Watching Animal-Computer Interaction: Effects on Perceptions of Animal Intellect

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ABSTRACT

Watching animals use digital technology is known to affect our attitudes towards them, but there has been little empirical study of this topic. There is a need for greater understanding of how technology can shape people's perceptions of other species, since human attitudes are a significant factor in animal welfare. We studied the effects of a digital installation, created as enrichment for zoo-housed orangutans. It was hypothesised that seeing the installation in use would strengthen zoo visitors' perceptions of orangutans' intellect and strengthen support for their conservation. Effects were investigated through visitor interviews (n=39) and surveys (n=101), comparing responses of people who saw the installation with those who did not. Seeing primates use the digital installation was found to be associated with stronger attribution of cognitive abilities. Watching animals comprehend game rules, and seeing their human-like patterns of interaction seemed to contribute to this effect. However, no overall impact was found on attitudes to orangutan conservation. This research provides insights into the potential effects of animal-computer interaction on the attitudes of human observers, and suggests avenues for technology design to strengthen people's understanding of animal minds.

CCS CONCEPTS

• **Human-centered computing** → Interaction design; Empirical studies in interaction design.

KEYWORDS

Animal-computer interaction, Belief in animal mind, Digital enrichment

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1 INTRODUCTION

People's attitudes towards animals and beliefs about animal minds shape the treatment and use of animals. The perceptions of people who work with animals, and broader societal attitudes, are significant factors in legislation, standards and norms relating to treatment of pets, livestock, zoo animals, working dogs, racing horses, and so on [20]. In particular, the extent to which people attribute cognitive abilities to animals, "belief in animal mind", is an important predictor of attitudes towards animal use, for e.g. research or entertainment [28, 32]. Similarly, concern for animal conservation and welfare is influenced by attitudes to the species and perceived similarity to humans [26] .

The potential impacts of animals' digital technology use on attitudes and perceptions of their mental capacities are at present poorly understood. It has been predicted that digital interventions for animals could have negative impacts on animal welfare, for example by promoting pet owners' misunderstandings of animals and their needs [34] or by interrupting positive human-animal interactions which contribute to livestock wellbeing [8, 30]. However, other works suggest that ACI can strengthen people's understanding of non-human users, with the potential to positively influence attitudes towards specific species. For example, primates' use of digital systems for cognitive research or enrichment has been investigated as a way to promote public interest in the species and their conservation in the wild [14, 44, 48] and has been shown to influence zoo visitors' empathic responses to the animals [55]. It has been argued that such interventions could play a valuable role in fostering moral respect for non-human primates by promoting contact, interaction, enlightenment and individualisation [7].
Responding to the need for deeper understandings of ACI impacts, we investigated how seeing a digital enrichment installation for orangutans impacted zoo visitors' perceptions of animal mind and conservation caring. This paper reports that the digital enrichment installation strengthened perceptions of orangutans' higher

cognitive abilities but had no effect on concern for the species' conservation in the wild. We offer insights into the ways in which installation design and the animals' interactions with the system contributed to perceived similarity to humans and their intelligence. From these, we propose that ACI design can contribute to public understandings of animal minds through 1) supporting people to accurately interpret animal behaviour and 2) promoting nuanced understanding of animal intelligence.

2 RELATED WORK

2.1 Scientific understandings of animal mind

Over the last two centuries there have been dramatic shifts in scientific thinking and expansion of knowledge about animals' capacity to think and feel. Early modern European thinking about animals was heavily influenced by Descartian notions of animals as "automatons" and the medieval concept of the "*Scala Naturae*" or 'great chain of being', in which animals are organised, and worth accorded, according to their apparent similarity to humanity [12:37]. From the latter 19th Century, Darwinian concepts of evolution challenged the notion of a fundamental distinction between emotional, behavioural and cognitive capacities of animals and humans [12:350; 19:35]. Knowledge about animal cognition and internal worlds has been developed through naturalistic experiments, comparative psychology, ethology, behavioural ecology and neuroanatomy [11, 39]. Animals' capacities for emotions are now being recognised by scientists from multiple disciplines [10, 39]. These advances have overturned the notion of a unidimensional 'scale' of intelligence, and given rise to deeper understandings of the complex ways in which a species' evolutionary history and associated survival pressures have given rise to distinct mental abilities [5].

2.2 Public understandings of animal mind

Public conceptions of animals' mental capacities diverge in several ways from scientific understandings. It is notable that most non-experts adhere to the notion of a single form of 'intelligence', generally do not link cognition with animals' evolution, and have a piecemeal understanding of what science has learned about animal minds [37]. Despite the widespread tendency to attribute thoughts and emotions to animals (particularly those with humanlike features) [54], intuitions about the minds of non-humans are often inaccurate, partially because they draw on people's abilities for reading other human minds [53]. ACI designers have confronted the challenge of interpreting animal behaviour to make accurate inferences about their motivations, preferences and desires with respect to novel interventions [21].

Studies of belief in animal mind indicate that people generally attribute greater cognitive capacity to animals which are closer to humans genetically, or in appearance closer to humans [13, 33]. Generally, less cognitive capacity and moral status is attributed to animals used for meat production but more to pets [3, 37], leading some to argue that the *Scala Naturae* has been replaced by a contemporary "sociozoologic scale" in which animals are ranked according to the benefits that they offer to humans [12:51]. The extent to which animals are seen as individuals with distinct personalities is another significant factor in its relative status. Generally only companion animals are afforded individual personalities, however it was found that after the experience of training chickens people were more likely to think that chickens have individual personalities [25]. Attribution of mind to animals is also influenced by factors such as gender, age, cultural background, education and prior experiences with the animal species [29, 35, 37, 38].

Prior research into belief in animal minds indicates that learning about animals' mental lives and cognitive abilities is associated with empathy for animals [29] and with stronger pro-animal attitudes [26]. Belief in animal mind seems to be an important factor underlying peoples' attitudes towards the use of animals for e.g. entertainment or research [32]. Interventions to strengthen knowledge about animals' mental capacities, for example through learning to train the animal, have been found to elicit more positive perceptions of the species [25].

2.3 Comparing animals to humans

In making inferences about animals' thoughts and feelings, it is common for people to unconsciously engage in "anthropomorphic thinking"; we have a tendency to apply the psychological mechanisms which allow us to "read" the inner states of other humans [53]. This often leads to misattribution of human-like mental states to animals. In doing this, people draw on knowledge of self, "egocentric knowledge", and of humans in general, "homocentric knowledge" [15]. It has been suggested that seeing animals use technology reminiscent of systems used by humans can create an "anthropic frame", in that it prompts people to draw on egocentric knowledge and homocentric knowledge to make inferences about animal behaviour [55].

2.4 A cross-disciplinary framework of animal mind

There is considerable diversity in the way that animal intelligence has been conceptualised by the psychological and social sciences. According, we adapt the transdisciplinary framework developed by Fraser et al. [20] to develop a conceptual framework of animals' cognitive capacities shown in Table 1. This framework defines nine categories of cognitive abilities (column 1) and a list of representative indices of cognitive abilities, which were identified through a literature review and peer discussion (column 2). Against these categories are mapped concepts related to belief in animal mind, identified through a review of social science literature.

Mental capacities attributed to animals can be broadly categorized in terms of *sensation,* including emotion, and *intellect* or cognitive capacities [32, 33]. Animals' experience of the world, including capacities related to *sensation* and emotion, are the focus of the majority of investigations into belief in animal mind [10]. These dimensions include *perception*, comprising sensory perception [41], the ability to experience pain or hunger [23], and the capacity for suffering [27]. The notion of animals' *awareness* is included in many studies [37], expressed by some as "consciousness" or "awareness of what is happening to them" [32]. Emotional capacities most commonly referenced comprise *basic emotions* [38], such as happiness, joy, contentment or pleasure; affection or liking; curiosity; anger; sadness; disgust and fear [32, 33, 37, 38, 41]. A small number of studies have examined peoples' attribution of *secondary emotions*, such as embarrassment, guilt, pride, jealousy, grief and moral

Table 1: Cognitive abilities identified in animal cognition research mapped against constructs of belief in animal mind. Adapted from Fraser et al. [20].

Cognition Categories	Animal Cognition Indices	Belief in Animal Mind
Social learning	Culture	Imitation, observation
	Teaching	Learning, culture
	Imitation	
Tool use	Architecture	Tool use
	Tool manufacture	
Concept learning	Match-to-sample discrimination	Categorizing objects
	Same / different discrimination	Recognizing objects by type, name
		Object permanence
Spatial awareness	Orientation	Spatial awareness
	Navigation	
	Cognitive maps	
Numerosity	Estimating quantities	Counting
	Counting	Sorting
	Numerical ranking	Estimating quantities
	Sorting and serial ordering	Judging more / less
Communication	Referential	Communication
	Symbolic	Language
	Language	
Decision-making	Attention	Decision making
	Advanced planning	Capacity to reason
	Intention	Plan for future, foresight
		Think what to do next
Awareness	Self-awareness	Self-awareness
	Theory of mind, Deception	Awareness of what is happening them
	Mirror self-recognition	Awareness of others' thoughts or intentions
	Empathy	Empathy
Creativity (Imagination)	Insight	Imagination
	Innovation	Creative
	Imagination	

thinking [23, 38, 41]. The scientific community generally attributes secondary emotions to humans only, [38], although some contend that animals may experience variants of these emotions [11].

With regards to *intellect*, studies of belief in animal mind tend to explore loosely-defined cognitive process such as *learning* [25, 37] and *memory* [23, 33, 37]. These forms of animal intellect are mapped by Fraser and colleagues [20] against categories of abilities identified in scientific studies of animal cognition. The resulting transdisciplinary framework proposes a set of nine constructs relating to intellect: social learning; tool use; concept formation; spatial awareness; numerosity; communication; decision-making; awareness; and creativity (or imagination), as outlined in Table 1. In this study, we adopt this set of constructs as a foundation for analysing zoo visitors' perceptions of orangutans' cognitive abilities.

The extent to which an animal seems similar to humans, or to the (human) self, is a significant factor in belief in animal mind. *Perceived similarity* can predispose people to feelings of empathy and, reciprocally, empathic responses can strengthen perceived similarity [29, 40]. A sense of affinity can be elicited by biological resemblances and apparent human-like qualities, regardless of phylogenetic similarities [3]. Perceived similarity is closely aligned with anthropomorphic thinking about animals [13, 40].

The term anthropomorphism is often used to imply the inappropriate attribution of human abilities to animals, and generally seen as something to be avoided in zoos and scientific presentations of animals. However, describing animals in anthropomorphic language (e.g. "this dog has a good sense of humour") has been found to induce stronger concern about animal welfare and societal treatment of animals [6]. In recent years, anthropomorphism has been found to foster empathy and concern for animals and for nature [50, 51, 54]. On the other hand, it is feared that using anthropomorphism for public explanations of animal cognition, rather than drawing attention to the specialised sensory and cognitive world of the species, might encourage simplistic and unidimensional understandings of animal minds [20, 45].

3 METHOD

3.1 System Design and Deployment

The interactive installation, developed in partnership with Zoos Victoria provided a touch-based interactive projection system and suite of simple, applications and games as a proof-of-concept for an

enrichment system for orangutans (see Figure 5 and 6). The system was installed in the indoor area of the orangutan exhibit, which also included two large, outdoor spaces. All three exhibit spaces offered structures for climbing, swaying and swinging, along with regular provision of food enrichment and a program of activities such as operant conditioning for husbandry procedures. The digital installation was intended to complement existing enrichment. The exhibit space also includes large-format signage, a video screen and an interactive installation for visitors which address the conservation issues faced by orangutans in the wild, with a specific focus on the effects of palm oil production and its association with consumer choices.

Following the approach described in [55], the system comprised a data projector pointing to the wall in the orangutan enclosure, and a Microsoft Kinect v2 depth-sensing camera capturing the projection area, installed behind toughened glass, and touch-detection software [56]. The software was calibrated and tested to detect touches not only with hands, but also with limbs and torso, and other objects. Games and applications were designed in collaboration with zoo keepers to elicit animals' attention and interaction, and provide visual stimuli of interest to the animals.

Approval for this research was provided by Zoos Victoria's Animal Ethics Committee and the University of Melbourne's Human Research Ethics Committee. System design, testing and the study described here were conducted with close oversight and guidance from Zoos Victoria's animal welfare specialist.

3.2 Study Aims and Hypotheses

This study set out to examine how the digital enrichment installation impacted visitors' belief in animal mind and attitudes to orangutans. An evaluation of a similar digital enrichment system for orangutans revealed that the installation prompted visitors to reflect on the orangutans' intellect, including learning and problem solving abilities, and elicited a variety of empathetic responses [55]. The present study investigated how orangutans' higher cognitive abilities were rated by visitors who saw the animals interacting with digital enrichment, in comparison to visitors who did not. This quasi-experiment set out to test the following hypothesis:

H1: Witnessing orangutans use an animal interactive strengthens people's attribution of higher cognitive abilities.

Given zoos' overarching aim of promoting conservation through presentation of wild species and tactics for engendering respect and a sense of connection, there was an interest in determining whether the digital enrichment installation had an effect on *conservation caring* [46, 47] (concern for, and willingness to take action for conservation of a species), as reflected in the second hypothesis:

H2: Witnessing orangutans use an animal interactive strengthens conservation caring for orangutans.

Interviews and surveys were conducted with two cohorts of visitors: those who witnessed orangutans' interaction with digital enrichment (the *treatment* cohort) and those who did not (the *control* cohort). Treatment days and control days were determined through random allocation prior to the start of the experiment.

Visitor groups (i.e. groups of families or friends visiting the zoo together) were interviewed about their perceptions of the orangutans both before and after visiting the exhibit. Interviews were conducted using Personal Meaning Mapping (PMM) [1, 2, 17, 18, 31] to elicit visitors' prior knowledge, attitudes and narratives regarding orangutans, and explore how these were influenced by the visit to the exhibit. The PMM approach is premised on a constructivist view of learning in zoos and museums, a view supported by prior research which indicates that visitors' existing attitudes, motivations and strategies shape the way that they learn from exhibits [16–18, 43]. Interviews conducted through PMM capture the range of attitudes and knowledge of the group as a whole, and respond to the importance of social exchanges and social learning in the experience of the zoo visit [4, 23, 52].

3.3 Survey Methods for Measuring Attribution of Higher Cognitive Abilities

To test the hypothesis that witnessing use of an animal interactive would strengthen visitors' attribution of higher cognitive abilities to the orangutans (H1), a survey instrument was developed. With reference to the conceptual framework shown in Table 1, and scientific understandings of orangutans' cognitive abilities, video footage of orangutans' interactions with the installation was reviewed to identify categories of cognitive abilities demonstrated in animals' interactions. Four such categories were identified: *tool use*; *concept formation*; *decision-making* and *creativity*. Survey items were developed to measure perceptions of the animals' abilities along these dimensions, with reference to instruments used in prior studies of belief in animal mind [25, 29, 37, 41, 45]. Two additional items were included. Firstly, an item examining attribution of *numerosity*, was included so as to examine whether the installation affected people's perceptions about a cognitive capability which is not elicited by the system. This item asked people whether they thought orangutans can count to ten. In reality, non-human primates are able to make 'more / less' judgements, but these entail representations of quantity which are inexact (such that it is difficult to distinguish between 8 and 10 items) and do not correspond to 'counting' as it is conducted by humans. Secondly, based on prior findings that visitors tended to compare orangutans' intelligence to that of human children, an item was included to measure the extent to which respondents thought orangutans had cognitive abilities beyond those of a young child. In the course of refinement, internal testing and a study pilot, two of the items (related to *tool use* and *creativity*) were combined to create an item relating to problem-solving abilities, a capability which relates to multiple categories of cognition [20]. The five items included in the survey instrument are shown at Table 2.

3.4 Survey Methods for Measuring Conservation Caring for Orangutans

Hypothesis H2 was tested using a pre-existing instrument, the Conservation Caring Scale (CCS) [46, 47] [52, 53], a tool commonly used zoos worldwide, and which has been found to be a strong predictor of pro-conservation behaviours. Six dimensions of the CCS were included in the visitor survey, as shown in Table 3. These items were combined with the five items for measuring attribution of higher cognitive abilities (Table 2) into a single survey which measured responses on a nine-point Likert Scale (from 1='Strongly Disagree' to 9='Strongly Agree').

Table 2: Survey items developed to measure attribution of intelligence

Survey items: Attribution of Intelligence	Dimension
I think orangutans can match objects by shape and colour	Category Learning
I think orangutans are good at solving puzzles	Problem Solving
I think orangutans can make plans and act intentionally	Decision Making
I think orangutans can count to ten	Numerosity
I think adult orangutans are smarter than a 2-year old human child	Comparative Intellect

Table 3: Survey items developed to measure attribution of conservation caring. Adapted from [52].

Survey items: Conservation Caring	Dimension
Ensuring the survival of orangutans is my highest priority	Personal priority on species survival
My emotional sense of well-being will be severely diminished by the extinction of orangutans	Wellbeing impact of extinction
I need to learn everything I can about orangutans	Educational interest
I will alter my lifestyle to help protect orangutans	Willingness to act for conservation
My connection to the orangutans I saw today has increased my connection to the species as a whole	Connectedness to species
Wildlife protection must be society's highest priority	Societal priority on wildlife protection

3.5 Procedure for Participant Recruitment and Data Collection

Following a randomized schedule, treatment sessions were conducted on half of the study days, and control sessions on the remaining half. On days designated for treatment sessions the digital installation was switched on. Traditional forms of enrichment (such ropes and climbing apparatus, forage and blankets or tarpaulins) were also provided, helping to safeguard animal welfare by ensuring orangutans had access to familiar objects and foods, and giving them a meaningful choice as to whether or not to interact with the digital system. Six applications were offered, on rotation. During control sessions, the digital installation was switched off, and only traditional forms of enrichment, as defined above, were provided to the orangutans.

Participant groups were recruited from amongst zoo visitors approaching the orangutan exhibit. Two of every three visitor groups recruited were asked to complete the survey, and every third group was asked to participate in an interview. Interviews were conducted with the groups (i.e. with the group of family or friends visiting the zoo together), and included intergenerational groups with members under 18. As described above, the PMM-based interview aimed to capture a snapshot of the shared, socially-constructed knowledge and attitudes regarding orangutans. Surveys were completed by adults only, individually, to capture the individual perceptions of orangutans and beliefs about their cognitive abilities. For all participants, the researcher collected visitor group data and demographic information. The purpose and nature of the research were briefly explained to participating groups, and consent was obtained for participation and audio recordings. Adult members of visitor groups were recruited at entry to the exhibit.

Interview participants were first asked about their existing knowledge and interest in orangutans. Responses of the visitor group as a whole were captured in a PMM, a rough conceptual map. Visitors then entered the exhibit. On exiting the exhibit, participant groups were shown their PMM again, and were prompted to expand on, add to, or modify the concepts previously mentioned. Interviewers prompted participants to provide additional detail, explanation or examples where appropriate, to create a rich understanding of how the visit to the exhibit had shaped their knowledge and attitudes. Finally, follow-up questions were asked to elicit visitors' thoughts about orangutans' intelligence, personalities, and the way that the orangutans were cared for, if these topics had not already been addressed.

After data collection was completed with one visitor group, the next approaching group of visitors was invited to participate. If a group declined, the next group was invited to take part. Three groups initially agreed to participate in interviews, but on leaving the orangutan exhibit declined the final interview. Data from these three groups was excluded. Some other groups gave final interviews which were very brief but were deemed to contribute valid data and so were included in the study.

A challenge of this experimental design was that it was uncertain whether visitors would see animal interaction, due to short visitor dwell time (often in the range of 2-5 minutes), and sporadic patterns of orangutans' use. To ensure consistency through the course of the study, video of the orangutans' interactions with the digital enrichment was displayed in the treatment condition. A three-minute compilation of short video clips was prepared, including a text overlay providing timestamp, and orangutans' name and age. During treatment sessions, this video was displayed on loop, on a screen adjacent to the installation, enabling all participants under this condition to witness the orangutans using the system. During control sessions, the video screen displayed on loop a video which is habitually displayed at the exhibit and which includes information about the zoo's care of orangutans and conservation campaign information.

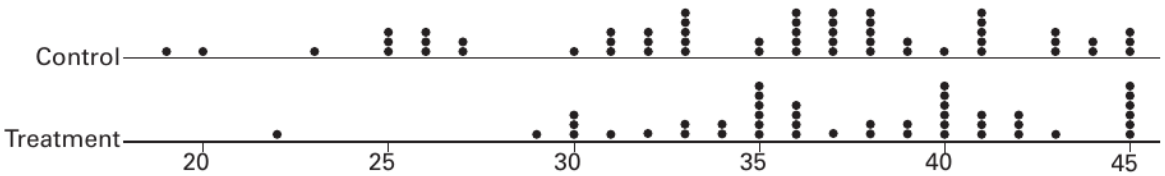

Figure 1: Dotplot of Attribution of higher cognitive abilities (sum of responses). Shows the sum of scores of participant ratings for all five items (per Table 2) were scored on a nine-point Likert Scale (from 1='Strongly Disagree' to 9='Strongly Agree"). Scores are summed to provide a score from 5 (no attribution) to 45 (strongest attribution).

4 FINDINGS

4.1 Survey Findings

A total of 101 participants completed surveys, 45 in the treatment condition and 56 in the control condition. Of survey respondents, 61 were female and 40 were male, 59 were visiting as part of an intergenerational group, 23 were visiting as a pair of adult visitors, 11 were solo visitors and 9 were in a group of three or more adults. A series of dot plots was created (shown in Figures 1, 2, 3 and 4), in which a dot marker represents the score for each respondent.

4.1.1 Survey Findings: Attribution of Intelligence Score. H1 posits that the attribution of higher cognitive abilities will be higher for visitors who had seen the orangutans using the digital enrichment installation compared to those that did not. An overall score of Attribution of intelligence, between 1 to 9, was calculated for each participant by taking the mean of responses to the five cognitive items in the survey. This construct was assessed through the Attribution of Intelligence Score, the average of the scores for the five cognitive ability survey items: Category Learning, Problem Solving, Decision Making, Numerosity and Comparative Intellect.

Two tests for significant difference were conducted. Goodman and Kruskal's gamma statistic (G) was calculated, as this provides a measure of rank correlation which can be used to analyze the strength of the association between two ordinal variables. The resulting G = 0.24 indicates a low level of concordance between condition (treatment versus control) and the overall score for attribution of cognition. Significance of this concordance was calculated as p = 0.04.

As this data (the sum of scores) is approximately continuous, we also used a Student T-Test to test for significant difference. Scores given by the 45 treatment participants (M = 37.6, SD = 5.04) compared to the scores given by the 56 control participants (M = 34.9, SD = 6.57) indicated that the digital enrichment had a significant effect on attribution of higher cognitive abilities, t(99) = -2.31, p = 0.02. Effect size is relatively small at 0.463. With α-level of 0.05 for this test, we can conclude that witnessing use of digital enrichment is associated with stronger perceptions of orangutans' cognitive abilities.

For the item corresponding to numerosity, "I think orangutans can count to ten" (Figure 2 D), responses from the treatment cohort are noticeably higher than for the control. For this item, Goodman and Kruskal's gamma statistic is calculated to be G = 0.42 (p=<0.01), which indicates that the effect on perceptions of numerosity was stronger than for other dimensions of cognition. This finding was unexpected, as the installation does not elicit any cognitive skills related to numerosity. Given that scientific evidence suggests that orangutans cannot count to ten, this finding suggests that seeing interaction with digital enrichment could promote misconceptions about primates' cognitive abilities.

4.1.2 Survey Findings: Conservation Caring. H2 posited that seeing digital enrichment in use would be associated with higher overall scores for conservation caring. The sum of scores for the six items (distribution shown in Figure 3) was calculated for each respondent. Comparing these scores for the treatment and control groups, the distributions were very similar for both groups (see Figure 3). The Goodman and Kruskal's gamma statistic identified no significant differences between conservation caring responses for the two groups. Likewise, the Student T-Test indicated no significant difference in Conservation Caring scores, $t(99) = -1.17$, $p=0.24$, between treatment condition (M = 41.2, SD = 7.75) and the control (M = 39.1, SD = 9.55).

The means for all of the six items were slightly higher for the experimental group than for the control (see Figure 4). For the item "Wildlife protection must be society's highest priority" a low level association was found between seeing the digital enrichment installation and higher scores (G = 0.28), significant at the α-level of 0.05 (p = 0.03). It is notable that a significant effect was detected for the only item which references wildlife in general, rather than the orangutan species. Across both treatment and control groups, the mean for this item is higher, and the variance is lower, than for other conservation caring items. Considering this finding in light of zoos' intent of communicating broad notions of environmentalism, it seems possible that some visitors' responses to the five items related specifically to orangutans might have been moderated by not wanting to prioritize conservation of orangutans over other species and ecosystem resources.

The lack of significant effect on conservation caring indicates that the installation does not encourage people to think about orangutans in more positive terms, generally. Rather, the effects of the installation are specifically related to belief in animal mind.

4.2 Interview Findings

4.2.1 Analysis of Visitor Interviews. Thematic analysis [24] was conducted to examine interviews and PMMs. Analysis to identify respondents' attribution of cognitive abilities was guided by the high-level conceptual framework shown in Table 1. In a first reading

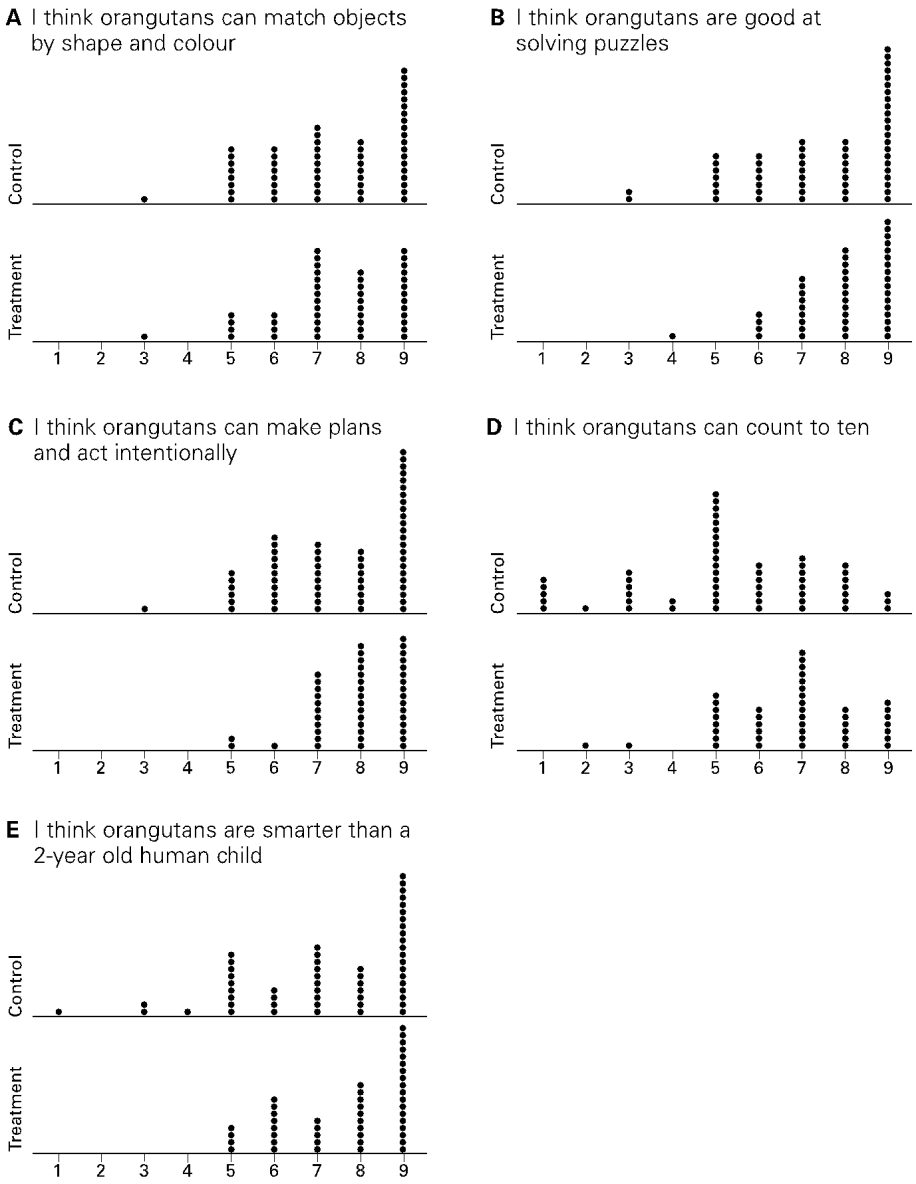

Figure 2: Dotplots of responses to individual attribution of higher cognitive abilities survey items (per Table 2).From 1 (Strongly disagree) to 9 (Strongly agree).

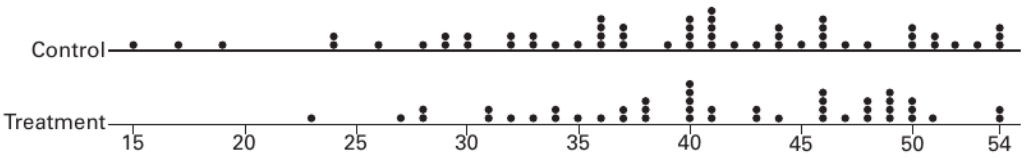

Figure 3: Dotplot of overall conservation caring responses. Shows the summed score of participants' ratings for the six conservation caring items (per Table 3). The six items were scored on a nine-point Likert Scale (from 1='Strongly Disagree' to 9='Strongly Agree") and summed here to provide a total score from 6 (No conservation caring) to 54 (Strongest conservation caring).

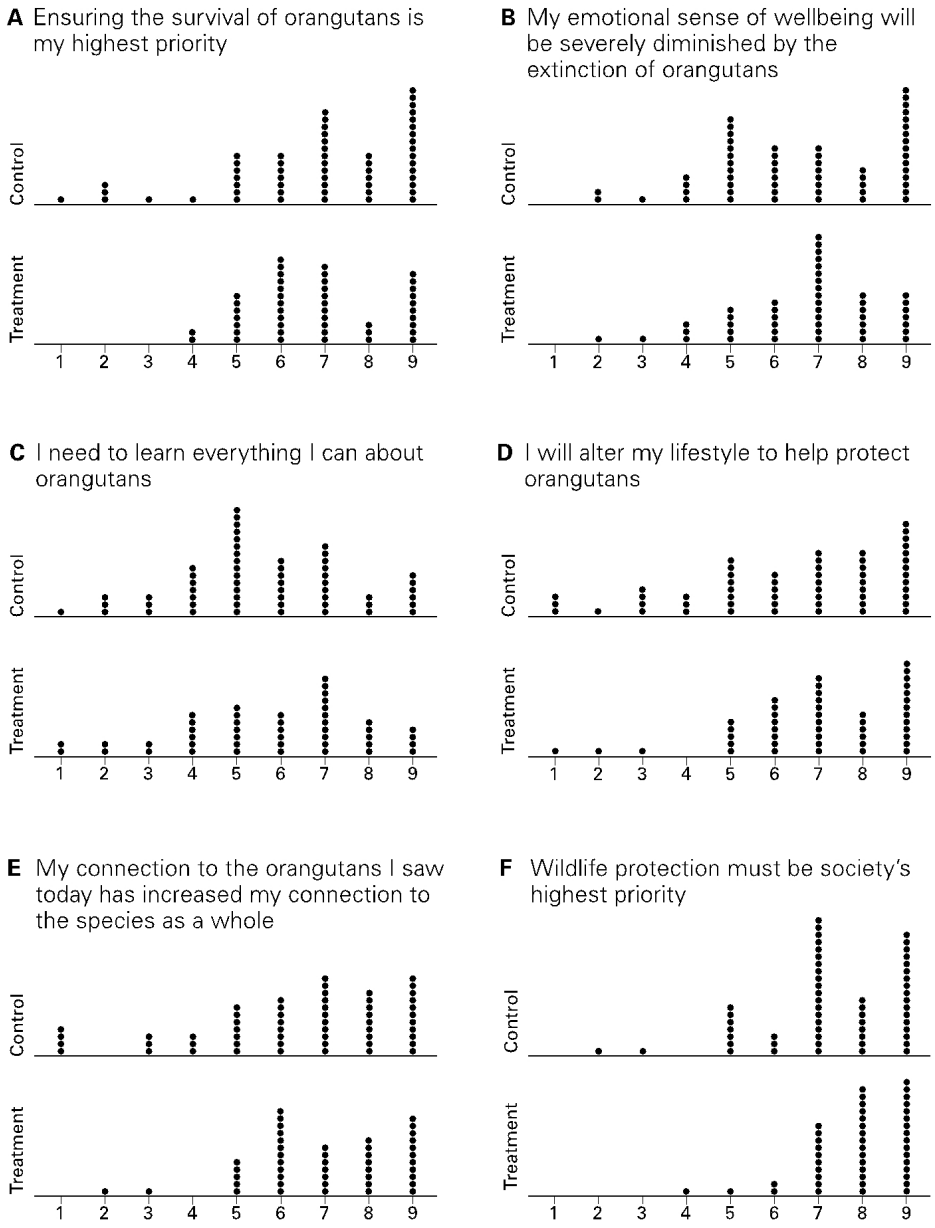

Figure 4: Dotplots of responses for individual conservation caring survey items (per Table 4). From 1 (Strongly *disagree) to 9* (Strongly agree).

of interview transcripts and PMMs, notes were made identifying salient ideas and content relevant to the conceptual framework. A codebook was developed, tested by a colleague not associated with the project, and refined. Coded content was examined systematically across the two groups of respondents, to compare perceptions of orangutans across the conditions and examine how participants reflected on orangutans as users of animal interactives as opposed to traditional enrichment. Nvivo cross-tabulation was used to examine relevant content across the two conditions, and to seek out cases which deviated from the identified patterns, with care taken to include these in the thematic analysis and report of findings.

4.2.2 Visitor Group Types and Prior Conceptions of Orangutans. Interviews and Personal Meaning Mapping were conducted with 39 visitor groups (18 in the treatment cohort, 21 in the control cohort), comprising a total of 79 visitors. Of these, 27 were intergenerational groups, 10 were pairs of adult visitors, 2 were solo visitors, and 2 were in groups of three or more adult visitors.

Analysis of entry interviews was conducted to understand visitor groups' knowledge and perceptions regarding orangutans. When

Figure 5: Common sequence of interaction: watch display, move hand, touch hand to display, watch displayed feedback.

asked what they knew or found interesting about orangutans, all visitors mentioned some form of externally observable characteristics of the animals, such as, appearance and anatomy (e.g. as colouring, facial features), physical behaviours (notably, climbing and swinging) and social behaviours (including mutual grooming and play).

A majority of visitor groups (30 of 39) in entry interviews referred to the animals as minded beings, mentioning examples of their cognitive abilities (such as physical problem solving or use of objects as tools) or, to a lesser extent, making inferences about the animals' affective states and emotional wellbeing needs (including social interaction and seeking comfort). A further 8 of these 30 respondents provided somewhat more complex statements about orangutans' intelligence, giving specific examples of behaviours which indicated intelligence, and inferring from those specific cognitive processes or intentions (for example, one respondent recounted an occasion on which an animal was seen to use a tarpaulin like a raincoat to keep dry [G19 M][1]).

4.2.3 Playing Digital Games Suggests Higher Cognitive Abilities. Visitor interviews revealed several interesting differences in the way that participants who saw digital enrichment spoke about the orangutans' cognitive processes, as compared to visitors who saw only traditional forms of enrichment. A large proportion of people who commented on orangutans' use of the installation cited it as an example of orangutans' intelligence, or even of their "*higher cognitive abilities*" [G23F]. Several respondents expressed surprise that the orangutans had understood how to use the applications offered. Responses in this vein suggest that seeing animals interact with a complex, technological interactive provides new information about animals' cognitive abilities. A few responses indicated that participants perceived there to be a 'correct' way of using digital enrichment, and that the orangutans have the cognitive capabilities to fathom and apply this correct form of interaction. For example, one respondent observed with apparent surprise that: "*they seemed to work out the rules of the game relatively quickly, whether it was just hitting the spot, or whatever it was*" [G27M].

This interpretation of the orangutans' behaviour also highlights that respondents believe the animals act with intention. For example, one of these respondents, watching an orangutan deliberately touching the moving coloured circles, commented with surprise: "*I didn't expect them to understand the digital – they're quite clever [. . .] like that one [pointing], like that. It doesn't seem accidental, it seems intentional.*" [G35F].

4.2.4 Motor Patterns of Orangutans and Humans: Perceived Similarity and Mimicry. Orangutans' hands and dexterity were mentioned by many respondents in both cohorts. Respondents who saw the installation in use tended to reflect on similarities to humans in the ways that orangutans used their hands. Visitors' descriptions of orangutans' behaviours suggest that in some instances, the animals' motor patterns promoted a strong sense of similarity to a human using a comparable interface. Orangutans' interactions often involved a behavioural sequence comprising: watch display; move hand towards interface; touch hand to interface element; watch displayed feedback. Visitors' responses to orangutans' careful, manual interactions indicated that this particular sequence evoked human use of comparable interfaces and drew attention to similarities between the orangutans' manual dexterity and humans'. It should be noted that not all interactions were careful and deliberate: some were performed rapidly and with high intensity; see Table 4 for a list of interaction types.

The design team, conscious of widely held notions of orangutans as human mimics, held some concerns that a video game-like installation might prompt misconceptions about orangutans capacities for, and interest in, playing human games. It is therefore notable that only one visitor, after seeing the installation in use, pondering whether the animals might be capable of playing strategy games such as chess [G38M]. Interestingly, four visitors in the control cohort reflected on orangutans' behaviours in terms which suggested they had the capacity to mimic humans, whether by copying humans at the enclosure window [G18F] or learning other human behaviours [G36M].

A small number of visitors who saw only traditional enrichment were impressed by the precision with which the animals manipulated objects. However, it is notable that visitors who reflected on these activities as evidence of the orangutans' cognitive abilities

[1]Respondents are referenced by a Group number, assigned sequentially to each group, and a unique referent which indicates the respondent's gender / age group (M=adult male, F=adult female, C=young person under 18 years). For example, "G19 M" refers to the only adult male respondent in Group 19. "G10 F2" refers to the second adult female respondent in Group 10.

Table 4: Types of interaction orangutans adopted in using the digital enrichment installation

Interaction Type	Description	Intensity
Face touch	Touch lips, nose or other part of face to the projection	Low
Finger touch	Lightly touch an element of projection with one finger, often with a small 'scratching' motion	
Hand sniff	Touch projection with hand or finger then sniff hand	
Hand / foot touch	Touch projection with palm or back of hand or with foot	
Play with light	Move body or object under the projector to watch the effect created by the moving light	
Body sprawl	Press body to the projection with arms spread	
Forearm sweep	Sweep side of forearm back and forth, generally in a static, seated position	
Body shunt	Slide body (on back or front) back and forth	
Scrub with object	Move object (e.g. cloth, wood wool) back and forth, often with rapid, repeated motions	
Hit with object	Hit projection surface with cloth, cardboard tube or other object, often repeatedly and vigorously	
Swipe while swinging	Swing from ceiling or from an item attached to the ceiling, swiping at the interface either with a limb or with an object	High

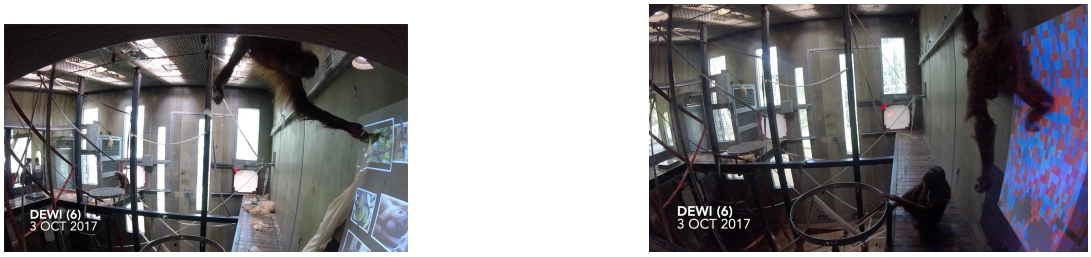

Figure 6: Forms of interaction considered "playful". i) Scrub with object ii) Swipe while swinging; ii) Foot touch

focused on differences between orangutans and humans, rather than similarities. For example, one visitor commented that "I'm not even sure that I could have figured that out to use a stick. I would have tried putting, like, my finger through the hole" [G16F]. Another noted that an orangutan's abilities were superior to those of her young son:

> "I saw that one [...], use the stick to try to get the almond out, and also another one that used the paper to cover himself. And that was, it seems they have fine motor skills and also they can do things greater than the one and a half year old boy. Because, I don't think he can actually use his sheet or the blanket to cover himself yet, so it seems to me that his ability of thinking is greater than a one and a half year old boy, in terms of motor skills." [G20F].

4.2.5 Digital Games Seem Playful, Foraging Devices Seem Frustrating. Seeing the orangutans' use of the installation - which did not provide food rewards - seemed to prompt people to reflect on how animals' emotional needs might be met by an interactive system. Interaction with the digital enrichment was commonly described as 'play', especially when they involved high intensity forms of interaction, (see Table 5).

By contrast, comments on animals' abilities at using traditional food enrichment, such as working food free from a maze-like puzzle, were overlaid with the intimation that these forms of enrichment constituted frustrating work for the orangutans. This is illustrated by the following comment:

> "So, it started on the other side, see where that thing is. He's moved it all the way there with his hand. He's trying to get it in, closer to there, with his arm and pull it through, to see if there's food in there. He's been working at it. [...] You got it, you got it. I hope there's something in there for him, after all that effort [...] Let's see, it might be empty.[...] Oh, it's empty, how sad. All that work!" [G25F]

Visitors generally felt that orangutans did not find these tasks particularly enjoyable or inherently rewarding: obtaining a food reward was seen as the animals' sole motivation.

4.2.6 Watching Digital Enrichment Prompts Reflection on How Animals' Cognitive Needs Might Best Be Met. Visitors' perceptions of orangutans' cognition were frequently expressed in terms of the animals' need for mental stimulation to ensure cognitive development. Several who saw use of the interactive installation mentioned

similarities between orangutans and young children, and tended to compare their cognitive development needs, for example:

> "Having a toddler, it's the same sort of thing, trying to develop their mental ability, keeping them occupied and interested". [G31F]

As this example suggests, these comparisons tended to make reference to planned activities arranged by parents to achieve specific developmental outcomes. Such comments indicates that the installation suggests to observers that orangutans are cognitively sophisticated beings who need to be mentally challenged and have opportunities to learn in order to reach their full potential.
One of these visitors deliberated at length about what sort of stimulation was appropriate for the orangutans, and how the system might cater to that, as the following excerpt suggests:

> "Um, I'm not sure how much they love it though. I think it's kind of more like 'Ooooh!'. It's not really like. . . I don't know... Maybe they'd be more interested if there was a reward system? If they got something? But that's kind of what they do in labs, with the chimps and stuff. If they do something right they get a treat. Is that kind of where you guys are looking at? [. . .] Maybe like their reward could be a picture that's something that they like seeing. I don't know, what do orangs like looking at? Maybe they like looking at other orangs, maybe, maybe not. Maybe they want to see pictures of fruit." [G39F].

In contrast, people in the control cohort also compared orangutans' behaviours to those of human children, but did so in terms which focused on physical, object-based play, such as playing with boxes, and did not refer to the cognitive aspects of such play. In this way, it seemed that ropes and climbing platforms were often noted by participants as providing opportunities for physical movement, but did not invite reflection on animals' mental capabilities or needs.
Highly physical forms of interaction allowed people to observe differences between individual orangutans' preferences. For example, it was apparent to a handful of visitors that some orangutans enjoyed using the installation more than others, or that different individuals enjoyed using the system in different ways, causing them to note differences in orangutans' "distinctive personalities" [G22M].

4.2.7 Encroachment of Digital Technology on the Naturalistic Zoo Setting. Some visitors perceived that digital enrichment might pose a risk to the animals' need to engage with natural and physical objects. A small number of visitors expressed concern that animals' use of digital interfaces might supplant their engagement with naturalistic features of their environment, as the following comment illustrates:

> "It's sort of sad, everything's computers. I know, I know it's technology, but I'm just saying, even for a poor orangutan. . . Aaah. It's so sad that, you know, they can't give them something more that actually would be out in the wild, like real, like touchy, feely stuff." [G25 F]

Interestingly, a few visitors in both groups expressed concerns about artificial elements of the enclosure (such as concrete and metal structures), and wondered whether more could be done to simulate the animals' wild habitat. A small number of respondents were of the opinion that a more heavily treed enclosure would be preferred by the orangutans and enable them to enact more natural behaviors, as suggested by the following comment, from a visitor who saw only traditional forms of enrichment:

> "[A]n exhibit like this, this is great because they've got lots of swinging stuff, but I'd like to see more trees, more natural- right? So that they can pull the leaves off if they want and Throw them around and stuff like that. So, this is very sterile, I guess?" [G11 F].

It is significant that the proportions of visitors who raised such issues were similar in both groups, which indicates that the installation was seen as an additional enrichment offering (rather than as a substitute for a naturalistic environment) and was not associated with greater concern about orangutans' need to interact with natural features.
Finally, several respondents had misgivings about encroachment of digital technology on visitors' experience of the naturalistic zoo setting. Comments of this nature centered on children's exposure to technology while at the zoo, which was considered to contradict parents' efforts to separate their children from digital devices and screens through a visit to the zoo. This is illustrated by one participant's comment in response to the digital enrichment installation:

> "I think that is a terrible idea [. . .] Because I think that the whole point of for me, I mean I have three kids, I mean obviously they're [adults] now, but the whole point of coming to the zoo is to get away from the video screen and the TV screen and so on and to experience life - in reality." [G38 F]

This group of participants saw the provision of animal interactives at the zoo as part of an inexorable and undesirable spread of digital technologies. This finding suggests that for a small proportion of visitors, computer-based installations are irreconcilable with the notion of the zoo as a site which simulates the natural world.

5 DISCUSSION

This research sheds new light on the ways in which animal-computer interaction can shape people's attitudes understandings of animal minds and perceptions of non-human others. In this section we first analyse the findings that zoo visitors' perceptions of primates' intellect can be shaped by seeing animals use a digital installation, but that there is no effect on conservation caring. We then discuss the implications of these findings for the design and deployment of technology for animal use, with consideration for the aims of the ACI discipline, that technological interventions should benefit animal users and non-human species. Two avenues are proposed for ACI design to shape people's understanding of animal minds: supporting people to accurately interpret animal behaviour and promoting nuanced understanding of animal intelligence.

5.1 Effects of Animal-Computer Interaction on Attribution of Higher Cognitive Abilities

Seeing orangutans interact with the digital installation strengthened attribution of higher cognitive abilities, providing support

for H1. However, the difference is relatively small and we posit that this could be partially due to the clustering of scores at the higher end of the scale (zoo visitors are generally likely to think that primates are intelligent), resulting in a ceiling effect. Thus, it might be that a greater effect would be observed using a survey instrument that could more effectively discriminate between the responses at the top end of the scale, or by measuring perception of cognitive abilities that are less commonly attributed to primates.

Seeing the digital installation had several effects which likely contributed to this result. Firstly, some visitors observed specific cognitive abilities they would not previously have attributed to the animals, such as "learning the rules" (corresponding to cognition category "Concept learning" in Table 1). Secondly, the orangutans' pattern of interaction with a familiar-looking, touch-based interface, strengthened people's perceptions that orangutans' dexterity and hand-eye coordination abilities are similar to those of humans. Thirdly, installation prompted reflection on the animals' similarity to human children in terms of their cognitive abilities and needs.
It is evident that some visitors over-estimated the abilities of orangutans to count to ten (cognition category "Numerosity" in Table 1). This aligns with previous findings that there are widespread misunderstandings about animals' cognitive abilities [41] and suggests that some visitors may be susceptible to forming inaccurate perceptions regarding animal cognition, and this could be exacerbated by animal-computer interaction. It is pertinent that this study was conducted with a broad, zoo-going public and that observers with greater knowledge of apes' behaviour and cognition (such as zoo staff or volunteers) might draw different conclusions from watching the installation in use.

5.2 Effects of Animal-Computer Interaction on Conservation Caring

The hypothesis that seeing animal interaction would support conservation caring (H2), was not supported, despite the effect on attribution of intellect. In interpreting this finding, it is pertinent that responses to conservation caring items are likely to reflect diverse aspects of visitors' experience of the zoo and broader attitudes towards wildlife and the environment. The attitudinal outcomes of a zoo visit can be influenced by numerous factors, including visitors' predispositions [35], animals' activity levels [36], visibility of animals [57] and even by the time of day [9]. Given the wide variety of factors at play, it seems likely that seeing animal interaction for a brief period might not result in an immediate effect on priority assigned to orangutan conservation.

It is notable that there was found to be a significant difference in scores for the item "Wildlife protection must be society's highest priority", the only item which references protection of *wildlife* (rather than orangutans, the focus of other items), and importance for *society* (rather than the individual respondent). This suggests that there is an opportunity to explore in greater detail the specific effects of animal-computer interaction on visitors' perspectives on conservation issues, and how these attitudinal effects play out in the context of a zoo visit. Digital installations might also contribute to zoos' efforts to present information about threats to survival of orangutans in the wild, interwoven with the experience of watching the animals.

5.3 Designing ACI to promote accurate interpretation of animal behaviour

Watching the digital enrichment installation, people attempted to interpret animals' interactions in terms of their motivations and cognitive processes, and it is apparent that interpretations were shaped by specific characteristics of the installation and the behaviours elicited. This signals the importance for ACI design to give careful attention to the types of behaviours that are elicited, and consider what additional support may be needed to enable people to make accurate interpretations and to engender positive attitudes, contributing to the appropriate and ethical treatment of animals. In this study, we identify three broad categories of interaction types.

Firstly, careful interactions reminiscent of adult human behaviour which prompt reflection on cognitive abilities (e.g. hand touch, finger touch). Secondly, rapid, demonstrative interactions interpreted as play, which might lead some to think of orangutans as child like, or as engaging in "mindless" play, despite the potential value of these interactions in terms of animal wellbeing and their potential to demonstrate inquisitive exploration or tool use. This seemed to prompt some visitors (notably, parents) to consider orangutans' developmental needs, casting them as dependent and child-like creatures, whose needs would be met by human carers. Corresponding to these first two categories, a risk for ACI designers lies in people's predisposition to draw on anthropomorphic processes when interpreting animal interaction. Non-experts readily notice interactions that resemble human behaviours and draw from this inferences about similarities between animals' cognitions and those of humans. While this impulse can elicit empathy for animals and motivate concern about animals' wellbeing [6, 50, 51], our findings suggest that it can also lead to misinterpretation of animals' intentions and over-attribution of higher cognitive abilities, as seen in our respondents' overestimation of orangutans' numerosity skills. This has important implications for organisations such as zoos, who frequently highlight animals' similarity to humans, to promote a sense of connection with wildlife and concern for nature. Thirdly, behaviours which are not part of usual human repertoire (such as orangutans' foot touch and forearm sweep) are less likely to prompt inference from human experience. This latter category may be of particular interest if there is an intent to reveal the specialised abilities of other species. From the perspective of animal-wellbeing contributions of ACI, it is important that interactional preferences of animal users should be prioritised. If such preferences entail behaviours which are difficult for people to interpret, or likely to lead to misinterpretation, we suggest there is a role for visual design (as well as signage or supporting information) to aid understanding.

5.4 Designing ACI to promote a nuanced understanding of animal intelligence

It is evident that watching animal-computer interaction can strengthen perceptions of animal cognition and that ACI design choices can shape people's perceptions in specific ways. Respondents' assessment of the orangutans' cognitive abilities of animals' relied primarily on comparison to human behaviour, making reference to human-like motor patterns, similarity to children's cognitive needs and animals' ability to understand the 'rules of the game'.

This reflects a tendency to evaluate animal intelligence against the yardstick of human intelligence, and we can intuit that the "anthropic frame" created by this style of digital enrichment [55] may have encouraged this anthropocentric model of intelligence. Although promoting notions of human-similarity through ACI could promote moral concern for animals [7], unidimensional notions of animal intelligence obscure the diversity of cognitive abilities that have evolved in response to varied evolutionary pressure. Consequently, appropriate ACI design requires careful choices regarding the extent to which technology resembles or replicates systems used by humans. This choice has significant implications for observers' perceptions of animal users, as interaction mechanisms and visual design which allude to familiar, human-oriented conventions seem to reinforce tendencies to think of animal minds simply through comparison to humans.

With consideration for the contemporary understanding of intelligence as multidimensional and emerging from a species' evolutionary history, we note that when interacting with a computer interface displaying abstract graphic elements, animals' cognitive abilities are decontextualized from survival challenges and evolutionary factors. Computer-based installations can also conflict with the naturalistic appearance of zoo exhibits, which contemporary visitors expect, even if they support the expression of important natural behaviours. In contrast, typical food enrichment for zoo animals and pets (such as foraging or food puzzles) might in theory help the observer create associations between cognitive skills and survival in the wild, and better communicate the inherent value of the species' cognitive specialisations. However, it is apparent that such activities are commonly interpreted as "frustrating", in contrast to animals' "play" with digital enrichment. Consequently, an interesting goal for ACI design is to enable people to observe and valorise cognitive skills in which humans are not dominant, and abilities which are not immediately seen as hallmarks of intelligence. A more ambitious aim would be to locate the animal's cognitive capacities in the context of their evolutionary history and their relevance for animal wellbeing. One design approach would be to reveal to observers how animals' ability to use digital technologies demonstrates cognitive flexibility, through applying skills which evolved to perform very different types of activities. An alternative approach might be to encourage viewers to compare animals' abilities to other non-human species, highlighting how cognitive skills have emerged from divergent evolutionary history.

6 CONCLUSION

This study investigated how watching animal-computer interaction can influence people's thinking about animal mind, by examining the effects of a digital enrichment installation on attribution of intellect to orangutans and attitudes towards the species. Through interviews and surveys conducted at the orangutan exhibit, we determined that seeing the installation in use strengthened attribution of higher cognitive abilities, and was associated with qualitative differences in visitor responses to the animals. However, there was no significant effect on attitudes towards conservation of orangutans as a species.

The study reveals how observers made inferences from animals' patterns of interaction with the installation to make inferences about their motivations and cognitive abilities. We identify specific characteristics of the installation, and the motor patterns elicited, that seem to prompt observers' attention to orangutans' intellect, and note that use of digital enrichment is considered playful, in contrast to use of traditional forms of food enrichment, which was commonly interpreted as frustrating. With relevance to human tendencies towards anthropomorphic thinking, we identify three broad categories of interactions which elicited different types of responses from visitors. Careful interactions reminiscent of human, adult behaviour prompted reflection on orangutans' cognitive abilities and may have strengthened perceived similarity. Demonstrative, rapid interaction suggested child-like play and prompted some to consider orangutans as dependent on human carers for their cognitive needs to be met. In contrast, unfamiliar forms of interaction such as foot touches were not so readily noticed and were not generally used in making inferences about cognitive processes. ACI interventions might be designed to increased understanding of animal cognition and so avoid the trap of encouraging observers to simply judge animals as more or less intelligent by comparing their intellect to that of humans. Firstly, ACI interventions can support observers to accurately interpret animals' behaviour and make appropriate inferences about motivations and internal processes. Secondly, ACI interventions might promote nuanced understandings of animal intelligence and the diversity of species' cognitive specialisations.

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