context overall. Though there will unarguably be variation among individuals in real populations (Heberlein and Ericsson, 2005; Sponarski et al., 2013), the following descriptions depict what processes might be transpiring in a representative individual of the respective attitude groups.

In recently recolonized wolf habitats, wolf presence is salient. It is experienced as a concrete danger to the values (protecting one's animals, managing the land), lifestyle and identity of many locals, directly or through imposed regulations (Krange and Skogen, 2011; Sjölander-Lindqvist, 2008; Slagle et al., 2019). The frequent negative exposure (Karlsson and Sjöström, 2007), direct (e.g., wolf encounters) and indirect (e.g., media, word of mouth), creates repeated associations that are readily accessible. Particularly direct encounters may be highly emotional, forming strong, rigid associations (Krosnick and Petty, 1995). While wolf encounters can also prompt positive emotions, this likelihood seems to decline for people living closer to wolf habitats (Arbieu et al., 2020; Arbieu et al., 2024). Efforts to change attitudes with information campaigns may hence fall short because they fail to create stronger or more accessible associations than the currently held ones. They can also create more ambivalence and hence unwillingness to participate (Conner and Sparks, 2002; Van Harreveld et al., 2009). Likewise, deliberate positive attitudes and explicitly reported cooperative intentions (Scenario 1) might be outpaced by implicit negativity when the ability to deliberate declines amidst increasing emotions and stress (Scenario 2). The capacity to engage in deliberate decisions and discourse, especially with opposing stakeholders, diminishes (Fazio et al., 1995). Social divides between groups increase as wolf- and human-related stereotypes and interpretations of the wolf in one's home area are implicitly reinforced through orientation to one's social circle (Jürgens et al., 2023; Jürgens and Hackett, 2017; Krange and Skogen, 2011). Conflicting information bubbles further create discomfort and distance, decreasing trust in management and science while increasing reliance on local sources (Barmoen et al., 2021; Caluori and Hunziker, 2001).

In contrast, for the average urban population, wolves resemble distant, symbolic entities with little importance in daily life. Indeed, abstract rather than concrete thoughts of wolves tend to be associated with positive attitudes (Slagle et al., 2019). Attitudes are presumably weakly held, with little ambivalence. Direct experience, if at all, is likely of positive valence during vacations, zoo visits or guided tours (Arbieu et al., 2020). Negative attitudes might stem from cultural stereotypes (depending on the region) (Jürgens and Hackett, 2017) or repeated biased media exposure (Nanni et al., 2020), but their lack of salience keeps them too weak to influence behaviour much (Scenario 3). And even if moderately strong, they are likely overridden by more pro-wolf,

ecocentric value-based attitudes that are common in urban spaces (Barmoen et al., 2024; Skogen and Thrane, 2007) (Scenario 1). Moreover, if the latter is built on a heavily involved pro-wolf identity and social circle, this pro-wolf attitude might be rather strong, easily accessible, and hence resistant to opposed knowledge or perceptions of the wolf (Petty and Cacioppo, 1986).

However, studies consistently report that when wolves return to an area where they had been previously extinct, positive attitudes tend to decline (Barmoen et al., 2024; Dressel et al., 2015; Franchini et al., 2021; Gosling et al., 2019; Johansson et al., 2012; Majič Skrbinšek and Skrbinšek, 2018; Williams et al., 2002), with only few studies reporting improvement over time (e.g., Majič and Bath, 2010; Zimmermann et al., 2001). This reaction has puzzled management and conservationists alike, given the reportedly positive attitudes towards wolves in the general public (reviewed in Barmoen et al., 2024; Williams et al., 2002) and wolves' supposedly limited direct impact on human populations (Linnell et al., 2021; Linnell and Cretois, 2018). With increasing proximity to wolves, all three attitude dimensions change (Fig. 2): With a reliance on local sources and quickly travelling negativity bias (Sjölander-Lindqvist et al., 2015; Skogen and Thrane, 2007), people around (prospective) wolf habitats become more frequently exposed to negative, increasingly accessible associations. Because weaker attitudes are more vulnerable to external information and emotions (Fazio et al., 1982), repeated exposure could quickly shift underlying associations in a negative direction. Attitude strength and salience also increase, as wolves turn from an abstract into a concrete entity that has real implications on one's own life or community (Slagle et al., 2019), even if no direct experience has occurred yet (e.g., fear for one's animals, worry about additional workload).

This is where pre-existing, latent implicit attitudes might play a particularly decisive role. Implicit attitudes are more likely to drive behaviour when they are strong, and when there is little energy or motivation for deliberate consideration (Fazio et al., 1982) (Scenario 2). Likewise, implicit attitudes become more accessible and stronger with repeated association and increasing personal relevance (Fazio et al., 1982). As wolf presence becomes more salient, latent pre-existing negative attitudes could surface, both through direct and indirect exposure. Different origins for such latent implicit negativity have been proposed. Jürgens and Hackett (2017) suggested that while cultural presentations of the wolf are region-dependent, its representation as the dangerous, cunning wolf in cultural stereotypes and present-day fiction may contribute to an underlying negative bias towards wolves in many Western societies (see cultural stereotypes in Supplement A; Boitani, 1995; Fritts et al., 2003). Additionally, Öhman and Mineka (2001) proposed that humans may have an evolutionary predisposition to avoid predators, similarly to our quickly learned fear of spiders and snakes. While these have been speculations so far, Flykt et al.'s (2013) finding that people in a Swedish sample showed implicit negative biases towards wolves regardless of explicitly reported fear of carnivores, underlines this point. However, to our knowledge, this is the only study comparing general explicit and implicit attitudes to date, so more research on this topic is inevitably necessary to ascertain their role.

Attitude strength and ambivalence also appear central in these attitude shifts but have received little attention in this field. It has been proposed that the wider public holds weaker attitudes compared to the impacted communities and is hence more likely to change (Ericsson and Heberlein, 2003; Eriksson et al., 2015; Heberlein and Ericsson, 2008; Manfredo and Manfredo, 2008). While this might be true considering second-hand information and low salience, studies often inferred weak attitudes from measuring prevalent neutral attitudes in quantitatively surveyed populations (Barmoen et al., 2024; Ericsson and Heberlein, 2003; Treves et al., 2013). Problematically, this might be an artifact of the flattened attitude measures: A checked midpoint on a bipolar scale leaves no way to differentiate neutrality (i.e. indifference) from ambivalence (holding two strong, differing, context dependent attitudes at the same time) (Van Harreveld et al., 2009). This inference might risk

misguiding management decisions during attitude shifts. True neutrality does not necessarily mean that an attitude is weak and easy to shift (Krosnick and Petty, 1995; Van Harreveld et al., 2009). Likewise, a person with two strong, opposing attitudes might change their behaviour rapidly in a context that alligns with one of these strong associations, but may resist outside initiatives to change attitudes (Petty and Cacioppo, 1986). This is particularly pertinent with coexisting experience-based, negative implicit attitudes and social-circle based positive explicit attitudes (Fazio et al., 1982). Since ambivalence, rather than neutrality, may explain rapid shifts in reactions, it is crucial to measure these differences on an individual level to understand if, why, and how change happens.

## 5. The way forward

Bringing together attitude models and past evidence, these are only a few possible implications for current and future dynamics, but they emphasize the potential importance of those measures in emotional, conflict-prone human-wolf contexts. In light of these mechanisms and the intangible costs, the “irrationality” of people’s reactions to the returning wolf becomes a lot more logical. We stress that the mechanisms and potential tools described in this Perspective paper are speculative in the wolf-context due to the paucity of research. However, considering that the sub-parts of the presented framework are evidence-based in other fields, we hope that these ideas can guide the exploration of evidence in the human-wolf context – to inspire researchers to dig deeper into attitude measures, test the assumptions of this framework to verify or falsify its sub-aspects, and focus on underlying causes and mechanisms rather than the desire to change attitudes. To push this agenda further, we shortly propose several methods and applications for each key point that support the investigation into these scenarios and potential application tools. Wherever possible, we highlight studies that have applied these concepts in the wolf or wildlife context or sketch out suggestions how this could be done.

### 5.1. Implicit attitudes

A crucial step towards understanding the range of human-wolf attitudes involves measuring implicit in addition to explicit attitudes. While often criticized for predicting behaviour no better or even worse than explicit attitudes (e.g., intended wildlife donations: Echeverri et al., 2017), previous studies emphasize that implicit attitudes come into effect particularly during reactive situations, when motivation and deliberative ability are drained, or when the stereotype is deeply rooted and unconsidered (reviewed in Ajzen et al., 2018) (Scenario 2). Whether this is the case in the wolf-context is so far underexplored, but might prove considerable where these conditions apply, such as retaliatory action, pressed decisions, stress reactions (e.g., the parent in Scenario 2), or social confrontations. Implicit attitudes cannot be accessed through self-report, but established psychological assessment tools exist. Implicit Association Tests (IATs) are perhaps the best-known method, wherein implicit bias is exemplified as the speed of correlating attitude objects with positive or negative concepts (Greenwald et al., 1998). It was this method Flykt et al. (2013) employed to uncover marked implicit negative associations with wolves. Recent technological advances allow IATs and similar methods (Krosnick et al., 2005; Petty et al., 2008) to be distributed online (e.g., Project Implicit: Ratliff and Smith, 2021), reaching larger, representative audiences. In face-to-face studies, (psycho-)physiology and behavioural measures can investigate neural activation, eye-movement, heart rate changes, or facial behaviour when presented with wolf stimuli (Flykt et al., 2013; Petty et al., 2008). Additionally, innovative methods have emerged for different populations. For instance, Prokop and Fančovičová (2024) measured changes in children’s implicit attitudes by comparing how many teeth they added to a wolf drawing after watching wolf videos. Similarly, Dieser and Bogner (2019) used word association in school children to

find that their implicit associations were more negative with wolves than with lynx. With these methods, one could explore how far negative implicit attitudes are indeed prevalent in locals or the wider public, how they are formed around the wolf or the conflict, during which situations they outweigh explicit attitudes, and what makes them susceptible to change.

Measures of implicit attitudes could also help navigating the often-neglected human-human conflict around wolves and the necessary discourse. Evidence suggests intergroup and social contexts are prone to a low correlation (and hence ambivalence) between explicit and implicit attitudes and a stronger correlation between implicit attitudes and behaviour (Greenwald et al., 2009; Nosek, 2007). Hence, in the emotionally charged and demanding situations locals in wolf habitats tend to find themselves in, explicit intentions to implement deterrence methods or engage amicably with the opposing stakeholders might succumb to overriding implicit processes, leading to opposing real-life behaviour (Fazio et al., 1982; Fazio et al., 1995; Flykt et al., 2022) (Scenario 2). Furthermore, investigating whether reported attitudes stem from biases against the wolf or rather against the opposing social groups in specific conflicts could guide prioritization between problem-solving and reconciliation. Implicit stereotypes could additionally stoke hostile behaviour, halting constructive dialogue on both sides of the attitude spectrum (Kawakami et al., 2017). Finally, negative mental states increase confirmation bias and decrease the willingness to engage with opposing information (Knobloch-Westerwick et al., 2020; Tang and Wu, 2022). This could explain why those most affected by wolves tend to fixate on (perceived) dangers and ignore potential solutions. Understanding how to create spaces where motivation and cognitive ability are fostered such that deliberate processing can withstand strong implicit reactions could hence be a promising tool to navigate these situations more safely and efficiently for everyone involved.

### 5.2. Attitude strength and accessibility

We outlined that attitude strength and accessibility are central to the balance of implicit and explicit attitudes and their ambivalence. Exploring what circumstances create strong or quick attitudes, in which groups they are prevalent, and what role social circles or repeated cultural and media symbolisms play remains to be explored in the human-wolf context. Perhaps most useful for management, attitude strength can help predict who is more likely to act and which stances may change (Fazio et al., 1982; Krosnick and Petty, 1995). Attitude accessibility can be measured by asking participants to share their beliefs and feelings about wolves under time pressure (Fazio et al., 1982; Manfredi and Manfredi, 2008). Attitude strength can be gauged by testing whether an attitude persists over time, withstands manipulation, or by assessing confidence about an expressed attitude (Krosnick and Petty, 1995; Manfredi and Manfredi, 2008). Bright (1997) used the latter to find that strong attitudes were better predictors for support for recreation management strategies than weaker attitudes.

Considering its dependence on emotional significance, direct experience, and personal relevance, increases in negative attitude strength are not surprising amidst accumulating negative emotional stories in one’s social circle (Krosnick and Petty, 1995). Nevertheless, actual direct experiences with wolves for non-farmers or -hunters are rather uncommon (Ericsson and Heberlein, 2003; Karlsson and Sjöström, 2007), meaning these attitudes are likely not overly strong. Involving communities not only in decision making (which is a widely agreed on prerequisite (Glikman et al., 2022; IUCN, 2023; Redpath et al., 2017)) but also in the research and management of wolf populations could create more balanced direct interaction with the species, allowing stakeholders to reconsider their appraisal of the carnivores and consider the species rather than its symbolism (see Marchini et al., 2021; Sjölander-Lindqvist, 2008). This applies not only to wolf sceptics but also to the pro-wolf side that has a tendency to sanctify the wolf above the ecological species as such (e.g., as harmless “ecological hero”, a

“friend and victim”, [Almarcha et al., 2022](#); [Drenthen, 2015](#); [Figari and Skogen, 2011](#)). The repeated exposure might be crucial, since a single positive exposure only modulated explicit but not implicit attitudes towards bears ([Johansson et al., 2016b](#)), and little is known about long-term changes ([Forscher et al., 2019](#); [Johansson et al., 2016a](#)). Moreover, self-generated knowledge is more likely considered than imposed knowledge ([Petty and Cacioppo, 1986](#)), which could further support communities when ambivalence arises and counteract conspiracy theories.

### 5.3. Attitude ambivalence

Exploring the range of polarisation within individuals is pivotal to differentiate between indifference and ambivalence. Whether ambivalence is already present, stems from strength-gaining implicit attitudes clashing with deliberate beliefs, or is induced by the effort to change someone’s attitudes, it creates high uncertainty in resulting wolf- and human-directed behaviour ([Conner and Sparks, 2002](#); [Van Harreveld et al., 2009](#)) (Scenario 4). Understanding these processes might provide approaches to navigate coexistence: While attitude strength typically correlates negatively with the willingness to incorporate new, outside knowledge ([Petty and Cacioppo, 1986](#)), people are more likely to seek information when ambivalence increases ([Van Harreveld et al., 2009](#)). Since less effortful, biased coping methods (e.g., conforming to the majority) are sought out more than effortful, unbiased information seeking (e.g., reading science based reports) ([Van Harreveld et al., 2009](#)), providing possibilities to effortlessly consume objective information could counteract increasing polarisation on either side. Considering the role of trust and effort, having easily accessible, trusted, and transparent information entities established in the community might be vital for this endeavour. Importantly, this information needs to be as objective and unintrusive as possible, since further intentions to bias ambivalent citizens’ views (e.g., by highlighting benefits over costs) could cause more ambiguity with the information from their social circle, and hence turn them away from mediating entities ([Petty and Cacioppo, 1986](#); [Sjölander-Lindqvist et al., 2015](#)).

Some qualitative studies have highlighted the presence of ambivalent attitudes ([Figari and Skogen, 2011](#); [Jürgens et al., 2023](#); [Von Essen and Allen, 2020](#)). Studying ambivalent attitudes more quantitatively could be achieved through bivariate scales, meaning one scale from neutral to favourable and one from neutral to unfavourable ([Van Harreveld et al., 2009](#)). Interestingly, some wolf-attitudes surveys already use varied questions on both scales (e.g., [Ericsson and Heberlein, 2003](#); [Opdam, 2022](#); [Treves et al., 2013](#)). So far these were generally reduced to one composite scale, but the raw data might still be useful to approximate ambivalent attitudes retrospectively.

In a related approach, [Lehnen et al. \(2022\)](#) describe how ambivalence between attitudes and behaviour can aid conservation management. Their Individual Relationship of Entities with Nature (IREN) typology describes how positive, negative, or neutral attitudes, behaviour preference, and behaviour towards the entity can co-occur and what this suggests for management and the stability of a situation. For example, latent intolerance (negative attitude and behavioural preference, but no action) would necessitate an entirely different management approach than indifference (neutral attitude, behavioural preference, and behaviour). Since their paper provides extensive guidance on how attitude, behaviour preference, and behaviours can be measured and assessed, we will refer to [Lehnen et al. \(2022\)](#) for further elaboration.

Focussing on the variation between rather than within individuals, [Arbieu et al. \(2023\)](#) challenge the norm of comparing group means in attitude research ([Barmoen et al., 2024](#)). Taking inspiration from functional ecology, their Attitudinal Space Framework uses quantitative surveys to measure attitude diversity in multidimensional space by quantifying polarisation, extremization, and group homogeneity. This revealed that the polarisation between pro- and anti-wolf proponents is not as large as previous mean-comparisons suggest ([Arbieu et al., 2023](#)).

The method can be implemented with most current survey designs and existing data to understand the difference between real and perceived polarisation ([Arbieu et al., 2023](#); [Arbieu et al., 2024](#)).

### 5.4. Context-dependency

Additionally to overlooking social norms and (perceived) control, neglecting context- and target-dependency in attitude-behaviour relations might have contributed to the poor predictive ability from attitudes to behaviour in previous studies (e.g., [Heberlein, 2012](#); [Niemic et al., 2022](#); [St John et al., 2010](#); [Vaske et al., 2021](#)). The principle of compatibility postulates that reliable predictions from attitude to behaviour can only occur if measures of attitude and behaviour involve the same specificity of target (i.e., attitude object or behaviour), act, context, and time elements ([Ajzen and Fishbein, 1977, 2000](#); [St John et al., 2010](#)). Translated to the complex interplay in the framework, this requirement ensures that both measures are influenced by the same attitude accessibility, strength, and ambivalence for better alignment. For instance, to predict support for lethal measures in a specific situation, one should assess attitudes towards shooting a wolf that has repeatedly preyed on livestock in one’s neighbouring village, rather than general attitudes towards lethal methods or wolves. Contrarily, a multiple-act measure, i.e., an average behaviour bias over multiple tasks/behaviours towards wolves, would be needed to capture the commonly employed general attitude measures ([Ajzen and Fishbein, 1977](#)), since the same positive general attitude towards wolves can present itself in different behaviours (e.g., joining political advocates rather than donating money to conservation agencies). This method is well established in areas like voting behaviour, health psychology, or social behaviour, among others (extensively reviewed in [Ajzen and Fishbein, 1977](#); [Ajzen et al., 2018](#)). Whether these methods can improve the predictability of wolf-attitudes to behaviour remains to be seen.

## 6. Conclusion & outlook

Over the past 50 years, attitude surveys and interviews advanced our understanding of *what* factors influence polarisation and (sometimes irrational) reactions around the wolf and *why* they might do so. Beyond the direct damages wolf presence causes, the intangible and unequally distributed costs have fostered feelings of marginalisation, while socio-spatio-cultural divides have created vastly different views of what wolves represent and how they should be managed. This Perspective argues that, in regards to attitudes, navigating coexistence now requires a focus on *how* polarised attitudes develop, how they shift amid expanding wolf populations, and how they connect to behaviour.

Bringing together attitude models and past evidence, we drafted a framework that emphasizes the need to consider not just explicit but also the previously neglected unconscious, implicit attitudes in conservation decisions, heated group dynamics, and future developments. Therein we described the roles of attitude strength, attitude accessibility, and attitude ambivalence in determining which attitudes are likely to influence behaviour and how attitudes might shift when wolf populations become more salient in one’s life. This highlighted the necessity to consider circumstantial factors and compatible measures when attempting to predict behaviour from attitudes.

Consequentially, seemingly ‘irrational reactions’ can be recognized as somewhat (psycho-)logical consequences of mental processes and social division. Insights into these psychological dynamics could not only foster empathy, but also surface attitudes that have been kept silent (consciously or unconsciously), to better represent the full spectrum of attitudes in management decisions. Therein, it could inform the development and application of targeted tools based on whether attitudes are directed at wolves, specific problems, or opposing social groups. The modulation of attitudes through repeated exposure and reliance on outside information during attitude ambivalence underscores the need for trustworthy, science-based information entities, inclusive

management, and deliberate conflict-resolution strategies, rather than solely top-down education and management efforts. These solutions have been proposed by many others before us (e.g., Arbieu et al., 2019; Linnell and Alleau, 2016; Madden and McQuinn, 2014; Marino et al., 2021; Redpath et al., 2015; Trainotti et al., 2023; Zscheischler and Friedrich, 2022), and we aim to complement them with a more holistic and effective guidance through a better understanding of the underlying psychological mechanisms.

The mechanisms and potential tools described in this Perspective paper might be speculative given the lack of research in this area, but we hope that their firm foundations in psychological concepts used to describe other between-group conflicts in more extensively studied fields (e.g., in/outgroup and intergroup social psychology) will inspire other actors in our field to think beyond merely positive-negative wolf-attitudes and guide the exploration of the actual evidence. The potential prevalence of (latent) negative implicit attitudes, how and when ambivalence and neutral attitudes drive attitude shifts, how different experiences change attitude accessibility and strength, and how these aspects can be integrated to navigate current (social) conflicts and pending attitude shifts amid expanding wolf populations are crucial questions that remain to be explored. We do not propose that the goal of conservationists, researchers, or politicians should be to shift the wolf into purely positive attitudes, especially given the rising number of predation and bold wolves entering urban areas (Boitani et al., 2022; Zanni et al., 2023). Rather, we hope that by understanding the attitude landscape, people's reactions can be recognized and more accurately assessed rather than criticized *ex ante*. By fostering more evidence-based, empathic, and constructive conversations, the challenges of coexistence with the ecological species rather than the symbols wolves have been subjected to by all sides could be tackled, where conflict might not be abolished but managed at a sustainable level for all parties involved. That this is possible is highlighted by the (admittedly few) studied places of coexistence in which attitudes have indeed improved over time due to conflict resolution (e.g., Kutal et al., 2018; Majić and Bath, 2010). In this endeavour, more collaboration with psychological and social sciences will be necessary to aid this process from conflict to coexistence, where compromising will likely be necessary from all sides. With these emerging tools, we hope that science, management, and policy will be better prepared to meet people's needs (rather than changing perception on the surface) in the face of expanding and increasingly urbanized wolf populations.

#### CRedit authorship contribution statement

**Svenja Capitain:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Data curation. **Claus Lamm:** Writing – review & editing, Supervision, Funding acquisition. **Sarah Marshall-Pescini:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Friederike Range:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization.

#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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#### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.biocon.2025.110976>.

#### Data availability

No data was used for the research described in the article.

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