Exploring the role of “aliveness” in children’s responses towards a dog, biomimetic robot, and toy dog.

1. Abstract

The Core Knowledge System of Agency states that children, from an early age, can discriminate between living agents and non-living artefacts. Building on this, the ‘Biophilia hypothesis’ suggests that children and adults have a natural affinity for living organisms and benefit from interacting with them. These theories may underpin the use of dogs for children’s general wellbeing and for therapeutic purposes, yet it is presently unclear whether a comparable non-living artefact, such as social robot, could capitalise on similar mechanisms. In the current study, child members of the public aged 14-months to 14-years old *(N =* 115), engaged in free interactions with a dog, a MiRo-E biomimetic robot, and a basic moving toy dog, and then completed an age-appropriate questionnaire evaluating their attitudes towards the three animal/robots *(N =* 99). As was predicted, most participants preferred the dog, and behavioural observations indicated that participants approached the dog first most frequently and spent the longest duration engaged in positive behaviours with the dog. Participants also attributed the dog with higher mental state abilities than the robot, with several participants referring to the “aliveness” of the dog when explaining their preference. However, similar emotions were reported for all conditions and participants spent a comparable amount of time overall with the dog and robot, and participants engaged in more exploratory behaviours with the toy. This suggested that, whilst the children recognised the categorical distinction between the living status of the three entities, the robot provided an enjoyable experience for the children and sustained their attention. Therefore, a biomimetic robot has the potential to provide a valid alternative to a live dog in certain contexts.

Keywords: animal assisted interactions, robot assisted interactions, human-animal interactions, human-robot interactions, social robot, animism.

2. Introduction

The Core Knowledge System of Agency theory (Carey & Spelke, 1996) suggests that humans have an innate universal ability to discriminate between ‘living beings’ and ‘non-living things’. This ability exists cross-culturally and emerges from an early age, with new-born infants exhibiting a preference for face-like configurations of shapes, 6-month-old infants associating some animate properties with people, and 9–12-month-olds understanding goal directed motion, even in the absence of no human-like features. Infants’ abilities in this domain continue to improve so that they apply these animate principles more broadly to animates and inanimates when they are in their second year (Kamewari et al., 2005; Opfer & Gelman, 2011; Rakison & Poulin-Dubois, 2001). It is reflected in increased attention behaviours, such as looking, directed towards animate objects by infants (Dellantonio et al., 2012). This seems to be the basis of our ability as adults to sort objects accurately, rapidly, and automatically into categories of living/non-living based on visual information alone. However, Piaget (1929) noted that children ascribe aliveness to non-living objects during both the pre-operational and operational stage (aged 2-11 years old). Thus, despite an early bias for lifelike entities, developmental and experiential factors are required for sorting ontologically ambiguous objects into living/non-living categories (Melson et al., 2005).

Even if infants show a preference for observing or interacting with living versus non-living objects, this does not imply that they are attributing mental states to those living objects, or have any conceptual awareness of this discrimination (Burge, 2018). Rather than having an understanding of biologically ‘living’ and ‘non-living’, young children may be focusing on other cues to animacy. These include stationary cues, such as the nature of the spatial context, the degree to which the entity seems human-like, the presence of limbs or curvilinear contour, facial features, whether to entity has a face or body and the shape of these features (Horowitz, 2018; Klapper et al., 2014; Tremoulet & Feldman, 2006). Movement could include the object suddenly stopping or pausing in its motion, accelerating or decelerating, changing trajectory, making contact with another object, and whether the apparent source of motion is self-propelled and agentive (Di Giorgio et al., 2017b; Setoh et al., 2013). Indeed, the movement and actions shown by an object have been suggested as being more influential in ratings of ‘aliveness’ by children than an object’s physical appearance (Di Giorgio et al., 2017a). In an attempt to disentangle the properties which children use to make such discriminations, research can look at comparisons of children’s attitudes towards animals, non-living objects, and biomimetic robots. While children as young as 7 years are more likely to attribute aliveness and mental states to animals than robots (Melson et al., 2005), highly advanced biomimetic robots can invoke the appearance of animacy to such an extent that children often believe that they are capable of mental processes, biological properties, and social and moral standing, at least to some degree (Barber et al., 2020; Jipson & Gelman, 2007; Okanda et al., 2021). This suggests these attributions are not “all or nothing” and become refined over time.

In addition to the ratings and attitudes declared by children, the precise ways in which children interact with living beings and non-living objects can also provide insights into children's conceptual knowledge of animacy. In trials where a live fish, hamster, and gecko were matched with a physically similar, but non-moving, toy version, the 1-3.5 year old children interacted with the live animals more frequently than the toys and used more gestures and talked more with the animals (Lobue et al., 2013). Previous research comparing a living dog and AIBO robot dog found that 7-15 year old children spent more time touching and in close proximity to the dog, although the majority of children treated the AIBO in a "dog-like" manner (Melson et al., 2005). Similar "dog-related" behaviours were reported for 11- 12 year old children towards a MIRO-E biomimetic robot animal, with children engaging in "positive social touch", approaching, and offering a toy to the robot and a dog for comparable durations (Barber et al., 2020). In contrast to the Melson et al. (2005) study, children spent more time with the robot (perhaps due to its novelty) despite reporting a preference for the living dog overall. These subtle differences in the behaviour of children towards living beings and non-living objects may provide insights into the development of an understanding of animacy. However, most studies are restricted to a single age group and direct comparison across studies is difficult.

As well as preferring to spend time with living beings, children often experience strong positive emotions during encounters with living animals and can form strong attachments to animals they encounter frequently (Barber & Proops, 2019; Melson & Fine, 2019; Ribi et al., 2008). There are a number of beneficial outcomes related to children's affiliation with animals, including increased empathy, social integration, and emotional and cognitive competence (Beck & Katcher, 1996). These positive emotions and outcomes are often reported when interacting with a therapy dog in the context of Animal Assisted Interactions (AAI) and may well underpin the reported beneficial effects (Beck & Katcher, 1996). AAI refers to planned, goal-directed activities that involve the use of animals as therapeutic adjuncts for the benefit of the human recipient (IAHAIO, 2018). Likewise, highly positive emotional experiences have also been reported during interactions with biomimetic robot animals (Barber et al., 2020; Ribi et al., 2008) and the relationship of people towards animal-like robots is assumed to be more like our relationship with pets, whereas humanoid robots are considered like our relationship with other people or with tools depending on culture (Nomura, 2017; Papadopoulos & Koulouglioti, 2018). It is also possible and normal for children to show affiliative behaviours towards non-living objects. This often occurs through the child anthropomorphising the non-living entity by imbuing it with emotions, intentions, and motivations (S. A. Gelman & Davidson, 2016), yet research has indicated that affiliative behaviours occurs less frequently with non-robotic toy animals than living pets (Beetz et al., 2011) and some people hold negative attitudes and engage in abusive behaviour towards robots (Bartneck & Hu, 2008; Nomura, 2017). However, this previous research finding was based on perceptions of humanoid robots, whereas users may have more of an emotional connection with the animal-like robots, particularly if they perceive the animal-like robot as having more mental state abilities (Keijsers & Bartneck, 2018).

This attraction to animals and the living world is outlined in the Biophilia hypothesis, which states that humans are predisposed to be attracted to and derive benefits from interacting with life and life-like processes (Wilson, 1984). There is a great deal of empirical support for the beneficial effect of interaction with life and lifelike processes (Melson & Fine, 2019) and it has been suggested that Biophilia may underpin the reported beneficial outcomes associated with AAI (Beetz, 2017). However, there are cultural and individual variations in the extent to which people affiliate with animals, and there are some criticisms of the Biophilia hypothesis as being vaguely defined and not specifying which features may be instrumental to the supposed beneficial effect (Joye, 2011; Serpell, 2004).

Social robots are becoming increasingly biomimetic and lifelike, thus adhering to the Biophilia hypothesis in the broadest sense and blurring the lines between animate and inanimate as described in the Core Knowledge System of Agency. They are also increasingly being used in therapeutic settings due to the advantages over real dogs, including that they can be thoroughly cleaned, are able to work for extended periods of time, and may be more cost effective (Miklósi & Gácsi, 2012). To determine the relative merits and disadvantages of using a therapy dog versus a robot more clearly, it is important to understand how children naturally interact with both. It is also important to determine whether there are systematic variations in how children of different ages interact with these animate and inanimate entities and how this may relate to the development of a concept of living beings, non-living objects, and mental state attribution through childhood, as these factors may affect the efficacy of animal/robot assisted interventions.

The current study aimed to explore the potential mechanisms of action underlying the use of therapy dogs and robots in AAI/RAI by looking at how children naturally interact with three types of entity: dogs (‘dog’), a biomimetic robot animal (‘robot’), and a toy dog (‘toy’) in a free-play environment within a Science Centre. This present study follows on from our previous study (Barber et al., 2020), in which children interacted with the dog and robot on a one-to-one basis in a highly controlled setting. Since the real-world encounters that children are likely to have with dogs and robots (either in informal settings or in Animal/Robot Assisted Interactions) are likely to involve more complex environments, this study extends the external validity of our work with children to a more naturalistic encounter with the dog/robots. This study was comprised of two parts: observation of the child’s interactions with their chosen entity/entities and, immediately afterwards, the completion of a short, age-appropriate questionnaire. We studied children across a wide age range, allowing for direct comparison of their behaviour and questionnaire responses. The experimental set up also permitted children to choose which entities to approach (enabling children fearful of dogs to potentially interact with the toy and/or robot). Predictions for this study were based on the above review of the Biophilia hypothesis and studies indicating that children ascribe lifelike properties differentially to dogs, biomimetic robots and toys, and differences in time spent with these entities. Thus, although some individual may dislike dogs, overall we predicted that the majority of children in all age groups would express a preference for the dog and would attribute more lifelike properties to them compared to the toy dog and biomimetic robot (S. A. Gelman & Davidson, 2016). We predicted that there would be differences in the time spent in proximity to the Animals and Robots ('AaRs', a term devised by the researchers to refer to the three entities in the experiment: the dog, robot animal, and toy), though the reason for spending time with these entities might vary (e.g., novelty versus pleasantness) and the direction of these differences have been mixed in previous research (Barber et al., 2020; Ribi et al., 2008). We also predicted children would engage differently with each entity, predicting more pleasant social touch with the dog and more exploratory touch with the robot and toy. Finally, it was predicted that any unpleasant, aggressive behaviour would only be directed to the toy, reflecting differential ascribing of lifelike properties to the dog and robot, and the novelty of the highly advanced, biomimetic robot.

3. Method

3.1 Participants

3.1.1 Human Participants

115 children and adolescents participated in the study. Of these, 99 participants stayed after interaction with the Animals and Robots (AaRs) to fill in the questionnaire, whereas 16 participants only completed the interaction portion of the study. Completed questionnaires indicated that 36 participants were male and 63 were female. They were aged between 14 months and 14 years of age (M = 6.93, SD = 2.85), with 19 children in the 14 month-4 years age group, 47 in the 5-8 years, and 33 in the 9 years+ category (see Supplementary Information for frequencies of participant ages). The participants have been grouped into these age bands to reflect Piaget's stages of Life and Consciousness Attribution in Children starting at age 4 years+ and then increasing in sophistication aged 9 years+ (Piaget, 1929). From a practical aspect, children below the age of 4 years may struggle to understand the questions and answer meaningfully, so children aged 14 month-4 years were only asked which entity was their favourite and their parent/legal guardian answered the demographic questions on their child's behalf. Participants were a volunteer sample from members of the public attending the Winchester Science Centre (Hampshire, UK) on four days January-February 2020.

Most children answered all the questions. Only one child indicated that they did not like animals (likes animals N = 97, missing responses N = 1). Four of the children who responded to the question reported that they did not like dogs (likes dogs N = 92), and nine who answered reported not liking robots (likes robots N = 76). Most participants had pets at home (N = 63; no pets at home N = 36), with most owning one or more dogs (N = 27) followed by owning one or more cats (N = 24). Conversely, the majority did not have a robotic pet at home (N = 30; no robotic pet at home N = 65) and of those that owned robots, 25 were animal-like robots and 5 were humanoid robots.

3.1.2 Dogs ('Dog')

Three therapy dogs were used in the study to increase generalisability of the findings: a small female 4-year-old Jack Russell-Poodle cross breed, and two large dogs: a male 10-year-old Flat Coated Retriever, and a male 2-year-old Samoyed (Figure 1). All of the dogs were registered as qualified therapy dogs with Pets as Therapy (a national charity that provides therapeutic visits to pedagogic and healthcare institutions in the UK; Pets as Therapy, 2017) and were experienced at visiting a range of settings and meeting unfamiliar people. The dogs remained on a loose lead throughout the study for their safety; the lead was held by a handler, known to the dog, and children were discouraged from touching the dog's lead.

3.1.3 Robot Animal ('Robot')

The robot used was MiRo-E, a biomimetic robot designed by Consequential Robots for use in education and in human-robot interaction research (http://consequentialrobotics.com/). The MiRo-E robot is animal-like in appearance and behaviour, has a control system based on the mammalian brain, and is designed to be appealing to the user (Collins et al., 2015). It has been used as a comparator to a living therapy dog in previous research (Barber et al., 2020). It uses stereo HD cameras for facial and body language detection and optical navigation, quad microphones to detect and locate noises, and three Raspberry Pi B 3+ processors to analyse sensory inputs. MiRo-E uses a triangular configuration of wheels to move forwards and backwards and to turn. It can raise, lower, and tilt its neck and head, and is able to open and shut its eyelids and turn its ears independently of each other.

To indicate its 'mood', MiRo-E can emote by wagging its tail, lifting its head, and turning ears forward to an 'alert' position. Lights on the lateral body panels change colour with mood (green for happy, white for neutral, red for angry, and orange when asleep) and a loudspeaker produces animal-like chirping vocalisations, the pitch and frequency of which also change with mood (faster and higher pitched when in a good mood, lower pitched when angry, and slow when asleep). After a cycle of approximately 5 minutes, sleep mode is activated, indicated by the robot closing its eyes, colour change of lights to orange and becoming unresponsive to interaction. MiRo-E wakes up after a period of three minutes. Although this function could be turned off, it was left enabled, as it was deemed more comparable with the living dogs as they were able to sleep in the study.

3.1.4 Toy Dog ('Toy')

The control 'toy' condition was a commercially available small toy dog bought from Amazon UK, manufactured by 'Animagic' (https://www.amazon.co.uk/gp/product/B079V262J1/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&psc=1). The toy resembled a black and tan Miniature Dachshund dog and was 16.3cm L x 30cm W x 23cm H. Pressing a button on its head caused the toy to walk forward approximately 0.5m and bark four times. As participants were discouraged from touching the lead of the dog and the robot did not have a lead, the toy's lead was removed to better match the other AaRs.

3.2 Ethics

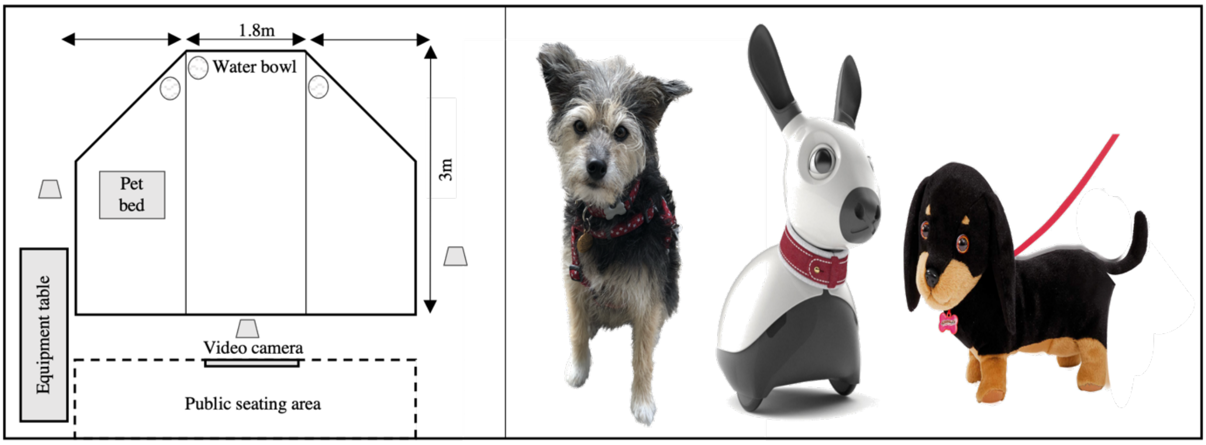
Ethical approval was attained from the University of Portsmouth's Science and Health Faculty Human Ethics Committee (ref: 2019 – 113A) and Animal Welfare and Ethical Review Body (ref: 1219D). The study adhered to British Psychological Society guidelines for human psychological research and the Society for Companion Animal Studies' Animal Assisted Interventions' Code of Practice (Society for Companion Animal Studies, 2019) and Guidelines for the Treatment of Animals in Behavioural Research (Association for the Study of Animal Behaviour, 2012). All potential participants and their parents/guardians were given an information sheet describing the study. written consent was attained from parents/guardians and the recruited children assented to participate. The dogs were used for a maximum of three hours per day, with ten-minute breaks every hour. The dogs had access to water throughout the sessions. The researcher, OB, who was familiar with the Department for Environment, Food & Rural Affairs' (DEFRA) guidance on dog-specific signs of stress, monitored the behaviour of the dog and children, and could terminate interactions if stress signals were exhibited. No interactions were ended early.

3.3 Procedure

The study was conducted at the Winchester Science Centre, an interactive science museum in Hampshire, UK, for 3 hours on each of four days January – February 2020. Signs were posted at the entrance of the Science Centre informing members of the public that there was an area of the museum set up by the University of Portsmouth where people would be allowed to meet some therapy "pets" (the AaRs). The signs included photographs of the AaRs. There was also a warning that people who were allergic to or nervous of dogs should avoid the specific location in the Science Centre where the experiment was conducted. This enabled visitors to make an informed choice about whether they approached the area.

The area consisted of three AaR "zones", where each of the AaRs was positioned with a researcher/handler (Figure 1). Each zone measured approximately 1.8m wide by 3m length (although constrained by the irregular shape of the area). The zones were cordoned off with white wooden balustrades approximately 4cm high and taped to the floor. This created distinct boundaries to prevent the AaRs from leaving the area and restricted the number of participants in each zone but allowed free movement of the children between the different zones. Three cameras (JVC Everio R435 series) were set up to record the behaviour of participants: one 1.5m in front of the zones, and one each to the left and right of the zones to ensure interactions would be visible at all times. One member of the research team sat on the floor with each of the AaRs as the 'AaR handler' to mimic the presence of a handler who would accompany a therapy dog on visits. There was also a medium-sized grey dog bed and a bowl of water for each of the AaRs. Allocation of AaRs to each zone and which member of the research handled each AaR was rotated throughout the day to ensure that participant behaviour was not affected by one area location or the unique characteristics of the AaR handlers. To the left of the study area was a table with the University of Portsmouth's banner and the tablets for the questionnaire and paper copies of the questionnaire. There was also a seating area with tables for members of the public, and participants either sat or stood at these tables to fill in their questionnaires.

Figure 1. *Experimental set up showing (a) the layout of AaR zones and (b) the robot, the toy and one of the dogs used in this study.*



a. b.

Potential participants approached the AaR zones of their own volition, however, a maximum of five people were allowed in each area at one time, although it was rare that more than three people were in each area together. The children always remained in sight of their parents/guardians and parents/guardians were able to accompany their children when they interacted with the AaRs if they chose to. No instructions were provided as to what the children could do with the AaRs to keep the situation as natural and child-led as possible (although the handler could provide guidance about how to interact with the AaRs if asked by participants). Participants were able to spend as long as they wished with each AaR and could move onto spending time with the next AaR when they wanted to, provided there were not too many people with the AaR already. They were also able to leave the area and return later if they wished. This meant that the amount of time a participant spent with the AaRs differed, and this was used in analysis as an indicator of interest in the AaR.

Whilst the children were spending time with the AaRs, a member of the research team approached the child's parents/guardians to explain the study and gain consent for their child's involvement. They were given an information sheet describing the purpose of the research and a consent form to sign. Attention was directed towards the cameras at this point to confirm that they were happy for the recordings of their children to be used for analysis. When the children had finished playing with the AaRs and had returned to their parents, the study was explained to them and verbal assent to participate was sought from the children. Consent from parents of very young children was sufficient for their participation. If the children did not want to participate in the study or if their parents/guardians did not consent to their child's participation, they were free to leave. Parents who did not provide consent for their children to participate were informed that footage of their child would be deleted if there were no other consenting children in the video. If other children who had consented to participate in the study were interacting with the entities at the same time, the non-consenting child's interaction would not be analysed and the non-consenting child would not be visible in any visual media presented as part of this research. Participants who were happy to continue completed the questionnaire on a tablet, sitting or standing in the public seating area. The questionnaire began with instructions that it was for them (the child) to complete, although they could be assisted to fill out the questionnaire by a member of the research team or their parents/guardians if they needed help. After they had spent time with the AaRs, all children were offered a certificate from the University of Portsmouth to thank them for their time, regardless of whether consenting to participate or not. After they had completed the questionnaire, participants and their families were free to leave.

3.4 Measures and Statistical Analysis

3.4.1 Questionnaires

Three questionnaires, adjusted to suit the developmental understanding of age groups 14 months-4 years, 5-8 years, 9+ years, were created on Google Forms, which were presented on Android tablets. We also had printed versions of the questionnaire as a back-up for any technological issues, although no issues occurred and all questionnaires were completed on the tablets. The order that participants were asked about the different AaRs for the mood, lifelikeness, and stroking ratings and Belief in Animal Mind scale were counterbalanced to prevent order effects. The contents of the questionnaires and details of analysis are outlined below:

Demographic questions: Participants were asked their age, gender (male, female, other, do not want to say), "do you have a pet at home?", followed by "if yes, please tick all the pets that you have: dog, cat, rabbit, guinea pig, hamster, rat/mouse, fish, bird, horse, reptile, other [free text]" and "do you have a robotic pet at home?", followed by "if yes, please tick all the pets that you have: tamogotchi, furby, walking pet, other [free text]". They were also asked "do you like animals?", "do you like dogs?", and "do you like robots?". The parents/legal guardians of participants aged 14 months - 4 years completed the demographic questions on their child's behalf.

Preference: Participants were given a single forced-choice question "which was your favourite pet to spend time with?", indicating their answer by selecting a picture of the dog, robot, or toy. Participants 14 months-4 years were only asked their preference and then their participation in the questionnaire was complete. Participants in the older two age groups (5-8yrs, 9yrs+) were also asked to provide a short written explanation for why they chose their answer (helped by their parents if necessary).

A chi-squared Goodness of Fit test was used to detect differences in AaR preference. Comparison of preference between the age groups was performed using the chi-squared test of association, with post hoc comparisons performed using pairwise Z tests with Bonferroni correction applied for an alpha level of $p < .006$. Themes were extracted from the participants' explanations of choice using a thematic analysis (Braun & Clarke, 2006), grouped together based on emerging similarities throughout all the question responses using the process of clustering (Miles & Huberman, 1994). The number of mentions of the themes and subthemes for each AaR were totalled. Prototypical examples of qualitative responses were chosen to illustrate points in the discussion.

Mood: To measure the participant's emotional state, participants were asked "how were you feeling when you spent time with the [dog/MiRo/toy]?". Participants could choose their response from 6 emotion pictograms (happy/cheerful, sad/worried, angry/mad, excited, relaxed, scared/frightened). Participants were informed that they could choose as many emotion words as they wanted to. The total frequencies of each emotion word selected by participants was compared between AaR conditions using Cochran's Q. Post hoc analysis with McNemar's tests comparing between the AaR conditions was conducted with Bonferroni correction applied, resulting in a significant level set at $p < .017$.

Lifelikeness: The definition of "lifelike" as meaning "that the thing looks and acts like it is alive" was provided in the questionnaires for the older two age groups (5-8yrs, 9yrs+) to ensure that participants understood the term before answering the question. The youngest children were not asked to rate lifelikeness because the concept and question was deemed too complex for them to understand. Participants were then asked to rate whether each of the AaRs were lifelike, using a three-option multiple choice response ('yes'/'a bit'/'no'). These responses were scored 3 for 'yes', 2 for 'a bit, and 1 for 'no'.

Stroking: Participants were asked to rate whether the AaRs were nice to stroke using the same three-option response format as the above 'lifelikeness' question and same scoring.

Differences in participant opinions of lifelikeness and niceness to stroke between the three AaR conditions were tested using the non-parametric Friedman's test. Post hoc analyses for these two questions were conducted using a Wilcoxon signed-rank test with Bonferroni correction applied, resulting in a significance level set at $p < .017$. The relationship between lifelikeness and stroking rating with age were tested using the non-parametric Spearman's rho.

Belief in Animal Mind scale (Knight et al., 2004)*:* Participants in the two older age groups completed the four-item Belief in Animal Mind ('BAM') questionnaire twice (once asking about the dog and once about the robot) to test for differences in mental state and ability attributions by the participants between AaRs. We did not ask the youngest age group of children as they would not have been able to provide meaningful responses and we did not ask about the toy comparison condition. Responses for each item scored between 1 and 5, with total scores ranging between 4 to 20. A higher total score indicated a higher attribution of mental capacity to animals and robots. Statements in the scale included: (i) Dogs/robots are unaware of what is happening to them, (ii) Dogs/Robots are capable of experiencing a range of feelings and emotions (e.g. pain, fear, happiness, love), (iii) Dogs/Robots are able to think to solve problems and make decisions about what to do, (iv) Dogs are more like computer programs. They react to their feelings without knowing what they are doing. The questionnaire was presented in its original format for the 9yrs+ age category, with the word 'animals' in the statements replaced with "dog" or "robot". For the 5-8yr olds, the statements were replaced with questions suitable for their understanding (e.g., 9yr+ version: "Dogs are unaware of what is happening to them", 5-8yr version: "Do dogs know what is going on?") and participants responded with the three-point agreement rating scale ('yes'/'a bit'/'no'). Internal reliability of the dog BAM scale was low ($\boldsymbol{\alpha}$ = 0.24) and that of the robot BAM scale was moderate ($\boldsymbol{\alpha}$ = 0.63). These were similar to the low to moderate reliability of these scales reported in our previous research (Barber et al., 2020), although they have been reported as reliable in past studies (Knight et al., 2004; Menor-Campos et al., 2018). Scores were non-normally distributed, so the Wilcoxon test was used to compare between scores for the dog and robot scales and Spearman's rho was used for correlations with age.

3.4.2 Behavioural Data

Video recordings were taken of the participants interacting with the AaRs. Videos were edited to produce discrete videos of participants that consented to participate in the research *(N* =115). Instances of individuals who did not want to participate were very rare and the majority of people were happy to participate. The AaR that the participant visited first was recorded as a measure of their "first choice", as well as whether AaRs were busy and whether the participant was encouraged to visit that AaR by a guardian. There was no impact of being encouraged to approach the AaR zones by parents (χ^2 (2) = 2.12, p = .35) or whether the zones were busy (χ^2 (2) = 2.14, p = .34) on first choice of AaR to visit, so these cases were retained in the dataset during subsequent analyses. Comparison of durations of time with, looking, and touching the AaR were performed using the Mann Whitney U test. The duration of specific state behaviours, and frequency of point behaviours, performed by the child participants was coded. Data were coded using BORIS (Friard & Gamba, 2016) (see Table 1 for coding scheme). Proximity to the AaR (child within 1m of the AaR), time looking at the AaR, and time touching the AaR was recorded (in sec) for each AaR the participant interacted with. If children left the AaR and returned later, behavioural coding was totalled across both visits (although only their initial first choice of AaR on their first visit was recorded); there only were five instances of this occurring. A Chi-squared Goodness of Fit test was used to detect differences in first choice of AaR visited, and the relationship between AaR first approached and length of time spent with the AaRs was assessed using multivariate logistic ANOVA tests.

Specific behaviours were distinct behavioural events performed by the child towards the AaRs, based on behaviours identified in previous research. These discrete behaviours were categorised into "pleasant", "exploratory", or "unpleasant" behaviour based on amount of pressure used, velocity, harshness of touch (Chinn et al., 2019) and holistic judgements of the participant's facial expressions, body language, and behaviour. Pleasant touches were defined as touches that were affiliative and were characterised as being light in pressure, smooth, performed at a slow velocity (Chinn et al., 2019) and performed in conjunction with positive (happy/relaxed) facial expressions, body language, and behaviour. Unpleasant touches were defined as behaviours that would likely not be enjoyable for the recipient (Ellingsen et al., 2016), being harder (more pressure), at faster velocity, and using harsher gestures. Exploratory touch was categorised as a form of active touch where information (e.g. about texture, composition, weight, temperature) was sought from the object being touched (Gibson, 1962; Hartmann, 2009). Exploratory touches were performed with slightly more force than pleasant touches but without the apparent negative intent or intense pressure of unpleasant touches. Judgment of exploratory intent was made by assessment of behaviour seen as being inquisitive, such as touching or gently manipulating the ears, tail, or collar of the AaR, lifting up the AaR and placing down carefully, looking closely at the AaR's head or body.

Additional behaviours coded included "representational play" (only observed in the toy condition), "participant vocalisation", and functional behaviours of "taps toy" (to start the movement mechanism) and "child relocates AaR" (also only seen in the toy condition). Comparisons were made between the duration (in sec) of specific behaviours and behaviour categories during the dog, robot, and toy interactions. Coding reliability was assessed by a trained observer watching a random selection of five videos of a child interacting with each AaR from each of the four test sessions (17.4% of total AaR videos). Cohen's Kappa coefficients for all behaviour variables ranged from 0.89-0.99 and therefore, the reliability could be considered excellent. To explore the effect of age, age in years was entered both as a continuous variable and as a categorical variable (14 months-4yrs; 5-8yrs and 9+yrs). As total durations of the various behaviours were non-normally distributed, Friedman's test was used to compare between the AaR conditions, with post hoc analysis conducted using a Wilcoxon signed-rank test with Bonferroni correction applied, resulting in a significance level set at $p < .017$.

Table 1

Coding Scheme for Behavioural Observations

Action	Definition
First choice	Indicate whether the AaR in question was the first AaR the child approached to within close proximity, measured by being within 50 cm. Record AaR type first approached on spreadsheet.
Encouraged by parent?	Did anyone else (parents, peers, researchers) encourage them to approach? Record Y/N (yes/no) on spreadsheet.
AaRs busy?	Did the AaR have any other children interacting with them when the first choice was made? Record Y/N (yes/no) on spreadsheet.
Proximity to AaR	Total amount of time the child is within 1 metre of the AaR. Mark start and end time points of each time child is within 2m during the session.
Total touching AaR	Total amount of time spent initiating interactions with the dog/robot during the session. Calculated by summing the total amount of time spent engaged in one or more touching behaviours outlined below.
Total looking at AaR	Total amount of time the child is looking at the AaR until they look elsewhere during the session.
Pleasant Behaviour	
Mark start and end time point of child touching AaR with 'pleasant touch'. Touch of the same type counts as a session, providing the child does not stop for longer than 2 seconds.	
Stroke	Total time child strokes the AaR with the front or back of open hand or fingers during the session.
Hug	Total time child's arms are encircled around the AaR at intimate distance (Forsell & Åström, 2012) during the session.
Lean on	Total time child rests portion of their body mass or head on AaR's body during the session.
Kiss (-)	Frequency count of the number of times child presses their lips to AaR's body (Kirshenbaum, 2011) during the session.
Pat (-)	Frequency count of number of times child makes single open hand contact of dog/robot's head or AaR's body during the session.
Exploratory Behaviour	
Mark start and end time point of child touching AaR with 'exploratory touch'. Touch of the same type counts as a session, providing the child does not stop for longer than 2 seconds.	
Exploratory touch	Total time child plays with ears, tail or collar of AaR with hands or fingers during the session.

Pick up	Total time child lifts the AaR into the air and gently places AaR back on ground in same location during the session.
Close looking	Total time child moves closer to the AaR to look intently at part of AaRs' head or body during the session.
Touch eye	Frequency count of number of times child gently touches the AaRs' eye with their finger during the session
Manipulates body part	Child holds body part of AaR with their hand and pulls away from AaRs' body or pushes body part to move it. (was pulls body part)
Sniff pet (-)	Frequency count of number of times child moves closer to the pet with their nose and inhales deeply during the session.
Lick (-)	Frequency count of number of times child puts tongue on pet during the session

Unpleasant Behaviour

Unpleasant touches are defined as behaviour that are not enjoyable for the recipient and are accompanied by negative affect and pain (Ellingsen et al., 2016). Characterised as being harder (more pressure), at faster velocity, and harsher gestures. Intention of child inferred by holistic assessment of more negative (angry/aggressive) facial expressions, body language, and behaviour.

Pinches (-)	Frequency count of number of times child exerts pressure, squeezing tip of thumb and forefinger together on part of animal's body during the session.
Throws (-)	Frequency count of number of times child lifts the AaR into the air and propels AaR away from their body through the air with force during the session.
Slaps (-)	Frequency count of number of times child hits the AaR's body with flat of hand using considerable force during the session.
Punches (-)	Frequency count of number of times child hits the AaR's body with closed fist using considerable force during the session.
Kicks (-)	Frequency count of number of times child's foot hits AaR's body with considerable force during the session
Pokes eyes/body (-)	Frequency count of number of times child's tip of one finger poked into AaR's eye with force during the session

Play Behaviour

Representational play	Total time spent playing in manner that treats the AaRs as a living animal during the session, e.g. taking the AaR for a "walk", tucking into bed. Record on spreadsheet what play is seen.

Child vocalisation	Total time child spends talking to handler, researcher, family member, or AaR during the session.
Child out of sight	Total time child cannot be seen in video frame, starting from when child exits the video frame or view of child is obscured to the point when the child re-enters camera frame or view is resumed.

Functional Behaviour

Taps toy	Frequency count of number of times child makes single open hand contact of toy's head to make it walk during the session.

Child relocates AaR	Total time child moves the AaR from one location to another location in the zone by picking up or pulling along ground, excluding instances where child is picking pet up to hug or play with the toy.
Offers treat (-)	Frequency count of number of times food treat is offered to AaR for them to eat during the session.

(-) = frequency point events.

4. Results

4.1 Questionnaires

Preference: Participants reported a significant preference for their interaction with the live dog (N = 67) compared to the robot (N = 12) and toy (N = 17), χ^2 (2) = 57.81, p < .001. There were differences in preference reported across age groups (χ^2 (4) = 25.61, p < .001), with a moderate effect size Cramer's V = .37 (Cohen, 1988). For the youngest age group of children (14 months-4yrs), preference was split fairly evenly between the toy (52.6%) and dog (36.8%, z = -0.98, p = .33), but fewer preferred the robot (10.5%; dog-robot: z = 1.91, p = .06; robot-toy: z = -2.79, p = .005). In the older age groups, there was a clear preference for the dog in both 5-8yr olds (dog = 68.1%, robot = 17.0%, toy = 14.9%; dog-robot z = 5.01, p < .001; robot-toy z = -0.28, p = .78, dog-toy z = 5.24, p < .001) and 9yr+ group (dog = 93.3%, robot = 6.7%, toy = 0.0%; dog-robot z = 6.71, p < .001; robot-toy z = 1.44, p = .15, dog-toy z = 7.25, p < .001).

There was no impact of gender (χ^2 (2) = 1.06, p = .61), pet ownership (χ^2 (2) = 1.01, p = .61) or robot ownership (χ^2 (2) = 1.65, p = .44) on preference. Almost all participants reported liking dogs (93.8% agreed) or animals (99.0% agreed), thus the effect of this on preference could not be analysed. There was no relationship between participants reporting that they liked robots (χ^2 (2) = 0.51, p = .78) and AaR preference.

Thematic Analysis indicated four themes and seven subthemes from participant responses explaining their selection of preference (Table 2). The main themes are explored in the Discussion.

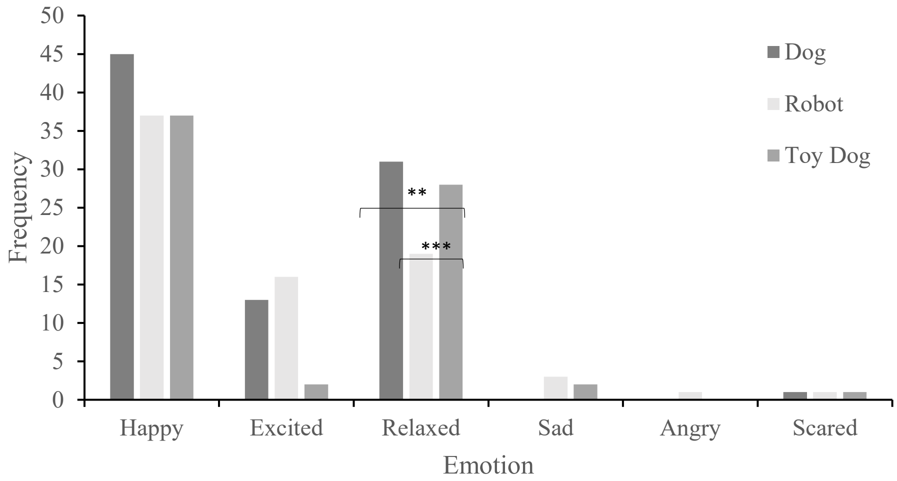
Table 2. *Themes and Subthemes Identified from Participants' Open Text Explanation of AaR Preference.*

Theme	Subtheme	Dog	Robot	Toy
Real dogs	Aliveness	18	1	-
	Relationship with other dogs	6	-	2
Aesthetic & tactile appeal	Appearance	7	-	1
	Fluffy/Furry	22	1 (-1)	-
	Pleasant social touch	6	-	-
Interactivity		7	4	2
Relaxation		7	4	-

Note: (- X) indicates a mention of theme indicating a negative attitude.

Mood: Participants reported feeling 'happy' a similar number of times for all AaR conditions (χ^2 (2) = 2.91, p = .23) but the number of 'excited' (χ^2 (2) = 13.04, p = .001) and 'relaxed' (χ^2 (2) = 6.69, p = .04) selections differed between AaR conditions (Figure 2). There was no difference between participants reporting they felt 'excited' between the dog and robot (p = .68), but far fewer participants reported feeling 'excited' about the toy when compared to the dog (p = .003) and robot (p < .01). Pairwise comparisons also revealed that there were no significant differences, after Bonferroni correction was applied, between feeling 'relaxed' for the dog and toy (p = .66), robot and toy (p = .09), or dog and robot (p = .03), although the latter comparison approached significance. Very few negative emotion words were selected by participants for any of the AaRs (dog $\Sigma = 1$, robot $\Sigma = 5$; toy $\Sigma = 3$), thus statistical analysis could not be performed [38].

Figure 2. *Frequency of Selections of Emotion Words for the Dog, the Robot, and the Toy.*

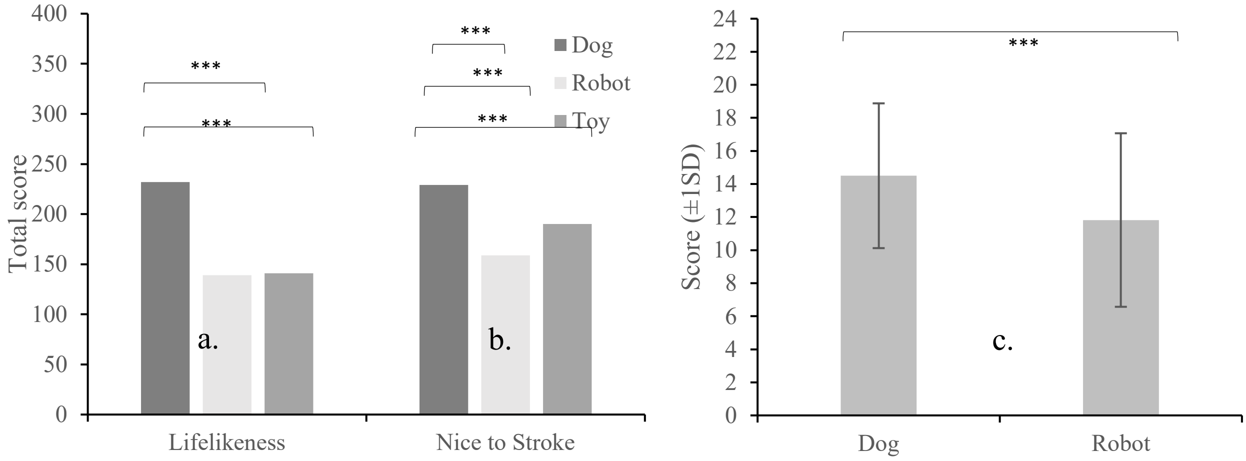


Note: * p < .05, ** p < .01, *** p < .001

Lifelikeness: There was a significant difference in lifelikeness ratings between the AaR conditions (Z = 81.21, p < .001), with participants rating the dog as more lifelike than the robot (Z = - 6.48, p < .001) and the toy (Z = - 6.72, p < .001) and no difference between the robot and toy (Z = - .11, p = .91; Figure 3a). There was no association of lifelikeness ratings with age for the dog (r_s = .10, p = .40) or robot (r_s = .13, p = .23), but there was a negative correlation between age and lifelikeness rating for the toy (r_s = -.35, p = .002), indicating that older children were less likely to rate the toy as lifelike.

'Niceness to stroke': Likewise, there was a significant difference in ratings of how nice the AaRs were to stroke ($Z(2)$ = 50.01, p < .001; Figure 3b). The dog was rated as the nicest to stroke, followed by the toy (dog-toy Z = - 3.62, p < .001), and the robot rated as the least nice to stroke (toy-robot Z = - 4.54, p < .001; dog-robot Z = - -5.40, p < .001). There was no association of age with stroking ratings for any AaR conditions (dog r_s = - .14, p = .23, robot r_s = - .17, p = .15), although the relationship between stroking rating and age approached significance (toy r_s = - .23, p = .06).

Figure 3. *Ratings for the three AaRs for (a) Lifelikeness, (b) 'Niceness to Stroke', and (c) Belief in Animal Mind.*



Note: * $p < .05$, ** $p < .01$, *** $p < .001$

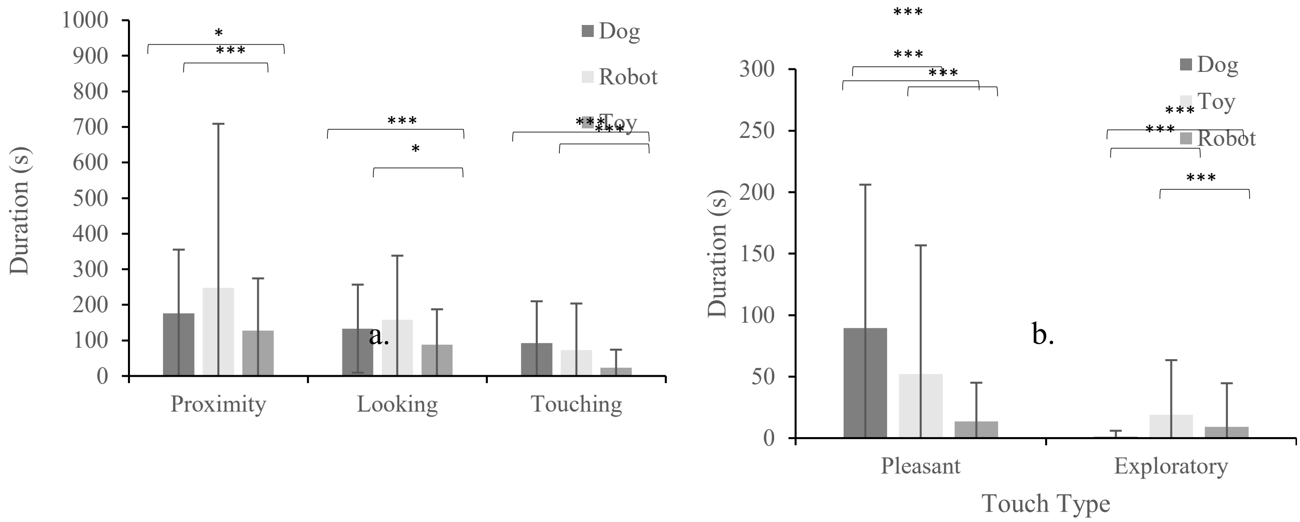
Belief in Animal Mind (BAM): Scale scores were higher for the dog than for robot (Figure 3c) indicating significantly higher attributions of mental capacity to the dogs than the robot, $Z = -4.17$, $p < .001$. There was a weak negative relationship between age of participant and BAM score for dog ($r_s = -.27$, $p = .02$) but no relationship between age and robot BAM score ($r_s = -.004$, $p = .98$). Participants who provided higher scores for the dog were also likely to score the robot highly ($r_s = .28$, $p = .01$), but there was no relationship between preference and BAM scores for the dog (χ^2 (2) = 1.19, $p = .55$) and robot (χ^2 (2) = .17, $p = .92$).

4.2 Behavioural Data

Participants approached the dog first most often ($N = 62$), followed by the robot ($N = 31$) and the toy was approached first least often ($N = 20$) χ^2 (2) = 25.19, $p < .001$. No relationship was found between first choice and amount of time in proximity to the AaR (χ^2 (6) = 9.32, $p = .16$). Observations demonstrated that participants who completed the questionnaire did not necessarily spend the longest amount of time with the AaR that they selected as their favourite in the questionnaire (χ^2 (4) = 8.45, $p = .08$) nor did they approach their stated favourite AaR first (χ^2 (6) = 7.45, $p = .28$). The choice of favourite AaR was not affected by how busy the zone was (χ^2 (2) = 0.37, $p = .83$) nor being encouraged by parents to approach a particular AaR (χ^2 (2) = 1.32, $p = .52$).

Participants spent different lengths of time with the three AaRs (Figure 4a), χ^2 (2) = 7.61, $p = .02$. Post hoc analyses indicated that participants spent a similar amount of time in proximity to, looking at, and touching the dog and the robot (proximity: $Z = -.95$, $p = .34$; looking: $Z = -.97$, $p = .33$, touching: $Z = -1.69$, $p = .09$), but less time with and looking at the toy compared to the dog or robot (dog-toy proximity: $Z = -2.28$, $p = .02$, looking: $Z = -4.19$, $p < .001$, touch: $Z = -6.24$, $p < .001$; robot-toy proximity: $Z = -3.36$, $p < .001$, looking time: $Z = -2.44$, $p = .02$, touch: Z = - 4.77, p < .001). Likewise, participants spoke for a similar amount of time in the dog and robot conditions (Z = -2.98, p = .003) and spoke during the toy condition for the shortest duration (dog-toy: Z = -2.98, p = .003; robot-toy: Z = -1.69, p = .09). If the zones were busy, participants spent more time in proximity to (busy M = 175.69, SD = 181.56, not busy M = 114.07, SD = 181.56, U = 6701.00, p < .001), looking at (busy M = 117.87, SD = 130.94, not busy M = 72.80, SD = 126.50, U = 6832.00, p < .001), and touching (busy M = 87.03, SD = 129.50, not busy M = 50.86, SD = 97.07, U = 7800.50, p < .001) the AaRs.

Figure 4. *Mean (+/-1SD) Amount of Time Children Spent in (a) Proximity to, Looking at, and Touching the AaRs and (b) engaging in Pleasant and Exploratory Touch)*



Note. * p < .05, ** p < .01, *** p < .001. Unpleasant behaviours are omitted from figure as very few unpleasant behaviours were observed.

There were differences in duration of categories of behaviour (pleasant and exploratory) used by participants towards the AaRs (Figure 4b). Participants engaged in pleasant behaviours for the longest duration with the dog, followed by the robot, and for the least amount of time with the toy (χ^2 (2) = 62.51, p < .001; post-hoc tests: dog-robot Z = -3.20, p = .001; dog-toy Z = -7.27, p < .001; robot-toy Z = -5.03, p < .001). Participants stroked the dog for longest, followed by the robot (χ^2 (2) = 27.00, p < .001; dog-robot Z = - 3.18, p = .001), and stroked the toy for the shortest amount of time (dog-toy Z = -7.40, p < .001; robot-toy Z = -5.22, p < .001).

Conversely, participants spent the shortest duration of time in exploratory behaviours with the dog and longest with the toy (χ^2 (2) = 26.66, p < .001; post-hoc tests: dog-robot Z = -4.79, p < .001; dog and toy Z = -3.50, p < .001; robot and toy Z = -2.37, p = .02). Data from all the participants showed five instances of the robot's eye being touched and three of it being poked. The toy was slapped five times. There were no instances of the dog's eye being touched (considered exploratory, see Table 1) nor of the dog or robot being slapped. A small number of participants of all ages (Σ = 14, 14 months-4yrs N = 3, 5-8yrs N = 7, 9+yrs N = 4) engaged in representational play with the toy and this included the participants placing the toy in the bed to sleep or encouraging the toy to eat from the food bowl. No representational play events were observed with the robot or dog. No unpleasant behaviours were observed for the dog, but the three instances each of poking the robot's eye and slapping the toy were recorded as unpleasant.

5. Discussion

The present study assessed children's attitudes and behaviour towards a dog, robot animal, and toy during free play in a naturalistic setting. Based on related work and the Biophilia hypothesis, it was predicted that children in all age groups would exhibit a preference for the dog and would attribute more lifelike properties to them. We also predicted that there would be differences in the time in proximity to the Animals and Robots (AaRs), and differences in the types of behaviour displayed towards the objects. In particular, it was thought that there would be more pleasant social touch with the dog, more exploratory touch with the robot and toy, and that any unpleasant, aggressive, behaviour would only be directed to the toy.

We found that most participants preferred the dog, although preference was split for the youngest age group of children (14 months-4yrs) between the dog and toy. Participants also rated the dog as more lifelike and nicer to stroke than the other AaRs. They scored the dog higher on the Belief in Animal Mind scale than the robot, attributing the dogs with awareness of their surroundings, having emotions, having motivations and mental processes, and several participants referred to the "aliveness" of the dog in their qualitative answers. However, there was a similar pattern of emotion words reported across all of the AaR conditions. Participants approached the dog first most frequently, although they spent a similar amount of in proximity to the dog and robot, possibly due to the novelty of the robot. They spent the longest duration engaging in pleasant behaviours with the dog, and in exploratory behaviours with the toy. Unpleasant behaviours were observed very infrequently (6 instances in total) and only with the toy and once with the robot, fortunately not replicating existing literature finding a propensity for abusive behaviour from people towards some robots (Bartneck & Hu, 2008; Keijsers & Bartneck, 2018).

The preference for the dog over a robot or toy was consistent with previous work and supports the stringent interpretation of the Biophilia hypothesis as referring principally to living organisms by demonstrating that children have an attraction to animals (Wilson, 1984). Most of the children reported that they like dogs and animals, and some (N = 6) referred to another dog that they like or have a relationship with when explaining their preference (e.g., "remind[ed] me of our old dog" or "even though I don't have a dog, I treat other ones as if they are part of my family"). The Biophilia hypothesis as a driver of preference for the dog was further reinforced by higher scores for "lifelikeness" and Belief in Animal Mind scale, and multiple mentions of the dog being "alive" or a "real dog" in qualitative explanations of preference. It was unclear why there was a weak inverse relationship between BAM score and age for the dog. Possibly, this could be due to the younger children's proneness to anthropomorphic and animistic thinking causing them to have ascribed more mental state abilities to the dogs than their more rationally-minded, older counterparts (Airenti, 2018; Russell & Dennis, 1939). The average BAM score in this study for 11-12year olds was lower than in a previous study of participants in this age group by the authors, possibly due to the children in the previous study having a familiarisation session with the AaRs prior to the test session (Barber et al., 2020). This suggests that increasing the amount of time and experience children have with non-human entities might change the animistic properties they ascribe to them, but this would require further investigation.

Due to the succinctness of participant written responses, the precise reasons for why being alive was such an important factor in their preference or explanations for how they made this distinction was unclear. One explanation may simply be that the dog was often referred to during the interactions by its real name thereby potentially anthropomorphising it and imbuing it with animism, whereas the robot was called by the brand name "MiRo robot" and toy referred to simply as "toy dog", so this should be controlled for in future research. It is important to note that the preference question was before questions about lifelikeness and the BAM scale, so it was unlikely that they were primed to mention this feature in their written feedback. In a previous study by Konok, Korcsok, Miklósi, and Gácsi (2018), aliveness was also given as the reason why participants preferred their living dog over the prospect of owning a robotic dog and contributed to views that robots could not be loved as much or make as good companions as dogs. Additional factors identified in Konok et al.,'s study as leading to a preference for dogs over companion robots included that dogs are able to display emotions, personality, and attachment. It may also be the case that factors other than the living/non-living status of the AaRs in our study influenced children's evaluations and interactions with them, such as the AaR's physical appearance, movement, or surface texture. Other environmental factors introduced by the naturalistic setting may also have influenced participant interactions and evaluations of the AaRs, such as the social influence of other people. The presence of others appears to have provided a social facilitation effect whereby participants spent more time in proximity to, looking at, and touching the AaRs when the zones were busy. Despite the additional social factors, the results observed here show strong parallels with the results of our previous controlled study of one-to-one interactions between children and AaRs (Barber et al., 2020). This new setting provided a good test of the effects of natural social interactions on children's behaviour towards and perceptions of AaRs in a location that is more comparable to the informal social settings in schools, hospitals, and other locations where Dog/Robot Assisted Interactions may occur.

Although we found an overall preference for the dog, AaR preference was split between the dog and toy for the youngest children (14 months-4yrs). Language and conceptual barriers prohibited us from asking the youngest age group of children the reasons for their preference or about the living status of the AaRs. The interest of the infants by the AaRs in our study is unsurprising, given the claims that the affinity for animate objects emerges at an early age (R. Gelman, 2002). There are many potential explanations for why the youngest children exhibited a preference for the toy at a higher rate than the older age groups, including lowered inhibition when playing with the toy due to familiarity with playing with toys (Casby, 2003), inability to play with a real dog in the same way as the toy, difficulties in interpreting the body language and intent of a real dog, or a wariness of the potential danger associated with a real dog (Arhant et al., 2017).

Despite using a highly advanced, biomimetic MiRo-E robot in this study, it was easily recognisable as being a human-designed machine to the children. BAM scores for the robot were stable for the different ages in this study, suggesting that there were no developmental changes for this particular animal-like robot in the age of children answering the BAM scale (5 years and older). This supported the assertion that children as young as 5 years old can readily discern between living animals and non-living, animal-like artifacts (R. Gelman, 2002). Participants rated the robot and toy as being comparably *non*-lifelike, which suggested that even the more animal-like control system and behaviour of the MiRo-E robot was insufficient in this case for challenging the ontological categories of the children. We found that even the self-propelled movement of the MiRo-E, identified as a requirement for being rated as alive by children found in previous literature and which sharply contrasted with the toy dog needing physical input to move, was insufficient to produce attributions of aliveness (Dellantonio et al., 2012; Di Giorgio et al., 2017a; Setoh et al., 2013).

Behavioural observations of the interactions also lent tentative support to the idea that the participants were aware of the categorical distinction of "aliveness" between the AaRs, influencing them to behave differently with the AaRs. For example, the children spent longer time engaging in pleasant social touch with the dog than the dog or robot. Stroking has been demonstrated in observational studies previously as a behaviour most commonly engaged in for children with dogs (Arhant et al., 2017) and stroking a dog increases oxytocin and lowers heart rate, leading to feelings of relaxation and stress regulation (Odendaal & Meintjes, 2003). Caution is advised however about assuming a causal relationship between aliveness and pleasant touch behaviour. Participants rated the dog as significantly nicer to stroke than the robot and toy, and several participants (*N* = 22) in our study mentioned the dog's "fluffy" or "furry" coat as a reason for their preference of the dog and, suggesting that the tactile surface of the dog's fur was important to their evaluations. Likewise, in ratings of nice to touch, the toy was considered significantly nicer than the robot. The robot had a hard plastic surface and the toy a fluffy covering over a hard surface. Thus, it could be argued that the increased amount of time in pleasant social touch was primarily because of the soft texture of the dog's fur rather than its aliveness. There may be additional stimuli associated with this, such as the warmth and softness of the dog's body under the fur, compared to the hard, unyielding surface of both the toy and robot. As a minimum, future studies should attempt to match the texture of AaR alternatives to that of a dog's fur.

Despite enjoying engaging in positive social interaction with the dog, the participants spent a comparable amount of time in proximity to the dog and robot, suggesting that some features of the robot were interesting and worthy of the participants' time. This result differs from our previous research, in which we found that children spent a longer amount of time interacting with the robot. However, both studies highlight the potential benefit of using robots in therapeutic contexts where they can be used for a long period of time without negative effects on their welfare and can sustain the prolonged attention of the user (Barber et al., 2020; Ribi et al., 2008). It may also lend support to findings from existing attitudinal studies that found people conceptualise animal-like robots as being pet- or toy-like role, whereas humanoid robots perform concrete tasks in society, thereby suggesting that children may be more comfortable interacting with the animal-like form (Nomura, 2017). The prolonged interaction durations recorded here may be due to the novelty of the MiRo-E robot, as certain participants were observed engaging in explorative touch with the robot and also may have spent more time discussing the robot with the handler, though it was not possible to interpret the audio recordings taken during data collection due to the level of background noise from the Science Centre. Future studies could investigate how to manipulate this novelty effect, possibly by increasing exposure to and knowledge about the AaRs prior to the experimental sessions.

The importance of novelty during these interactions is further supported by participants spending the longest amount of time performing exploratory touches with the toy. Exploratory touch is likely to facilitate the child's hypothesis-testing about the unfamiliar robot and toy, and has been demonstrated as being a superior method for knowledge acquisition about objects than identifying by name or description of function (Legare, 2012). Representational play in the form of the children performing actions typically associated with caring for a real dog (McCune, 1995), such as placing into bed or taking for a walk, was observed only in the toy condition. It was interesting that children engaged in representational play with the toy dog given that its lead had been removed; in future, a collar and lead will be put on all of the AaRs in our studies to better match the one worn by the real dog. Exploratory behaviours were barely observed and play never observed with the dog. Rather, children spent most of the time with the dog simply stroking it. This likely reflects children having been socialised (or even received formal instructions) about the "correct" way to interact with dogs for the safety and wellbeing of both parties. Likewise, we also observed either only short durations or no instances of the children hugging, leaning on, or kissing the dog. These and exploratory behaviours often seem benign to human observers but can cause discomfort or fear in dogs and resultantly, are frequently associated with succeeding dog snaps or bites (Arhant et al., 2017).

One of the goals of the study was to allow participants access to the AaRs without requiring them to spend time with the dog, thereby enabling participants to encounter alternative AaRs if they did not like dogs. There are many people who do not enjoy interacting with dogs for a variety of reasons and between 2.5% and 15% of the population are allergic to dogs (Bjerke et al., 2001; Lakestani et al., 2011) Consequently, individuals who do not like dogs are less likely to partake in AAI sessions, volunteer to participate in scientific research about the efficacy of therapy dogs, or derive benefits from interacting with them. For these individuals, a social robot used in Robot Assisted Interventions ('RAI') may be preferable and, as one participant wrote about the robot: "you know you are going to be safe". Despite individuals being able to participate by only interacting with the robot or toy dog, only four individuals who did not like dogs participated in the study. This number is far lower than the proportion of children reported to have a fear of dogs in the United Kingdom (37%; Dogs Trust, 2016), meaning that it may have been that the presence of a dog in the near vicinity of the other AaRs was sufficiently aversive for the child to not want to participate.

Overall, the children in this study seemed to recognise the categorical distinction between the living status of the AaRs, as evidenced by differences in 'lifelikeness' ratings and Belief in Animal/Robot Mind scores and also demonstrated in differences in participant behaviour between the AaRs. It seems that the interplay of children recognising the living status of the dog as suggested by the Core Knowledge Systems of Agency and the "natural affinity for life" proposed by the Biophilia hypothesis was a major contributor to the majority of participants selecting this condition as their favourite. However, despite this, the robot was successful in sustaining the attention and in generating positive mood in participants, and therefore may be considered as a suitably novel alternative for the living dog.

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7. Supplementary Information

Table 1. Frequency of Participant Ages

Age (years)	Number of Participants	Study Group
1	2	14 months-4 years
2	5	
3	4	
4	8	
5	14	5-8 years
6	17	
7	9	
8	7	
9	13	9 years+
10	8	
11	8	
12	8	
13	2	
14	2	