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Children's age influences their use of biological and mechanical questions towards a humanoid

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Abstract. Complex autonomous interactions, biomimetic appearances, and responsive behaviours are increasingly seen in social robots. These features, by design or otherwise, may substantially influence young children's beliefs of a robot's animacy. Young children are believed to hold naive theories of animacy, and can miscategorise objects as living agents with intentions; however, this develops with age to a biological understanding. Prior research indicates that children frequently categorise a responsive humanoid as being a hybrid of person and machine; although, with age, children tend towards classifying the humanoid as being more machine-like. Our current research explores this phenomenon, using an unobtrusive method: recording childrens conversational interaction with the humanoid and classifying indications of animacy beliefs in childrens questions asked. Our results indicate that established findings are not an artefact of prior research methods: young children tend to converse with the humanoid as if it is more animate than older children do.

Keywords: human-robot interaction, humanoid, animacy, psychology

1 Introduction

With the increase in social robots developed for children as users in human-robot interaction (HRI), understanding how children perceive and evaluate robots is critical for effective HRI progress. A theoretical understanding of childrens perceptions of social robots can both promote greater user-centered design, and address key psychological questions in child development (e.g., [1]). Given recent advances in autonomy and interaction capabilities, there is potential for social robots to span boundaries between object and agent in a child's perspective [2].

Children hold their own naive theories of animacy in early development. They can attribute objects substantially simpler than modern robotics as possessing life [3] and invent conclusions of the objects having *intentions*. These naive beliefs are supplanted by an understanding of biology in later childhood [1, 4].

However, even among adults with a biological understanding of animacy, their wider perceptions and interaction behaviors with robots are shaped by beliefs of a robot's animacy [5]. Children's early, naive understandings of animacy may have a significant impact on how they understand and interact with robots.

1.1 Children's Understanding animacy in HRI

Current HRI research exploring animacy offers mixed indications concerning the development of children's perceptions of robots as (in)animate (see [6] for an overview). Studies point towards aspects of Carey's model of conceptual change [4] but others offer contrasting outcomes (e.g., young children have shown both consistent [7] and inconsistent [8] animacy beliefs about a robot dog).

The mixed picture that research findings offer has lead to development of a new approach in understanding children's perceptions of robots as beings that can exist 'between' animate and inanimate [10, 9]. With this in mind, we explore children's beliefs of animacy concerning a responsive, autonomous, humanoid. Prior work suggests a continuum from animate to inanimate in children's beliefs [11], although this may be an artefact of the testing procedure (see section 1.3); in this paper, we undertake a new method to examine children's beliefs of animacy.

1.2 Perceived animacy of a humanoid

Cameron and colleagues observed a significant difference between older and younger children in their ratings of a humanoid robot (Robokind Zeno R25 [12], Figure 1): younger children (age five and six) considered the robot to be more 'like a person' than older children (age seven or eight) did [11]. On average, both groups of children rated the robot as having some elements of animacy, as a hybrid of machine and person. In that study, children took part in an interactive scenario with an autonomous, responsive, expressive robot; the authors suggest that the richness of the interaction, congruent with a humanoid morphology, may contribute to the mixed ratings.

Two subsequent studies show similar findings to [11], even with a substantially simpler interaction scenario [13, 14]. In these studies, children played a simple guessing game about the robot's actions; the robot neither communicated with the children nor responded to their behaviour. Results indicate that, on average, children report the humanoid to be a hybrid of person and machine, albeit somewhat more machine-like than the ratings in [11]. Again, younger children are more likely to rate the robot as being more like a person, than older children do.

1.3 Measuring animacy beliefs

In developmental research, it can be a challenge to maintain children's attention for extended or repeated questions. Cameron and colleagues suggest that a key advantage of the above studies is the single-item measure used for animacy [14],

Fig. 1. The Robokind Zeno R25 platform (humanoid figure approximately 60cm tall)

which keeps post-HRI questionnaires brief and preserves children's engagement. Moreover, results gathered from using 100 point thermometer scale [11] and Likert scale variants [13] of the measure offer theoretically consistent findings [4].

However, the brief measure does currently present a limitation. While the measures addresses the emerging idea that robots can exist as between animate and inanimate (e.g., [10]), specific findings using the measure may be an artefact of the question's design. In essence, children may describe the humanoid as a machine-person hybrid simply because the option is presented as a continuum and they feel obliged to. Given these limitations, it remains to be seen if children's beliefs of a robots animacy are well represented as a continuum.

The current study seeks to examine two key matters from earlier studies [11, 13], namely 1) Are children's reports of a humanoid as being a person-machine hybrid artefacts of the measure used? 2) Do children show variation with age in their beliefs about animacy in HRI?

To address this, we use an alternative method of open-ended interviews, which have previously explored children's beliefs about robotic agents with promising results [15]. In contrast to prior work in which researchers may guide children to the towards the topic of animacy, We offer children the opportunity to ask self-generated questions towards the robot after HRI scenarios. We anticipate that the opportunity to converse with a robot on their own terms could promote children to explore topics of genuine interest to them. We anticipate:

(1a) Children will self-generate questions exploring a robot's animacy. (1b) Children will ask questions that reflect the perceived machine-person hybrid nature of the humanoid[3]. (2a) Younger children will, on average, ask more person-themed questions than older children. (2b) Older children will, on average, ask more mechanical-themed questions than younger children.

[3] This may be reflected within a single question, or reflected through status incongruency across multiple questions

2 Method

2.1 Design

We employed a between subjects design, with an independent variable of age. The content of children's questions asked towards the Zeno R25 robot were used as the dependent variable.

2.2 Participants

Participants were drawn from two local primary schools. Both schools invited research staff to demonstrate current robotics. In total, 91 children took part, divided across three year-groups; twenty-seven children were from Primary school *A*, ages ranged from five to seven. Sixty-four children took part from primary school *B*, ages ranged from nine to ten. Consent was obtained prior to children's participant from teachers at both schools and, where applicable, parents.

2.3 Procedure

Participants' questions for the robot were recorded at the end of one of two HRI scenarios (see below). Children were invited to ask Zeno as many questions as they liked. Pre-scripted answers were provided for the anticipated likely questions; if there was no suitable answer for the question asked, a variety of stock phrases were used, such as 'What a great question!'. Zeno's responses were initiated by the lead computer scientist covertly selecting appropriate answers.

HRI scenarios Two interactive scenarios, developed to explore HRI in an educational context (Expressive agents for Symbiotic Education and Learning, EASEL [16],[17]) were used for data collection. Both scenarios had been pretested for suitability as a social and educational interaction for the age groups in this study.

Younger children took part in a game of 'Simon-Says' with Zeno. The procedure for the interaction is described in detail in [18] and summarised here. Children completed ten rounds of the game Simon-Says, with Zeno verbally stating instructions and feedback on children's performance. The interaction was delivered autonomously and the robot was responsive to children's movements. Children completed this interaction alone. After the game, Zeno asked children questions about their exercise and asked if they had any questions to ask it.

Older children completed a 'Healthy-Living Tutoring' scenario. The procedure for the interaction is described in detail in [9] and summarised here. Children followed the verbal instructions from Zeno to engage in light, moderate, and intense physical activity. Zeno gave autonomous feedback on the energy used with each activity. Children completed the interaction in front of peers. After completing the physical activity, Zeno gave children a series of questions about physical activity and invited children to share questions they had.

Data collection The question recording differed across HRI scenarios as a result of the testing environment available.

The Simon-Says scenario was conducted in a lab-like environment. Children spoke their questions into a headset microphone as part of a corpus-development exercise used for training an automatic speech recognition program [19].

The healthy living scenario was conducted in a classroom environment. Children took turns in interacting with Zeno, while classmates observed. While waiting to take part, children completed a written task that included writing a description of the interaction and, critically, any questions that they would have for Zeno. Children were informed that, at the end of the whole classes interaction, randomly selected children would read out their questions for Zeno.

Text analysis Questions asked by children were transcribed and coded by two researchers, naive to conditions and hypotheses for the study. The pool of questions were divided equally between researchers. A random sample comprising 10% of transcriptions from each researcher were checked for accuracy by their counterpart; no content errors were detected.

A card-sort procedure was used to classify the questions asked. Each researcher was given the unique 263 questions children asked[4] and instructed to sort the questions into as many or as few mutually exclusive categories as they felt necessary to best reflected their own perceptions of the similarities and differences. After all questions were categorised, researchers were asked to name or describe each category that they had created to help identify commonalities between the questions within each group.

Researchers discussed their categories created to identify overlap in emergent themes. Themes agreed to be sufficiently similar were merged and questions redistributed amongst the categories as appropriate.

3 Results

There were no significant difference between the two groups in the number of questions asked $t(89) = .60$, $p = .55$. On average, older children asked 3.81 (S.D. = 2.44) questions, while younger children asked 3.48 (S.D. = 2.28) questions.

3.1 Classification of questions

Researchers identified that, of the 263 unique questions asked, 40 are directed towards the research team *about* Zeno rather than being directed *towards* Zeno. Examples of such questions included ‘Can he dance?’ and ‘How does Zeno talk?’. For each of the 40 questions asked to researchers, there were also examples of other children directing the same question to Zeno.

[4] 398 questions were asked in total, if duplicates are counted. Common duplicates included questions on Zeno’s age, family, and abilities

In general, there was strong agreement between researchers: Researcher A created eleven distinct categories, while Researcher B created seven. After discussion, researchers agreed on a total of seven over-arching categories, based on researcher B's classification, with two of those each containing two sub-categories, based on Researcher A's classification (see Table 1). Two categories suggested by Researcher A (Exercise and Routine Tasks) were agreed to be sufficiently similar to the Robot Capabilities category, so the questions were reallocated.

Table 1. Category development of questions children ask towards Zeno

Agreed Categories	Example Questions	Unique Q. Count
Biological functions	What do you eat? When do you sleep?	27
Social relationships	Do you have a sister? Do you have friends?	17
Robot capabilities	What is 12x12? Can you Whip and Nae Nae?	82
Favourites	What is your favourite animal [sport, colour]?	15
Robot Feelings	Do you feel? What are you most afraid of?'	34
Origin		
• Manufacture	How were you programmed? Who made you?	17
• Biological	When is your birthday? How old are you?	6
Identity		
• As robot	Are you a robot? What do you think you are?	17
• As Gender	Are you a boy? Would you rather be a girl?	8

3.2 Question frequency

Researchers identified multiple categories of questions exploring a robot's life-like nature: Biological Functions, Biological Origin, and Gender Identity. Researchers further identified cases where children asked conceptually inconsistent questions (or series of questions), suggesting issues for some children in establishing Zeno's animacy. Examples include: 'Do you go to the doctors to get your wires checked?' and 'When is your birthday?... How were you made?'.

A series of nine chi squares are run, with appropriate bonferroni correction, to examine differences between age groups in the frequency for each type of question asked[5]. If children asked multiple questions *across* categories, each were included in analysis; multiple questions *within* categories were counted as a single entry.

Younger children ask proportionally more questions than older children do concerning Zeno's Biological Functions $\chi^2(2{,}91) = 9.37$, $p = .002$ and Zeno's Biological Age $\chi^2(2{,}91) = 10.63$, $p = .001$.

In contrast, older children ask proportionally more questions concerning Zeno's Robot Capabilities $\chi^2(2{,}91) = 7.89$, $\text{p} = .005$; Zeno's capacity for, or experience of, Robot Feelings $\chi^2(2{,}91) = 7.76$, $p = .005$; Zeno's Gender Identity $\chi^2(2{,}91) = 8.82$, $p = .003$; and at threshold for Zeno's Identity as a Robot $\chi^2(2{,}91) = 7.48$, $p = .006$.

[5] Given the nine tests run we consider a significant result to occur at $\text{p} = .006$

There are no observed differences between age groups for Zeno's Social Relationships $\chi^2(2,91) = 1.71$, $p = .181$; Zeno's Favourites $\chi^2(2,91) = .86$, $p = .355$; or Zeno's Mechanical origin $\chi^2(2,91) = 3.27$, $p = .070$.

4 Discussion

The format of children asking open-ended questions towards a robot yields a substantial number that explore a robot's animacy and identity. It appears that these are of immediate personal interest to children during HRI, supporting hypothesis (1a). Results further indicate significant differences in the types of questions younger and older children tend to ask the humanoid robot, immediately following HRI. Younger children are more likely to ask questions concerning the humanoid's age and its biology, whereas older children tend to ask questions concerning the humanoid's identity and its capacity for behaviours and affect.

Prior research identifies that children tend to describe the humanoid Zeno as a hybrid of person and machine [11, 13] and that younger children view the robot as being more person-like than older children do. The current study, using an unstructured and open-conversation format for children to ask questions of Zeno, offers early support to both claims in the prior work.

First, children ask questions that can blur the boundaries of animacy. They may also switch between questions of an animate and inanimate nature in the same conversation with the robot. However, these were infrequent in the data set collected and, as yet, not suited to statistical analysis, offering some support for hypothesis (1b). Further research on children's mixed beliefs about humanoids may be more fruitful with using greater-depth interviews, such as those used in developmental research [4] and in HRI with the biommimetic Aibo [20].

Second, younger children are more likely to address the robot as if it was animate than older children do, supporting hypothesis (2a). Younger children's questions primarily concern life supporting functions and the robot's age (in terms of Zeno having a birthday rather than date of manufacture). Older children's questions tended to show a mixed picture, suggesting an understanding that Zeno is a machine (as reflected in their interest in its mechanical capabilities), albeit an emotionally expressive [12] and cognizant one (particularly one that self-identifies as a robot), offering some support for hypothesis (2b). Responsive, autonomous, and expressive robots may blur the boundaries between object and agent even for older children [2].

Older children were substantially more likely than younger children to ask questions regarding Zeno's gender identity. Given the relative low frequency of older children asking other questions regarding Zeno's 'biology', we interpret this as a social question towards the robot. Young children are argued to understand their own and others' gender identities; however, in later childhood, children observe and learn that gender is used as a cue to shape the social expectancies and interactions of themselves and others [21]. In essence, the older children's questions of Zeno's gender may exist as an implied, 'Once I know your gender, I know how to treat you'. Issues of gender have been raised in prior work with the Zeno humanoid [13, 18] and further work in this area may offer both insights into child development and more effective social robotics.

It should be noted that the children's questions came after interaction with a responsive and autonomous humanoid and, as such, are perhaps reflective of the children's cognitions *in the context of the HRI experience*. In addition to the robot's morphology, its behaviours in HRI, and a user's prior beliefs or experiences with robots, the *context* in which the HRI scenario takes place, may substantially shape the user's interaction experience [22]. In this context, children were instructed to direct questions towards the robot, which could prime beliefs of agency and animacy. In alternative contexts, children may generate different questions (e.g., writing a pen-pal style letter to a humanoid that a child has not yet met). A deeper understanding of children's beliefs concerning robot animacy can best come from an array of studies exploring aspects such as: morphology, autonomy, and responsiveness across a range of HRI contexts [14].

Further work to better develop an understanding of children's beliefs of animacy in robots could include expanding the corpus of questions, possibly thorough inclusion of children from different backgrounds and ages. Following this, the development of a more complete classification of questions, using a wider range of individuals to generate question categories. As it stands, the current research is an early starting point, offering insights into children's personal interests in understanding robotic agents. The format of open-ended questions is an unobtrusive means of exploring children's beliefs of animacy in robots and results suggest authentic beliefs of mixed or partial animacy in a humanoid. The current research offers support to use of measures [11, 13] and research frameworks exploring mixed animacy [10] and findings consistent with theoretical understandings [4] of children's development in beliefs of animacy.

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