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RESEARCH ARTICLE

Autism, pets, and the importance of seeing human

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Abstract

People often see the human in the nonhuman, a process called anthropomorphism. Anthropomorphism is particularly prolific regarding the humanization of pets. Some research suggests that people with autism may not anthropomorphize to the same degree as neurotypicals. In this study, we explored whether there were differences in how autistic and neurotypical pet owners anthropomorphized their pets. We also examined differences in levels of connectedness to nature and experiences of loneliness and how this corresponded to autistic traits in the entire sample. We found anthropomorphism was as common among autistic pet owners as in neurotypicals. However, autistic pet owners reported greater loneliness and were more likely to substitute pets for people. We also found that neurotypical pet owners rated pets more highly on physical, non-anthropomorphic traits (i.e., muscular, active). In contrast, autistic pet owners were likelier to rate pets equally between physical and anthropomorphic traits. Moreover, we found that anthropomorphism and connection to nature were positively correlated with autistic traits. These findings challenge accounts stating that individuals with autism may not anthropomorphize to the same degree as neurotypicals. Implications for animal-based interventions supporting adults on the spectrum are discussed.

Lay Summary

Autistic people are often assumed to have deficits in the understanding and appreciation of mental states. In this study, we examined whether that was true in the context of animals and the natural environment. We found that autistic people were just as likely to anthropomorphise or humanize their pets and were more likely to think about pets using mental versus physical traits. We also found that autistic traits were correlated with anthropomorphism and connection to nature. These findings corroborate autistic accounts highlighting a strong connection to the natural world.

KEYWORDS

anthropomorphism, AQ, autism, loneliness, pets, theory of mind

INTRODUCTION

Anthropomorphism ascribes human characteristics to nonhumans and features prominently across cultures and time (such as belief in nonhuman deities) (Gervais, 2013). Using human-like explanations for the nonhuman serves several essential purposes. By making something 'like me,' we can better plan how to interact with an otherwise unknown entity, bringing social control back into our lives (Waytz et al., 2010). Furthermore, by making something nonhuman human, we can experience companionship with an unlikely source, mainly when no human companionship is available (insert scenes from the movie Castaway here) (Epley et al., 2008).

For many, anthropomorphism is perhaps most relevant in the context in which it is most common; in our

relationships with our pets. More people own pets than do not (in the US, for example, an estimated 60% of people have pets, Applebaum et al., 2020). People spend tens of billions of dollars each year caring for their pets in ways comparable to caring for human offspring (Henderson, 2013). For instance, along with specialist doctors, prescription medication and top-of-the-range food, it is not unheard of to throw a pet a birthday party, take them to daycare and even buy them designer clothing. Indeed, research suggests that most owners consider their pets to be full-fledged family members with 'people status' (Cain, 1985), and they may rely on them for social support, sometimes more so than their human family members (Taylor et al., 2006).

As discussed in detail by Serpell (2003), most pet owners regularly engage in the anthropomorphism of pets. We may be primed to do so beginning in early development when children are encouraged to view animals as social subjects in cartoons and stories. Talking animals provide escapism, variety, and a social connection to an otherwise strange creature (Markowsky, 1975). Serpell (2003) argues that evolutionarily speaking, without anthropomorphism, humans would not have become 'super predators' who understand the minds of their prey. Equally, pet ownership would have never evolved had we not welcomed animals into our social spheres. A world without pets is, for many, unimaginable, and perhaps for a good reason. Research suggests that pet ownership links with the development of empathy in childhood (Daly & Morton, 2009) and comes with mental health benefits analogous to what one would expect if a pet's ultimate purpose is to provide loving, stable social support (Albert & Bulcroft, 1988).

As pets can socially synchronize with their owner's emotional cues in ways reminiscent of human-like empathy (Duranton & Gaunet, 2015), it is perhaps unsurprising that pet owners, in turn, use the same heuristics to understand their pet's emotions as they do their own emotions (Konok et al., 2015). Thus, people who own pets see them in human ways, and use pet relationships as a form of social support (Antonacopoulos & Pychyl, 2008). Indeed, well-known scholars of anthropomorphism, such as Epley et al. (2007), emphasize the importance of measuring loneliness when evaluating the tendency to anthropomorphise. More recent experimental work supports this, revealing a bidirectional relationship between anthropomorphism and loneliness (Bartz et al., 2016; Epley et al., 2008; Mourey et al., 2017; Paul et al., 2014).

There are several proposed mechanisms for why people anthropomorphise. Airenti (2018) argues that anthropomorphism is not a set of beliefs about an object being more or less human, but rather 'a way of relating with a nonhuman entity by addressing it as it were a human partner in a communicative situation.' (p. 8). Airenti (2018) argues several facets of cognition influence anthropomorphism. One is motivation to engage with a nonhuman in a human-like way because that entity elicited a strong emotional response (love, anger, fear, and surprise). This then leads one to interact with the entity in question in an attempt to cooperate with it (to start the car that will not turn on, to pick up and cuddle the plush toy). In doing so, the person establishes an anthropomorphic relationship by imagining the mental and affective states of the entity to influence that entity.

As Airenti (2018), Epley et al. (2007), and Serpell (2003) discuss, fundamental to anthropomorphism may be the reflexive desire to understand the mind of the nonhuman entity. Thus, one mechanism of anthropomorphism may be using one's theory of mind (ToM) or one's ability to understand or imagine different mental states (Premack & Woodruff, 1978) to simulate the experience of the nonhuman agent (Goldman, 2006). Pretend play in early childhood is a pertinent example of how anthropomorphism and ToM may overlap. Children who pretend that their babydolls are human babies, or that their action figures are fighting, or that they have an imaginary friend are both attributing human characteristics to nonhumans (anthropomorphism) and imagining the mental states of those agents (ToM) (Piaget, 1929). While some studies suggest ToM underpins a child's ability to anthropomorphise (Dore et al., 2015), others have interestingly found that anthropomorphism can improve ToM in children (Lillard & Sobel, 1999).

In describing the ToM aspects of anthropomorphism, Epley et al. (2007) use autistic people as an example of a subgroup not prone to this type of thinking. Specifically, they write that 'the lack of sophisticated theories about the self, about others, and human-typical mental capacities demonstrated in people with autism seem to at least partly explain their lack of anthropomorphism' (p. 870). Indeed, a good deal of research would support the prediction that autistic people would be poor anthropomorphisers. For one, difficulties with imagination and a lack of pretend play, which are early milestones in developing both skills, comprise some of the most famous early accounts of autistic children. Kanner's (1943) case studies and Wing and Gould's (1979) 'triad of impairments,' (later used as the basis for the inclusion of autism in the DSM-III, 1979) define autism through a lack of imaginative pretend play and a difficulty appreciating the social aspects of situations.

However, the main thrust of the argument that autistic people would be poor anthropomorphisers made by Epley et al. (2007) is that autistic people perform differently than neurotypicals on a test of ToM that is also anthropomorphic, the Social Attribution Task (Heider & Simmel, 1944; Klin, 2000). In several studies, autistic children did not use human mental state explanations for the movement of shapes to the same degree as neurotypicals. For example, while neurotypicals tend to offer animate and human-like explanations of shapes moving around a screen (involving concepts like mothers protecting young or agents chasing and playing), such

descriptions are missing in autistic individuals' descriptions of these scenes (Burger-Caplan et al., 2016; Klin, 2000).

There are, however, important distinctions between different types of anthropomorphism and different types of ToM. Indeed, both anthropomorphism and ToM are, in a sense, umbrella terms that are used to describe a variety of responses to social stimuli in many different contexts. For instance, both can be tested dispositionally (how likely are you to see a tree as a human? How likely are you to consider what someone else is thinking?) and actively (describe the robot's reaction, describe the man's response). Some research suggests that the two forms may not be directly related.

For instance, Hortensius et al. (2021) tested how predictive dispositional anthropomorphism (i.e., self-reported tendency to anthropomorphise) was to ToM abilities. They had participants watch a cartoon film about an anthropomorphic stork and clouds that has been shown to activate ToM networks in the brain and measured activity in these regions. They did not find that dispositional anthropomorphism predicted ToM brain network activity. Tahiroglu and Taylor (2019) also measured anthropomorphism, ToM and history of imaginary companions in an adult and child sample. They also found that dispositional anthropomorphism was dissociable from ToM. Interestingly, they did find that imaginary companionship was linked with anthropomorphism, which other studies have found to predict ToM abilities throughout childhood (Taylor et al., 2004).

In short, links between ToM and anthropomorphism, while complex, would seem to suggest that autistic people, who often struggle with ToM, would be less likely to anthropomorphise than people who are neurotypical. This is because, more broadly, autistic people are often used as examples of those with 'mindblindness', referring to their supposed absence or underdeveloped ToM (for a critique, see Duffy & Dorner, 2011), or people with low social motivation (Chevallier et al., 2012). These oft-used narratives that often dominate the landscape of autism research are perhaps why researchers state that autistic people are 'particularly unable to reason about the minds of others [and] they are unlikely to anthropomorphise.' (Epley et al., 2013, p. 143).

However, several aspects of this characterization contradict research on the human-animal bond in autistic samples. Autistic people have been shown to have strong and decidedly *social* bonds with companion animals (Carlisle, 2015). Animal interventions for autism have successfully improved various symptoms (O'Haire, 2013) and therapeutic outcomes (Martin & Farnum, 2002; Sams et al., 2006). Even in naturalistic settings, autistic children are more socially responsive in the presence of pets (O'Haire et al., 2015). Qualitative research on the autism-animal bond describes people whose joys in life are made possible through the bond with their pets (Malcolm et al., 2017; Solomon, 2010). Furthermore, recent work by Atherton et al. (2022) showed that not only are autistic individuals just as likely attached to their pets, but pet ownership also corresponded with improved mental health and social outcomes.

This body of work does not suggest that autistic people are bonding with companion animals for nonsocial reasons, such as purely sensory enjoyment; it appears that the companionship of animals is vital to their lives. Thus, human-animal bonds among autistic people are notable, particularly when juxtaposed with social responsiveness towards humans (Celani, 2002; Prothmann et al., 2009). This begs the question, if autism is incompatible with anthropomorphism, which appears to be integral to a typically developed animal bond, how can we understand autism in the context of a companion animal bond?

We contend that autism is not incompatible with anthropomorphism; indeed, it may even be an aspect of the autistic phenotype, as suggested (Atherton & Cross, 2018; White & Remington, 2019). Qualitative research by Atherton et al. (2018) indicates that anthropomorphism may be fundamental to ToM development in everyday life among autistic adolescents. Other research suggests that autistic individuals not only anthropomorphise but that it may be linked with, and in some cases even improve, ToM (Atherton & Cross, 2019, 2021; Cross et al., 2019, 2022; Negri et al., 2019), similar to research showing anthropomorphism improves ToM in children (Lillard & Sobel, 1999).

In a recent study by Caruana et al. (2021), autistic traits were correlated with an increased tendency to anthropomorphise nonhuman entities, such as the weather, technology and toys. They also found that in a clinical autistic sample, those who showed elevated rates of loneliness were those who anthropomorphized the most. Increased rates of loneliness, similar to increased rates of anthropomorphism, often contradict theories of autism. Some, for instance, suggest that autism can be understood as a condition characterized by decreased social motivation (Chevallier et al., 2012), which would reduce a tendency to anthropomorphise (Epley et al., 2013). However, as reflected in Caruana et al. (2021), autistic traits are often found to be associated with loneliness (Jobe & Williams White, 2007; Lamport & Zlomke, 2014; Mazurek, 2013), highlighting that while those on the spectrum may be more alone, they are not insensitive to their social exclusion. Indeed, it is suggested by Caruana et al. (2021) that the reduced opportunities for social connection often experienced by autistic people may heighten their tendency to anthropomorphise, as they may search for social outlets in unlikely places out of a need for social contact.

Thus, we hypothesize that those on the spectrum anthropomorphise their pets in line with neurotypicals and may show evidence of increased anthropomorphism out of a need for non-traditional social outlets (as suggested by Atherton et al., 2022). An intact or even increased tendency to anthropomorphise pets would

TABLE 1 Demographic information.

		Biological sex		Gender				
	N	Female	Male	Female	Male	Other	Mean age	SD
Autistic	207	106	101	94	97	14	29.07	10.57
Neurotypical	330	247	83	240	85	5	34.49	13.07

further support research on animal companionship that suggests pet ownership serves an important social function for those on the spectrum. It would also offer a departure from the narrative of autistic people being disinterested in mental states. Such a characterization has long been criticized as a simplistic, inaccurate account of autistic ToM development (Gernsbacher & Yergeau, 2019), which, among other things, does not account for the bidirectional effects that ToM differences may have on wider social acceptance (Banerjee et al., 2011).

Finally, some research suggests that autism is related to connectedness to nature in that, like those who anthropomorphise, they can see the social self beyond a narrow, human-specific agent (Davidson & Smith, 2009). For instance, Davidson and Smith (2009) analyzed 45 published autistic autobiographies. The authors often discussed their intense, emotional relationship with 'natural' things and places, such as animals and the biological world. Davidson and Smith (2009) suggest that a rich relationship with the more-than-human world may characterize autism. The concept of a 'broader' concept of sociality is itself linked to anthropomorphism. It requires viewing things not traditionally considered 'living' to be capable of social connection. Indeed, research such as Tam et al. (2013) found that the anthropomorphism of nature increases conservation and that when nature is anthropomorphized; people feel a greater appreciation for nature. Therefore, it was interesting to explore whether connectedness to nature was an aspect of the autistic phenotype, whether it aligned with anthropomorphism, and whether it differed between autistic individuals and neurotypicals.

METHODS

Participants

Five hundred and forty-nine pet owners took part in this study recruited via Prolific (Oxford, UK). This study was advertised solely for pet owners (current or previous), as two of the scales of interest are about a person's experience with their current or past pets. We sought a roughly equal sample of neurotypical and autistic participants. Of the total participants, 40% had a diagnosis of autism. Of those who reported being autistic, 12 did not have a medical diagnosis and were excluded from the analysis, leaving 537 participants. A full breakdown of participants' demographics can be found in Table 1.

Participants were paid in line with UK minimum wage for time spent filling out the survey, which took 30 min. This data was from a broader study examining autistic traits, pet ownership, and mental health (Atherton et al., 2022). The Edge Hill University ethics committee granted ethical approval for this study. All participants provided written informed consent.

Design, materials, and procedure

This study used a survey design administered online on Qualtrics hosted on Prolific. Participants' demographic information was first recorded, followed by several self-report questions assessing people substitution, anthropomorphism and physical ratings of pets, connectedness to nature, loneliness and level of autistic traits (described in detail below). Finally, participants with autism were asked to confirm that this diagnosis was given to them by a medical professional and at what age they received it. This method of diagnostic verification is obtained from Daniels et al. (2012). Participants who were able to provide their age of diagnosis and whether a medical professional diagnosed them were positively correlated with the actual existence of diagnosis. This method has been used in previous large-scale online autism studies (Baron-Cohen et al., 2015).

First, participants completed The Lexington Attachment to Pets subscale 'People Substitution' (Johnson et al., 1992), consisting of seven questions on a four-point Likert scale. This scale measures the degree to which a person uses their pet as a substitute for human companionship (i.e., 'I believe my pet is my best friend', 'I love my pet because he/she is more loyal to me than most of the people in my life'). Participants were instructed to answer these questions with one of their pets specifically in mind. The Critical Pet Rating scale (Epley et al., 2008) was used to measure anthropomorphism. Participants scored 14 traits (such as 'considerate' and 'agile') on a scale of 0–100, ranging from not at all characteristic to very characteristic concerning how much the trait describes their pet. Seven of the 14 traits were anthropomorphic (i.e., 'jealous,' 'creative,' and 'thoughtful'), and the remaining seven were non-anthropomorphic or physical descriptors (i.e., 'muscular,' 'energetic', 'lethargic'). Items were presented randomly, and participants were

instructed to answer all questions with one of their pets in mind. Next, participants completed the Connectedness to Nature Scale (Mayer & Frantz, 2004), a 14-item test scored on a 5-point Likert scale that measures a person's traits about feeling emotionally connected to the natural world (i.e., 'I often feel a kinship with animals and plants'). They then completed the UCLA Loneliness scale (Russell et al., 1980), a 20-item measure scored on a four-point Likert scale measuring subjective feelings of loneliness and social isolation (i.e., 'I cannot tolerate being so alone', 'I feel left out').

Finally, participants completed the Autism Quotient (AQ) (Baron-Cohen et al., 2001) to measure autistic traits. In the AQ participants reported their agreement with 50 statements indicative of autistic traits (i.e., 'I prefer going to the library than a party') using a 5-point Likert scale. The entire Likert scale was used to form AQ scores rather than the Baron-Cohen et al. (2001) original dichotomous response method, as Likert scoring the AQ has been shown to more adequately retain the detail in responses, increase the variability in scores and increase the overall reliability and validity of the measure (Stevenson & Hart, 2017). The AQ-50 is normally distributed in a general population sample and can detect autistic traits in clinical and neurotypical samples (Ruzich et al., 2015; Woodbury-Smith et al., 2005).

TABLE 2 Kolmogorov–Smirnov tests of normality.

	Autistic	Neurotypical
People substitution	KS (207) = 0.151, $p < 0.001$	KS (330) = 0.105, $p < 0.001$
Connectedness to nature	KS (207) = 0.073, $p = 0.010$	KS (330) = 0.051, $p = 0.040$
Anthropomorphism	KS (207) = 0.096, $p < 0.001$	KS (330) = 0.048, $p = 0.060$
Physical	KS (207) = 0.050, $p = 0.200$	KS (330) = 0.068, $p < 0.001$
AQ	KS (207) = 0.068, $p < 0.001$	KS (330) = 0.046, $p = 0.091$
Loneliness	KS (207) = 0.073, $p = 0.009$	KS (330) = 0.052, $p = 0.033$

RESULTS

The data distributions across all five scales for autistic and neurotypical respondents deviated significantly from normality (see Table 2 for KS test results). Nonparametric tests were therefore used throughout.

First, we explored whether differences between those with and without a diagnosis of autism were present for our constructs of interest. Mann Whitney U tests in Table 3 showed that autistic people reported significantly higher People Substitution, AQ and Loneliness scores than those without a diagnosis. They also reported significantly lower Physical ratings of pets than neurotypicals. In contrast, the two groups did not score significantly different in Connectedness to Nature and Anthropomorphism. Bayesian Mann Whitney U tests were also performed on these two variables using default priors in JASP (JASP Team, 2018) to allow us to evaluate support for the null hypothesis. Bayes Factors expressing the probability of the data given the research hypothesis (BF10) relative to the null hypothesis (BF01) showed stronger support for the null hypothesis in both cases. This analysis confirmed that the autistic and neurotypical groups did not differ on these measures (see Table 3 for inferential and descriptive statistics).

We were also interested in exploring the anthropomorphic versus physical ratings of pets. Specifically, given that autistic participants showed a higher endorsement of most measures, we wanted to understand whether they also tended to rate pets more highly on either physical and mental states or whether neurotypicals, compared to autistic people, rated pets more highly on mental states, as would typically be suggested by ToM deficit accounts of autism. To explore this, a Wilcoxon rank test was conducted to compare anthropomorphic and physical ratings. This was conducted for autistic and neurotypical participants separately. Results showed no difference in how autistic people rated their pets physically versus anthropomorphically ($U = 11{,}187$, $p = 0.540$). Neurotypicals, however, provided significantly higher ratings for physical features than anthropomorphic ones ($U = 21{,}300$, $p = 0.002$). In other words, neurotypicals weighted physical characteristics more

TABLE 3 Inferential statistics and descriptive statistics for each group on all measures.

		Autistic		Neurotypical	
	Inferential statistics	Median	Range	Median	Range
People substitution	$U = 28932.50$, $p = 0.003$, $r = 0.129$	23.00	10–28	22.00	7–28
Connectedness to nature	$U = 33507.50$, $p = 0.711$, $r = 0.016$ BF01 = 9.59/ BF10 = 0.10	53.00	25–70	52.00	28–70
Anthropomorphism physical	$U = 32844.00$, $p = 0.454$, $r = 0.032$ BF01 = 6.62/BF10 = 0.15 $U = 37799.50$, $p = 0.037$, $r = 0.089$	339.00 335.00	0–687 75–678	325.50 348.50	0–678 0–633
AQ	$U = 8672.00$, $p < 0.001$, $r = 0.628$	145.00	92–191	114.00	66–164
Loneliness	$U = 20065.50$, $p < 0.001$, $r = 0.348$	56.00	20–79	44.00	20–79

heavily than anthropomorphic ones when characterizing their pets, which was not the case for autistic people.

It was also interesting to investigate whether autistic traits related to our variables of interest. Examining the entire spectrum of autistic traits as they relate to our construct of interest rather than simply exploring differences between those with and without a diagnosis is essential as it allows a deeper understanding of the autistic phenotype, as 'the expression of autistic traits extends beyond the clinical boundaries of autism' (Sucksmith et al., 2011). To investigate the autistic phenotype, Spearman's correlations were performed between the total scores of all variables to explore the relationship between our variables of interest across the whole sample. These tests confirmed that autistic traits, as measured by the AQ, correlated positively with People Substitution, Connectedness to Nature, Anthropomorphism and Loneliness among the entire sample. Anthropomorphism also correlated positively with Loneliness. See Table 4 for all inferential statistics relating to the correlations.

To test whether the relationship between these variables was driven by one of the two samples, we repeated Spearman's correlations and included neurotypical participants (Table 5) or autistic participants (Table 6). Most correlations were significant when all participants and the single samples were included. However, AQ was no longer significantly correlated to Anthropomorphism within the neurotypical group and Connectedness to Nature within the autistic group. This probably occurred because splitting the sample reduced the range of the AQ scores. Loneliness was also no longer significantly correlated to Anthropomorphism when the two samples were split. Again, given that autistic people had higher Loneliness scores than neurotypicals, this might be because splitting the sample reduced the variability of Loneliness. More interestingly, Anthropomorphism was no longer significantly correlated to Connectedness to Nature when only neurotypical people were included.

Given that correlations showed that anthropomorphism was related to AQ and Loneliness, we tested whether the anthropomorphism was driven by one of these two factors, or both. A multiple regression with Anthropomorphism as the outcome and AQ and Loneliness scores as predictors showed that Loneliness was a significant predictor ($\beta = 0.101$, $p = 0.043$), but AQ was not ($\beta = 0.042$, $p = 0.401$) ($R^2 = 0.01$, $F(2, 534) = 4.35$, $p = 0.013$). This suggests that the positive correlation between AQ and Anthropomorphism occurred because individuals with higher traits felt lonelier. In other words, autism did not impact anthropomorphism directly.

DISCUSSION

In this study, we were interested in exploring whether researchers of anthropomorphism were correct in

TABLE 4 Spearman's rank correlations including all participants.

	People substitution	Connectedness to nature	Anthropomorphism	AQ
Connectedness to nature	0.385**			
Anthropomorphism	0.383**	0.191**		
Autism quotient	0.251**	0.103*	0.090*	
Loneliness	0.228**	0.031	0.116**	0.497**

Note: *$p < 0.01$; **$p < 0.001$.

TABLE 5 Spearman's rank correlations including neurotypical participants only.

	People substitution	Connectedness to nature	Anthropomorphism	AQ
Connectedness to nature	0.442**			
Anthropomorphism	0.286**	*0.119*		
Autism quotient	0.278**	0.200*	*−0.049*	
Loneliness	0.208*	0.017	*0.095*	0.224**

Note: *$p < 0.01$, **$p < 0.001$. Values in italic denote the coefficients that were significant when all participants were included (Table 4), but not here.

TABLE 6 Spearman's rank correlations including autistic participants only.

	People substitution	Connectedness to nature	Anthropomorphism	AQ
Connectedness to nature	0.383**			
Anthropomorphism	0.366**	0.196**		
Autism quotient	0.163*	*0.058*	0.164*	
Loneliness	0.192**	0.058	*0.101*	0.463**

Note: *$p < 0.01$; **$p < 0.001$. Values in italic denote the coefficients that were significant when all participants were included (Table 4), but not here.

assuming that autistic people engaged in less mental state reasoning about the nonhuman compared to neurotypicals. As discussed, prominent researchers on anthropomorphism, such as Epley et al. (2007), use the autistic population as an example of those who are unlikely to anthropomorphise. Much of this is based on evidence using anthropomorphic reasoning deficits, as shown on spontaneous ToM measures such as the Social Attribution Task (Klin, 2000). To investigate whether this characterization applied to the self-reported anthropomorphism of pets, we surveyed 537 autistic and neurotypical pet owners on a range of measures centered on this facet of ToM.

The results showed that the autistic individuals in this study did not report experiencing less anthropomorphism, as measured by the degree to which they perceive their pets to possess human-like personality characteristics (i.e., 'jealous' and 'creative') using the Critical Pet Rating Scale (Epley et al., 2008). Indeed, autistic individuals indicated that their pets possessed human-like features as much as neurotypicals. Furthermore, while neurotypicals provided higher ratings for physical than anthropomorphic characteristics, autistic people did not show this bias, providing similar ratings for physical and anthropomorphic features.

Even more surprising, the correlations showed that individuals with higher autistic traits anthropomorphise their pets more than those with lower autistic traits. However, the regression later indicated that it occurred because the former felt lonelier than the latter. Loneliness, rather than AQ, influenced anthropomorphic ratings, with more lonesome individuals anthropomorphizing more. This would also explain why there was no significant difference in anthropomorphic scores between autistic and neurotypicals. Autistic people were also more likely to substitute their pets for human companionship when compared to neurotypical participants. This is in line with previous work showing that lonely people are more likely to use companion animals as surrogates for human companions (Atherton et al., 2022; Veevers, 1985).

Of interest in this line of research is to understand how to reconcile recent research which finds intact or enhanced anthropomorphic tendencies in autistic participants with past research suggesting anthropomorphism is decreased in this population. For instance, studies such as Klin (2000) found reduced anthropomorphism in autistic subjects using the Social Attribution Task. More recent studies that found heightened anthropomorphism, such as this present study, along with White and Remington (2019) and Caruana et al. (2021), have found intact or even heightened anthropomorphism in autistic individuals. Significantly, these studies differ in the way they measure anthropomorphism. The social attribution task is a spontaneous measure of anthropomorphism. In the Social Attribution Task, participants are assessed on how they respond in real-time to unknown anthropomorphic entities, and their responses are independently rated based on verbal elicitations. As alluded to earlier, the Social Attribution Task also uses shapes as the agent of evaluation, which may offer less clear or logical avenues to anthropomorphise than animals. Self-report measures of anthropomorphism used in studies such as this, White and Remington (2019), and Caruana et al. (2021), asks participants to reflect on anthropomorphism as they remember experiencing it explicitly, and participants are prompted to anthropomorphise specific, familiar agent(s) such as pets.

Research into ToM suggests that it includes online and offline social reasoning (Frith & Frith, 2006). Online ToM measures such as the Social Attribution Task are of interest because they show a person's ToM' in action.' By assessing how a person infers meaning from a collection of shapes moving in human-like ways, one can predict how a person might similarly perform in similar real-life social situations (i.e., spontaneous metalizing in everyday interactions). The difficulties autistic people demonstrate during online ToM measures such as the Social Attribution Task indicate the difficulties often reported in real-life interactions, including misreading social cues or misinterpreting the situational context. While some interpret this as stemming from a disinterest in social stimuli, our findings suggest dissociable aspects of ToM, and not all may be impaired in autistic people. The Social Attribution Task, for instance, is not just a measure of anthropomorphism. It also relies on executive functions such as working memory, attention to visual cues, and task switching, all three of which are atypical in autistic people. Thus, disparities between anthropomorphism as measured by the Social Attribution Task compared to self-report measures may reflect deficits in executive functioning rather than a reduced social motivation, which can influence performance on open-ended tasks (White et al., 2009).

Interestingly, while White and Remington (2019) show heightened anthropomorphism of objects compared to neurotypicals, our results suggest that neurotypicals and autistic people anthropomorphise their pets at equal rates. This may be particularly important as it shows a shared appreciation and reliance on pets for social connection that can be a source of mutual understanding between autistic and neurotypical people. Future research may want to examine how social cognition concerning pets can be encouraged in autistic and neurotypical populations to improve 'double empathy' or the mismatches between autistic and neurotypical social partners. As both autistic and neurotypical people alike are prone to relating to pets in human ways, relating to one another through pets (i.e., meetups at dog parks, animal clubs, and volunteerism at animal shelters) could be a way for autistic and neurotypical people to, in turn, relate to one another.

Our results also showed that autistic traits correlated with a connection to nature. This aligns with research suggesting that autistic people have a 'more than human'

connection to the natural world, as described in autistic autobiographies (Davidson & Smith, 2009). Indeed, some of the most famous autistic people in the world, such as Temple Grandin and Greta Thunberg, often discuss their connection to nature and interest in the nonhuman social world. Interestingly, research does not entirely support our findings. Taylor et al. (2021) also investigated the relationship between autistic traits and environmental behaviors, including pro-environmental attitudes and climate change beliefs. They found that autistic traits were negatively related to pro-environmental behaviors, and there was no relation between traits and environmental attitudes or beliefs. One point, however is that their sample was not split between autistic and non-autistic people, but recruited from the general population alone. Thus, it may be that including a larger clinical sample in the investigation of autistic traits and appreciation of nature may change findings, particularly as people who are diagnosed may be more aware of their social differences and explicitly seek out social alternatives.

There are several limitations to this study. First, this study focused on anthropomorphism as a function of pet ownership. As such, individuals who had never owned a pet were not included. Thus, conclusions cannot be generalized to non-pet owners. While research suggests that most of the population has experienced pet ownership at some point in their lives (an estimated 86%), future research may want to include measures of anthropomorphism that can be tested on non-pet owners towards animals in general. Second, this study measured anthropomorphism only related to pets, in contrast to studies such as White and Remington (2019) and Caruana et al. (2021), who examined the anthropomorphism or personification of objects.

Similarly, our study did not measure online or spontaneous measures of anthropomorphism, such as the Social Attribution Task. Thus, we can only report how individuals report their tendency to anthropomorphise rather than a more objective measure of anthropomorphism as it occurs in real time. Future work may wish to measure autistic and neurotypical participants on a battery of anthropomorphic assessments, including pet/object-focused assessments and cued/non-cued assessments, to create a more precise cognitive profile regarding this ability. As it is hypothesized that other cognitive processes may affect performance on online anthropomorphism measures such as the Social Attribution Task, including measures of executive function would be a valuable addition to such a study.

Finally, other mental or physical health conditions and factors were not measured in this work, so we cannot assess how these may have affected factors relating to loneliness or people substitution within or between groups here. It should also be noted that this work relied on self-report scales, so the limitations surrounding introspection, participant bias and subjectivity should be duly noted.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the manuscript's contents, and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT

Approval was obtained from the local ethics committee.

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