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People Do Not Always Know Best: Preschoolers' Trust in Social Robots

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ABSTRACT

In this paper, we investigated whether Canadian preschoolers prefer to learn from a competent robot over an incompetent human using the classic trust paradigm. An adapted Naive Biology task was also administered to assess children's perception of robots. In Study 1, 3-year-olds and 5-year-olds were presented with two informants; A social, humanoid robot (Nao) who labeled familiar objects correctly, while a human informant labeled them incorrectly. Both informants then labeled unfamiliar objects with novel labels. It was found that 3-year-old children equally endorsed the labels provided by the robot and the human, but 5-year-old children learned significantly more from the competent robot. Interestingly, 5-year-olds endorsed Nao's labels even though they accurately categorized the robot as having mechanical insides. In contrast, 3-year-old children associated Nao with biological or mechanical insides equally. In Study 2, new samples of 3-year-olds and 5-year-olds were tested to determine whether the human-like appearance of the robot informant impacted children's trust judgments. The procedure was identical to that of Study 1, except that a non-humanoid robot, Cozmo, replaced Nao. It was found that 3-year-old children still trusted the robot and the human equally and that 5-year-olds preferred to learn new labels from the robot, suggesting that the robot's morphology does not play a key role in their selective trust strategies. It is concluded that by 5 years of age, preschoolers show a robust sensitivity to epistemic characteristics (e.g., competency), but that younger children's decisions are equally driven by the animacy of the informant.

Introduction

Selective trust, also known as epistemic trust, is the ability to select from whom to learn new information (Harris & Corriveau, 2011; Mills, 2013; Poulin-Dubois & Brosseau-Liard, 2016; Sobel & Finiasz, 2020). Not all the information we receive from others is accurate, as informants can be unreliable and purposefully or unintentionally provide inaccurate information (Harris, Koenig, Corriveau, & Jaswal, 2018; Koenig & Harris, 2005b). However, people can filter the information provided by considering the informant's past evidence of reliability and accuracy. Thus, humans can select the information they deem to be accurate and ignore incorrect and/or outdated information (Koenig & Harris, 2005a). Once developed, this ability allows humans to efficiently acquire novel knowledge from human and

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non-human informants (Tong, Wang, & Danovitch, 2019). Although selective trust might be emerging early, it appears to be primarily guided by the social characteristics of the informant. For example, infants as young as 14 months can selectively learn from various informants based on the conventionality of their behaviors and/or emotional displays (Poulin-Dubois & Brosseau-Liard, 2016).

Developmental shift

A decade of research on selective trust has revealed that 4 years of age appears to be the critical transition period at which children begin to display epistemic trust, that is, favor epistemic (e.g., competency, accuracy, reliability, expertise) over social characteristics (e.g., gender, familiarity, benevolence, ingroup status) of the informant when deciding whom to learn from (Henrich & Broesch, 2011; Tong et al., 2019). For example, numerous studies have revealed that 3-year-olds appear to consider both social and epistemic characteristics when deciding which informant to endorse, whereas older children are predominantly guided by epistemic characteristics when both characteristics are present (Tong et al., 2019). The developmental trajectory from relying on social characteristics to epistemic characteristics supports Henrich and Broesch's two-stage theory of transmission (Tong et al., 2019). According to this theory, children rely most on familiarity, showing a preference to learn from close relatives and parents early in childhood (Henrich & Broesch, 2011; Lucas et al., 2017). When children are novice learners, prioritizing social characteristics helps them adapt to social interactions. However, as children grow older and have more experiences interacting with others, their reliance on familiarity lessens. By 5 years of age, children instead elect to preferentially learn from knowledgeable informants (Lucas et al., 2017).

A variety of skills may contribute to the development of epistemic trust (Heyes, 2016; Poulin-Dubois & Brosseau-Liard, 2016; Sobel & Kushnir, 2013). A transition from social to epistemic characteristics appears to be guided by the development of a theory of mind (ToM), the ability to attribute mental states to oneself and to others (Poulin-Dubois, Azar, Elkaim, & Burnside, 2020; Wellman, 2014). A large body of work has revealed a link between ToM skills and performance in the selective trust task (Brosseau-Liard, Penney, & Poulin-Dubois, 2015; Crivello, Phillips, & Poulin-Dubois, 2017; DiYanni & Kelemen, 2008; Fusaro & Harris, 2008; Lucas et al., 2017; Palmquist & Fierro, 2018; Resendes, Benchimol-Elkaim, Delisle, René, & Poulin-Dubois, 2021). However, a few studies have failed to find such a link (Pasquini, Corriveau, Koenig, & Harris, 2007; Souza et al, 2021). A secondary, more exploratory goal of the present study was to examine the role of ToM when a robot informant is paired with a human informant in a selective trust task. To examine whether there is a link between children's ToM and selective trust, parents in the present studies filled out a parental measure of ToM, the Children's Social Understanding Scale (Tahiroglu et al, 2014). Due to younger children's reliance on social characteristics in selecting an informant, one would expect that individual differences in social affiliation would be negatively linked to epistemic trust. Therefore, another exploratory parental survey was administered, the Children's Prosocial Behavior Questionnaire (CPBQ) (Brazzelli, Farina, Grazzani, & Pepe, 2018).

Robots as informants

Interestingly, prior work has revealed that children can learn from non-human informants, specifically technological informants (e.g., computers, the internet) (Danovitch & Alzahabi, 2013; Noles, Danovitch, & Shafto, 2015; Wang, Tong, & Danovitch, 2019). For example, Danovitch and Alzahabi (2013) found that 3-, 4- and 5-year-olds relied on information from a computer informant who had previously displayed accuracy to identify novel objects and answer questions about unfamiliar facts. One unique way to examine what is driving the developmental shift from reliance on social versus epistemic characteristics would be to use social robots. A recent meta-analysis has shown that children interact with and learn from social robots (Stower, Calvo-Barajas, Castellano, & Kappas, 2021). However, much of the prior work either presented children with a single robot informant (Di Dio et al., 2020; Kory & Breazeal, 2014; O'Connell, Poulin-Dubois, Demke, & Guay, 2009; Oranç & Küntay, 2020) or pitted two robot informants against one another (Breazeal et al., 2016; Brink & Wellman, 2020; Geiskkovitch et al., 2019). To our knowledge, no previous study has used a human speaker and a social robot in a selective trust paradigm. By doing so, we can examine whether younger children prioritize social affiliation and/or in-group membership or the competency of the robot informant (epistemic characteristic) as more important when selecting whom to learn from. Notably, the present study aimed to provide a conservative test of 5-year-olds' reliance on epistemic characteristics in selective trust. If the epistemic bias is robust, children should prefer to learn from a competent inanimate informant.

Only a few studies have examined children's epistemic trust in social robots. Breazeal et al. (2016) introduced children between the ages of 3 and 5 years to two non-humanoid robots (Nao) that provided information about unfamiliar animals. Both informants were deemed reliable, yet sociability was manipulated. The socially sensitive robot looked at the experimenter when talking and looked down at the objects while they were being discussed. The socially insensitive robot appeared to be disengaged when the experimenter and child were talking (i.e., the robot looked at the experimenter and children when it was speaking but looked away for the rest of the time). The researchers found that the children treated the two robots as informants from whom they could learn. However, the children preferred to seek and endorse the information provided by the socially engaged robot compared to the socially disengaged robot.

Brink and Wellman (2020) also presented 3- to 4-year-old children with a selective word-learning task. The children were provided with labels for familiar and novel objects by two humanoid robots (Nao). The two robots were identical except for their color; one had orange accents, the other purple. During the selective word-learning task, one of the robots provided the children with accurate labels (i.e., competent), whereas the other gave inaccurate labels (i.e., incompetent). The researchers found that children learned from, and trusted information provided by both robots (i.e., names for novel items), similarly to the way they trust humans. Children trusted information from the accurate social robot more than the inaccurate social robot.

Similarly, Westlund et al. (2017), have shown that children aged 4 to 6 can learn new words from both a human, a tablet, and a robot. In their study, children were exposed to one informant at a time and learned six new words from each. However, Westlund did not pit a human and a robot directly against one another to see whom they would choose to learn novel words from after both had demonstrated accuracy. Children even reported that they preferred to learn from the robot informant, perhaps due to its novelty. Thus, prior work has converged to show that children prefer to learn from knowledgeable robots as they do knowledgeable humans. However, further research is needed to understand how children can learn words from social robots, especially in direct comparison to human informants.

The present studies

Although there is evidence that children can trust robots, what has not yet been studied is whom children will learn from when forced to choose between a robot or a human informant. Importantly, the present work examined whether children prioritize social or competency characteristics when asked to select between a human or robot informant. Such contrast allows for a conservative test of epistemic trust, as it requires children to focus on competence despite the lack of animacy of the informant. The classic trust paradigm developed by Koenig and colleagues (2004), was administered to Canadian 3- and 5-year-old children to contrast a competent social humanoid robot (Nao) with an incompetent human (Study 1). In Study 2, the same tasks were administered using a non-humanoid robot, Cozmo. By manipulating the physical appearance of the robot, we examined what role, if any, human-like morphology plays in selective trust and how its importance might change with age. How does the human-like appearance of the robot impact children's conceptualization and learning from robots? One would expect that physical appearance would be irrelevant to older children if epistemic characteristics dominate decision-making in the selective trust context. We hypothesized that the 3-year-olds would prioritize social affiliation over competency and elect to learn from the incompetent human. In contrast, we predicted the 5-year-olds would prioritize competency and learn more from the competent robot Nao.

To test if children are willing to learn from a social robot, despite the robot being an inanimate object, we needed to assess children's animacy judgment of the robot. Adults see robots as depictions of social agents, agents that can be interacted with but are not, in themselves, alive (Clark & Fischer, 2022). Yet, one might ask, how do children perceive robots? To date, studies have reported that children tend to classify humanoid robots as artifacts by 4 or 5 years of age when tested using an interview format (e.g., Is this alive? Does it have wires inside?) (Kim, Yi, & Lee, 2019; Okita et al., 2006; Somanader, Saylor, & Levin, 2011). Something lacking in the field so far are more interactive, child-friendly tasks meant to measure children's animacy judgment of robots.We elected to administer a task that directly measures children's conceptualization of robots instead of using an interview. A recent study using a Naïve Biology task has found that by 5 years of age, children attribute mechanical, rather than biological insides to robots (Goldman, Baumann, & Poulin-Dubois, 2023). Specifically, we used a modified version of Gottfried and Gelman's (2005) naïve biology task. The Naïve Biology task examined children's thoughts on the internal properties of unfamiliar animals, mechanical objects, and robots. Specifically, the naïve biology task provided insight into whether children would categorize the robot as a mechanical or biological entity. This task also served as a manipulation check. If children learn from a robot while still recognizing it as mechanical, the conservative nature of our test is confirmed. Based on previous research with artifacts, we predicted that 5-year-old children would correctly associate the robot with a mechanical inside, but that 3-year-olds would be confused about what should go inside robots. We administered the robot naïve biology trial both before and after the epistemic trust task. This allowed testing for a possible shift towards more attribution of biological insides after children see the robot behave in a competent, social manner. Additionally, two parent-report measures, the CSUS and the CPBQ, were used to assess children's ToM skills and prosocial behavior. We predicted that children who scored higher on ToM (the CSUS) would opt to learn the novel words from the robot (i.e., score higher on the trust task). We expected that those who displayed better prosocial skills (the CPBQ) would perform worse on the trust task (i.e., choosing the incompetent informant), as children who are more prosocial might demonstrate stronger in-group bias when it comes to learning from informants.

Study 1

Method

Participants

The sample consisted of 3-year-old Canadian children (N = 50, M_{age} = 3.52 years, SD = 1.86, N_{male} = 27) and 5-year-old children (N = 45, M_{age} = 5.41 years, SD = 1.82, N_{male} = 23) who were recruited from an existing database of participants and from birth lists provided by a governmental health agency. An a priori G*Power 3.1 analysis (Faul, Erdfelder, Lang, & Buchner, 2007) was run to determine the appropriate sample size for a 2 × 3 repeated measures analysis of variance. Our goal was to obtain .80 power to detect a medium effect size of .25 at the standard .05 alpha error probability. The analysis revealed a minimum sample size of 43, per group. Therefore, our current sample of 50 3-year-olds and 45 5-year-olds exceeds the minimum needed sample size. Due to COVID-19, children were tested virtually over the Zoom video platform. Parents were given the choice to have their child tested in either English or French as the experiment took place in a large metropolitan city in which most residents speak either English, French, or both languages. Most of the children in our sample were tested in English (N = 78). Prior to their participation, parents filled out a consent form. As compensation, parents received a $20 gift card to a local bookstore, and children received a certificate of merit for their participation. A total of 17 additional participants were tested but excluded; due to parental or sibling interference (n = 8), experimenter error (n = 2), prior robot exposure (n = 1), completing the study on a screen deemed too small (under 10 inches) (n = 2), and fussiness (n = 4). Parents also completed a demographic form. Approximately half of our sample was Caucasian (56.84%), a quarter of the sample was mixed race (25.26%), and the remainder of the sample (17.9%) consisted of various other ethnic groups (i.e., African, Asian, South American). In terms of socioeconomic status (SES), 57.89% of our participants identified as high SES families (>$100,000), 26.32% belonged to middle SES households ($50,000–$100,000), and 15.79% came from low SES households (< $50,000). All videos were re-coded by a second coder blind to the hypotheses to check the child's responses and attentiveness. Only two disagreements occurred (i.e., disagreement about which label the child endorsed). In these cases, an additional coder broke the tie.

Naïve biology task

The naïve biology task was adapted from Gottfried and Gelman (2005). The study began with two training trials. Each training trial featured an image of a familiar furniture item (i.e., a fridge or closet) that was missing a center piece. The missing piece was denoted with a white rectangle. Next to the familiar item were two options children could choose from. The correct option was something that would be likely to go inside that item (i.e., food, the correct option for the fridge training trial), and the other option had something that would not normally be placed inside the familiar item (i.e., clothing, something that would not be appropriate to place in the fridge). During the first training trial, the experimenter demonstrated which inside was correct. During the second training trial, the child had to pick between the two options independently. Whether the fridge or closet was presented first was counterbalanced.

During the test trials, children were shown four unfamiliar animals (i.e., ibek, pacarana, tapir, cavy), four unfamiliar artifacts (i.e., intercom, espresso maker, voice recorder, electric razor), and a picture of the robot Nao. All these images were also missing a piece in their center. As in the training trials, the missing piece was indicated by a white rectangle. The unfamiliar images (i.e., animals, artifacts, Nao) were presented one at a time. For every trial, one of four biological insides (i.e., muscle, lungs, heart, bone) and one of four mechanical insides (i.e., gears, circuit, batteries, wires) was presented for pairing to the child (see Figure 1). The experimenter asked the child which of the two unfamiliar options (i.e., one biological option and one mechanical option) should go inside. Children were asked to respond verbally and indicate which of the options they thought belonged inside. However, if the child did not respond after a few attempts due to shyness or other reasons, then the experimenter asked the child to point to their chosen image, and the parent was asked to indicate which option the child was pointing at (i.e., the top or bottom). Once the child picked an option, the experimenter moved the selected option into the missing "inside" and confirmed the child's choice. The internal insides paired with each unfamiliar image, the order of the unfamiliar images, and whether the biological or mechanical inside was on the

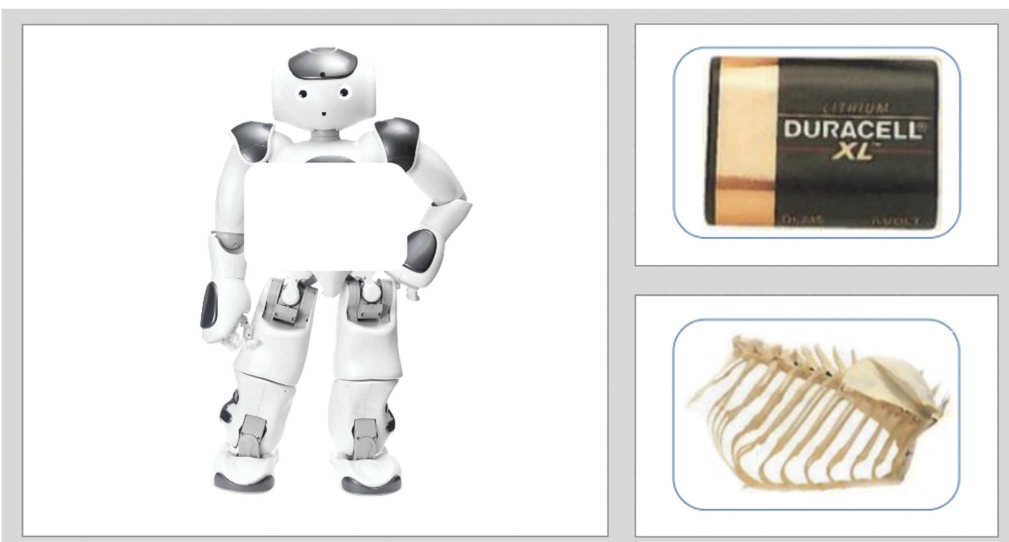

Figure 1. Robot trial from the naïve biology task. Note. Children selected whether the biological or mechanical option belonged inside the target robot image (i.e., seen on the left). Nao Robot: copyright © Aldebaran, part of United Robotics Group.

top or the bottom of the screen was counterbalanced. The counterbalancing resulted in four conditions.

In their study, Gottfried and Gelman (2005) verified that the mechanical and biological objects featured in the task are novel to children. To make sure the robot was also novel to children, a parental-report demographic form asked parents if their child(ren) had any regular exposure to robots. Overall, parents reported very low robot exposure, with only one parent reporting regular exposure. As a result of reporting regular exposure to a robot, this participant was excluded. Parents who reported their children watched robots occasionally on TV or had a conversational voice interface device (e.g., Google Home, Amazon Alexa) in their home were not excluded.

Scoring

Children received a point each time they properly assigned the correct inside to the target picture (i.e., mechanical inside to the artifacts and the robot, and a biological inside to the animals).

Selective trust task

The standard selective trust task originally designed by Koenig et al. (2004) was also administered. To introduce the selective trust task, the child was told that they would now meet the experimenter's robot and human friends and that these friends had toys they wanted to show the child. If the child's attention lapsed, the experimenter kindly asked the child to return their attention to the screen. The experimenter referred to both Nao and Ina by their names and introduced both informants as being the experimenter's friends. The experimenter also labeled Nao as a robot and Ina as a human throughout the selective trust task while asking the questions. All videos were pre-recorded and played to the child over Zoom.

Introductory video. To introduce the two informants, a video of the robot and human was played, in which they both pointed toward themselves and said, "Hi! My name is [Ina/Nao], I am excited to play a game with you today" (see Figure 2).

Familiarization trials. There were three familiarization trials. In each familiarization trial, Nao and Ina each labeled a familiar object. These objects included a toy car, a ball, and a cup. Nao always labeled the objects correctly, whereas Ina, the human informant, always labeled them incorrectly (e.g., Nao labeled the toy car as a car, while Ina labeled the toy car as a book; see Table 1 for the complete list of labels). The child was then asked to endorse one of the object labels provided by the informants (i.e., "can you tell me what this is called?," endorse trials). Following the three familiarization trials, the child was asked to identify whether Nao or Ina had provided them with correct or incorrect information (i.e., "my friends just told you a lot of things, did either of them say something [right/wrong]?," judgment trials). The familiarization trial judgment question served as an explicit judgment of the informants' reliability and thus allowed the children to verbally express which informant they deemed to be reliable. We anticipated that children would answer this question correctly since the items presented were familiar items.

Figure 2. Still frame of the video setup for the selective trust task. Nao Robot: copyright © Aldebaran, part of United Robotics Group.

Test trials. There were three test trials. In each test trial, Nao and Ina labeled an unfamiliar object. The novel objects included a blue cylinder (blue twine), a white rubber bulb (top of a Turkey baster), and a red silicone mold (resembled a muffin tin). Prior to playing the videos of Nao and Ina labeling the novel objects, the children were asked if they knew what the object was called. If a child said that they knew what the object was called and subsequently labeled it, the experimenter would state, "That's a good guess, but I don't think that's what this is called. Let's see if our friends can help us figure it out." Please note there was no difference in performance between the children who offered a name for at least one object vs those who did not, on any of the trials across both studies ($t(182) < -1.66$, $p > .10$). The child was then prompted to tell the experimenter which informant they wished to ask for the label of the novel object (i.e., ask questions). The ask questions were used to identify previous biases that may exist and to examine if the familiarization trials rendered Nao reliable. Nao and Ina labeled the objects using different nonsense labels such as a "toma" and a "mido" (see Table 1 for the complete list of labels). Since the novel objects were likely unfamiliar to the child, they had to rely on one of the informants to learn the labels. The experimenter then asked the child to endorse one of the informant's labels by asking the child to name the object (i.e., endorse questions). Correct responses for this task required children to endorse the label that was provided by Nao, as Nao was the informant who consistently labeled the familiar objects correctly in the familiarization trials. After completing the test trials, the children were again asked to indicate which informant provided correct or incorrect labels (i.e., test trial judgment question).

Table 1. The selective trust task procedure, per trial, for both the familiarization and test trials.

Familiarization Trials	Object	Robot Label	Human Label	Endorse Trials	Explicit judgment Trials
"Let's see what my friends think this is called."		Car	Book	*"CHILD, what do you think this is called?"*	*"Now my friends just told you a lot of things. Did either of my friends say something [right/ wrong]?"*
		Ball	Shoe		
		Cup	Dog		

Knowledge Check	Ask Trials	Test Trials	Object	Robot Label	Human Label	Endorse Trials	Explicit judgment Trials
Show Child Object, *"Do you Know what this is?"* If yes, *"I don't think that's what this is called, but let's see what my friends have to say."*	*"Who do you want to ask what this is called?"*	*"Let's see what my friends think this is called."*		Toma	Mido	*"CHILD, what do you think this is called?"*	*"Now my friends again told you a lot of things. Did either of my friends say something [right/wrong]?"*
				Fep	Dax		
				Bosa	Dawnoo		

There were four versions of the selective trust task. Each child was shown the same familiar and unfamiliar objects in the same order; however, who spoke first (i.e., Nao or Ina) and the position of the first speaker (i.e., on the right or the left) was counterbalanced across the conditions. Furthermore, the explicit judgment question was also counterbalanced; half of the participants were asked to identify the accurate speaker (i.e., who said something right?), while the other half were asked to identify the inaccurate speaker (i.e., who said something wrong?). Counterbalancing helped to ensure internal validity and controlled for any possible confounds that could have been created by sequence or order effects (e.g., the child always endorsing the label they heard last or always selecting the informant on the left).

Scoring. For both the familiarization and test trials of the selective trust task, children received a score out of three for the ask questions (i.e., whom they asked for help), a score out of three for the endorse questions (i.e., whose label they used), and a score out of two points for the judgment question (i.e., who said something right or wrong). Children received a point each time they asked Nao for the label for the ask trials. For the endorse trials, children received a point when they endorsed the label that was provided by Nao. When asked who said something right, children who selected Nao received a point, and when asked who said something wrong, children who selected Ina received a point.

Children's social understanding scale (CSUS)

In addition to the two tasks, parents filled out two forms. Parents filled the forms out either before or after the testing session. The CSUS is a parental report measure of children's social understanding, or theory of mind, between the ages of 2 and 7 years. The survey included 42 questions or statements, which parents responded to on a 4-point Likert scale ranging from "definitely untrue (1)" to "definitely true (4)." There was also a "don't know" option parents could select if they could not accurately judge their child's behavior for that item. The questions fall into six domains, with seven questions in each: emotion, intention, desire, perception, knowledge, and belief. An average score per child was determined combining all domain (Tahiroglu et al., 2014). The French version of the CSUS has been validated by Brosseau-Liard et al. (2019).

Child prosocial behavior questionnaire (CPBQ)

To our knowledge, there is no parental report measure that assesses all facets of social affiliation. As an informed choice, we selected the CPBQ, an instrument for detecting and measuring different aspects of prosocial behaviors in children, which have been found to relate to social affiliation (Sparks, Schinkel, & Moore, 2017). The CPBQ is a parental report measure of children's prosocial behavior towards adults and children that is validated for ages 1 to 4 years. It consisted of 10 questions, which parents responded to on a 5-point Likert scale which ranged from "Never (1)" to "Always (5)." The questions fall into three domains: comforting (3 questions), helping (3 questions), and sharing (4 questions). An average score per child was determined combining all domain (Brazzelli et al., 2018). The CPBQ was translated into French for the purpose of the current study.

Procedure

As the study took place online, the parent and their child joined a Zoom meeting for the testing session. The Zoom session lasted between 15 and 30 minutes, and the children were seated in front of or beside their parents. Parents were informed that the study could only be completed on a tablet or computer, not a phone. A minimum screen size of 10 inches was required to properly view the videos and other stimuli. Prior to the study, the parent(s) were briefed on the study's goals and filled out a consent form. The two forms (CSUS and CPBQ) and the demographics form were completed either before or after the Zoom session. Participants first completed the naïve biology task, then the selective trust task, and finally were shown the Nao (robot) naïve biology trial again. Parents were then debriefed, informed of the study's purpose, and given a chance to ask any questions.

Materials

Materials included the robot Nao, developed by Softbank robotics. Nao is an autonomous, programmable, humanoid robot standing at 23 inches in height. A laptop with the Zoom application installed was used to administer the study. The images and videos for both tasks were presented over Zoom using Microsoft PowerPoint.

Results

Data cleaning and transformation

Participants who selected neither option, both options, or made a conflicting choice (i.e., said they wanted to endorse the robot's label but then picked the human's label) on the tasks (selective trust, naïve biology) received a score of 0 on that trial for failing to make a clear choice (n = 11 trials).

All data was checked for normality. If a deviation from normality was found, appropriate corrections were applied, and nonparametric tests were run. If a given analysis changed in significance (i.e., became insignificant or trending), that change is reported below. Analyses were checked for interactions between gender (male or female) and testing language (French or English) on both tasks (selective trust, naïve biology), but no significant interactions with the tasks were found. Therefore, gender and language were collapsed across all subsequent analyses. Due to the selective trust task and the naïve biology task having a different number of trials, the raw scores were transformed into proportions for the purposes of cross-trial or cross-task analyses.

Table 2. Mean scores and chance analyses per age group for the selective trust task.

Selective Trust Trial	n	Age	Mean	SD	Chance Analysis
Ask	50	3	2.44	0.86	$t(49) = 7.72, p < .001, d = 1.09$***
Ask	45	5	2.31	0.73	$t(44) = 7.42, p < .001, d = 1.11$***
Endorse	50	3	1.46	0.95	$t(49) = -0.30, p = .77, d = -0.04$
Endorse	45	5	2.07	0.99	$t(44) = 3.85, p < .001, d = 0.58$***
judgment	50	3	1.36	0.72	$t(49) = 3.53, p < .001, d = 0.50$***
judgment	45	5	1.62	0.49	$t(44) = 8.51, p < .001, d = 1.27$***

The ask and endorse trials were scored out of /3. The judgment trial was scored out of /2. *** Indicates significance below $p < .001$.

Selective trust

Accuracy trials. After each of the three familiar items were labeled, children responded to the question, "what do you think this is called?" Children responded with the correct label, presented by Nao, 99.97% of the time. Therefore, children endorsed the robot Nao's correct labels (over Ina's incorrect labels) when presented with items that were likely already familiar to them.

Chance analyses (out of 4 trials) revealed that all children performed well on all trials, that is, chose the competent speaker, except for the 3-year-olds on the endorse trials (see Table 2). A 2 (age) x 3 (trial type) repeated-measures analysis of variance (ANOVA) test compared the proportion of correct trials (ask, endorse, and judgment trials) with age as a between-subjects factor. The ANOVA revealed a main effect of trial ($F(2, 186) = 20.23$, $p < .001$, $\eta_p^2 = 0.18$). This main effect was driven by children performing better on the endorse trials, compared to the ask ($t(93) = 6.06$, $P_{holm} < .001$) and judgment trials ($t(93) = -4.69$, $P_{holm} < .001$). A main effect of age was also significant ($F(1, 93) = 4.02$, $p = .048$, $\eta_p^2 = 0.04$), with 5-year-olds performing better on selective trust overall when compared to 3-year-olds ($t(93) = -2.01$, $P_{holm} = .048$). A significant interaction was found between trial and age (3 and 5 year-olds) ($F(2, 186) = 7.98$, $p = .001$, $\eta_p^2 = 0.07$). This relationship was further investigated with independent t-tests for each trial type (ask, endorse, and judgment), split by age. The 5-year-old children outperformed the 3-year-olds on the endorse trials ($t(93) = -3.05$, $p = .003$, $d = .16$). There was no age difference in performance on the ask trials ($t(93) = 0.78$, $p = .44$, $d = -.63$). Finally, the 5-year-olds were trending towards better performance on the judgment trials after normality corrections ($t(93) = -2.05$, $p = .04$, $d = -.42$; *Mann-Whitney* $= 928.00$, $p = .096$, $d = -.18$).

It is important to note that there was no difference in children's performance between the first and third endorse trials. Therefore these results are not simply due to children "forgetting" the robot's accuracy as the test is administered (First trial (twine): $M = .58$, $SD = .50$, Third trial (funnel): $M = .60$, $SD = .49$; $t(94) = -0.45$, $p = .66$, $d = -0.05$).

Naïve biology task

The number of trials with a correct part chosen (biological for animals, mechanical for robots, and artifacts) was the dependent variable. Chance analyses (out of 4 trials) revealed that all children performed well on all trials except for the robot trials at age 3 (see Table 3). A repeated-measures analysis of variance (ANOVA) test compared the proportion of correct trials (animal, artifact, and robot) with age as a between-subjects factor. Mauchly's test of sphericity indicated that the assumption of sphericity was violated ($p > .05$). Therefore, a Greenhouse-Geisser correction was applied to this analysis. The ANOVA

Table 3. Mean scores and chance analyses per age for the naïve biology task.

Naïve Biology Domain	n	Age	Mean	SD	Chance Analysis
Animal	50	3	2.50	1.11	$t(49) = 3.18$, $p = .003$, $d = 0.45$**
Animal	45	5	3.56	0.87	$t(44) = 19.76$, $p < .001$, $d = 2.95$***
Artifact	50	3	2.40	1.13	$t(49) = 2.51$, $p = .02$, $d = 0.36$*
Artifact	45	5	3.58	0.69	$t(44) = 25.04$, $p < .001$, $d = 3.73$***
Robot	50	3	1.14	0.83	$t(49) = 1.19$, $p = .24$, $d = 0.17$
Robot	45	5	1.82	0.44	$t(44) = 12.49$, $p < .001$, $d = 1.86$***

The animal and artifact trials were scored out of /4. The robot trials were scored out of /2. *** Indicates significance below $p < .001$. ** Indicates significance below $p < .01$. * Indicates significance below $p < .05$.

revealed a main effect of trial (F(1.88, 174.47) = 110.59, $p < .001$, $\eta_p^2 = 0.54$), with animals being rated as less mechanical than both artifacts (t(93) = −12.96, $P_{holm} < .001$) and the robot (t(93) = −12.79, $P_{holm} < .001$). A main effect of age was also found (F(1, 93) = 12.13, $p < .001$, $\eta_p^2 = 0.16$), with older children outperforming younger ones (t(93) = −3.48, $P_{holm} < .001$). The interaction between trial and age was also significant (F(1.88, 174.47) = 37.47, $p < .001$, $\eta_p^2 = 0.29$), with 5-year-olds outperforming 3-year-olds on the animal (t(93) = 5.12, $p < .001$, d = 1.05), artifact (t(93) = −6.07, $p < .001$, d = −1.25), and robot (t(93) = −4.91, $p < .001$, d = −1.01) trials.

There was no significant difference between children's judgments of the robot before compared to after the selective trust task for either age group (t(49) = 0.77, p = .44, d = 0.11 for 3-year-olds, t(44) = −1.67, p = .10, d = −0.25 for 5-year-olds). The scores on the robot trials were not significantly correlated with the endorse trials at ages 3 or 5 years. Importantly, when the two samples were combined, only the endorse trials were found to weakly correlate with the combined naïve biology robot score (r(93) = .21, p = .04). Finally, the robot trials were not correlated with the ask trials or the judgment trials at either age or when both age groups were combined.

CPBQ questionnaire

In total, 91 parents filled out the CPBQ parental questionnaire (the CPBQ data for four children was missing). The 3-year-old children's average CPBQ score was 3.69 out of 5 (SD = 0.53). The 5-year-old children's average CPBQ score was 2.94 out of 5 (SD = 0.25). This is in line with a previous study that used this assessment tool with 1- to 4-year-olds (16–42 months, M = 3.23, SD = 1.08; Brazzelli, 2018). No correlational links were found between any selective trust trials (ask, endorse, or judgment) and the CPBQ score (all analyses, r(89) < .10, p > .34).

CSUS questionnaire

Four children were missing CSUS parental report responses (n = 91 parental responses). The 3-year-old children's average CSUS score was 3.05 out of 4 (SD = 0.41), and the 5-year-old children's average CSUS score was 3.38 out of 4 (SD = 0.32). These average scores are in line with the prior work (28–84 months, M = 3.08, SD = 0.45; Tahiroglu et al., 2014). When the sample was split by age, no significant correlations were found between the CSUS score and selective trust performance. However, when the 3- and 5-year-old samples were combined, a moderate positive correlation emerged only between the score on the endorse trials and the combined CSUS score (r(89) = .22, p = .04), with greater Theory of Mind predicting greater endorsement of Nao, the competent robot informant.

Overall linear regression

The CSUS correlations above revealed a potential link between ToM and selective trust, specifically the endorsement trials. However, the effects were weak. To investigate overall trends and to examine if this link would emerge in a complete study model, a stepwise linear regression was run with the endorse trials as the outcome measure. Age was entered into model 1, overall Naïve Biology score in model 2, and scores from both questionnaires (CPBQ and CSUS) were entered in model 3. The first model was significant (F(1, 86) = 8.71, p = .004), with age accounting for 9% of the variance in the endorse scores (R^2 = .092). Model 2, including the overall Naïve Biology score, proved insignificant ($F(1, 85) = 0.06$, $p = .81$), explaining only a further .001% of the variance (R^2 = .093). Model 3 (including the CSUS and CPBQ overall scores) was removed from the regression due to insignificance, not meeting the criterion for inclusion.

Discussion

The main goal of this study was to examine whether children aged 3 and 5 years would prefer to learn new words from a competent robot over an incompetent human. As such, the main contribution of the present work was to provide a highly conservative test of this developmental shift in comparison to previous studies contrasting two human or robot informants. Importantly, the informant that children endorsed in the test trials differed by age group. As expected, older children in our sample (the 5-year-olds) endorsed the labels of the competent robot over the incompetent human. This finding mirrors prior work that used two human informants (Tong et al., 2019) and significantly extends upon it since the competent inanimate social informant was pitted directly against an incompetent human social informant. The inanimate status of the robot was confirmed through the naïve biology task, where 5-year-olds assigned a mechanical inside to Nao. Thus, 5-year-olds knew Nao was inanimate (i.e., had mechanical insides) yet still elected to learn from Nao.

In contrast, 3-year-olds were ambivalent regarding the animacy status of the robot and whom to endorse during the test trials. For the animal and artifact trials, our findings replicate and extend previous work on the knowledge of insides of artifacts and animals (Gottfried & Gelman, 2005). The ambivalence of the younger children was unexpected as we had predicted that most of the younger children would endorse the human informant as she belonged to the "same group" as the child (e.g., a shared social affiliation). The results do, however, align with the Tong et al. (2019) meta-analysis, which found that 3-year-old children consider both social and epistemic characteristics when they are pitted against one another. Thus, given that both informants displayed social characteristics (e.g., human-like morphology, speech, goal-directedness), young children's lack of preference suggests a bias towards social characteristics over epistemic ones. While the 3-year-olds may consider the competency of the informant, their sensitivity to epistemic characteristics appears to be insufficient to trump social characteristics.

The fact that 3-year-olds showed no clear preference could be explained by having missed the critical information during the familiarization phase. This is unlikely as both 3- and 5-year-olds in our sample were equally competent at judging who gave the right or wrong information. Furthermore, both the 3- and 5-year-old children knew to ask the robot for the label. Although we cannot identify the motivational differences across the age groups, we speculate that the 3-year-olds were motivated to interact socially with the robot during the ask questions, showing that the ask and endorse questions rely on different underlying information. Specifically, one could ask someone for more information without wanting to endorse or use the information that was provided. This also further emphasizes the validity of the task, as even 3-year-old children knew who was right (the robot) and asked the robot for the label, yet still did not always choose to learn from (i.e., endorse) the robot. This pattern of results confirms the meta-analysis by Tong et al. (2019), showing that age is a moderator for the endorse but not the ask questions. Matching their performance on the selective trust task, the 3-year-old children associated Nao equally with a biological or mechanical inside, whereas 5-year-old children correctly categorized the robot as mechanical. Thus, the 5-year-old children endorsed Nao's labels, even though they knew Nao was mechanical, confirming the conservative nature of this test of epistemic characteristics.

An exploratory goal was to examine what skills may drive the developmental shift toward a greater reliance on epistemic characteristics by 5 years of age. Among the two skills tested, prosociality (CPBQ) and ToM (CSUS), only ToM correlated to the endorse selective trust trials. As expected, children with more ToM skills performed better on the endorse trials. We speculate that, as children develop an understanding of others' mental states, it becomes easier not to rely solely on "like me" social characteristics but to also consider other characteristics, such as competency, even in non-human informants. Important to note, however, is that this correlational effect is rather weak and did not survive in the overall linear regression.

One potential explanation for the ambivalence of the 3-year-olds is that the robot informant was humanoid in appearance, resulting in social characteristics that were judged equivalent to a human speaker at that age. Thus, it is possible that a robot with a less human-like appearance would shed light on what is driving 3-year-old's trust choices. To clarify this issue, we ran a follow-up study with the same procedure, except that we pitted the incompetent human against Cozmo, a competent non-human-looking robot. Cozmo lacked almost all the human characteristics of Nao, as Cozmo was small in size, had wheels/treads and a mechanical lift rather than feet and hands but still possessed eyes, spoke, and moved autonomously. If human appearance is critical when evaluating which informant to trust, we predicted that the 3-year-olds would show a preference for the incompetent human informant in Study 2.

Study 2

Method

Participants

The sample consisted of 43 Canadian 3-year-old children (M_{age} = 3.34 years, SD = 1.31, N_{male} = 26) and 46 Canadian 5-year-old children (M_{age} = 5.50 years, SD = 1.70, N_{male} = 24) who were recruited from an existing database of participants. See Study 1 for a justification of our sample size. As in Study 1, a majority of our sample was Caucasian (60.92%), roughly a quarter of our sample (22.99%) identified as mixed race, and the remainder of our sample (16.09%) belonged to other ethnic groups (African, Asian, South American). In terms of the socioeconomic status (SES), 69.05% of our participants belonged to high SES families (>$100,000), 28.57% were from middle SES households ($50,000–$100,000), and 2.38% came from low SES households (<$50,000). The study was conducted online in either English (n = 55) or French (n = 34) on the video conference application Zoom. Prior to participation, parents signed a consent form on behalf of their child. The compensation received and the exclusion criteria were identical to Study 1. Out of

Figure 3. Still frame of the selective trust video setup in Study 2. Cozmo Robot: copyright © Digital Dream Labs.

the 105 total children tested, 16 participants had to be excluded due to: parental or sibling interference (n = 10), familiarity with the robot (n = 1), technical difficulties (n = 1), or fussiness (n = 4).

The tasks, methods, procedures, and materials of Study 2 were identical to those of Study 1, with one significant change. The human-looking robot Nao was replaced with the non-human-looking Cozmo (see Figure 3). Cozmo is a non-humanoid toy robot that had wheels, treads, and a mechanical lift and is produced by Digital Dream Labs. Cozmo is 2.5 inches tall. To confirm that Cozmo was less human-looking than Nao, undergraduate students ($N = 23$) were asked to rate a variety of robots, including Nao and Cozmo. Students were asked how human looking the robots were using a 5-point Likert scale; the higher the score, the more human looking the robot was rated. Nao (M = 4.09, SD = 0.90) was rated significantly more human-looking than Cozmo (M = 1.91, SD = 0.95; $t(22) = -13.41$, $p < .001$, $d = -2.80$). Therefore, Cozmo was selected since it was rated as significantly less human-looking in appearance than Nao. On the demographic form, parents were asked to report their child's exposure to robots. All parents rated their children as unfamiliar with robots.

Results

Data cleaning and transformations

As in Study 1, participants who selected neither option, both options, or made a conflicting choice (i.e., said they wanted to endorse the robot's label but then picked the human's label) on the tasks (selective trust, naïve biology) received a score of 0 on that particular trial for failing to make a choice (n = 7 trials).

All analyses were checked for normality. If a deviation from normality was found, appropriate corrections were applied, and nonparametric tests were run. If a given analysis changed in significance (i.e., become insignificant or trending), that change is reported below. Analyses were checked for interactions between gender (male or female) and testing language (French or English) on both tasks (selective trust, naïve biology). The only significant interaction was between the naïve biology task and testing language. The interaction between the overall naïve biology task (scored as the proportion of correct trials /10) and testing language was significant (F(1.84, 158.32) = 3.60, p = .03, η_p^2 = 0.04), with the French children (n = 34, M = 5.44, SD = 1.24) outperforming the English children (n = 55, M = 5.13, SD = 1.02). Due to the unequal sample sizes between the two language groups, this finding is most likely spurious. Gender and testing language were collapsed across all other analyses.

Selective trust

Accuracy trials. In the familiarization trials, the children responded to the endorse question (i.e., "what do you think this is called?") with the correct label, presented by Cozmo, 96.25% of the time. Children trusted Cozmo's labels when presented with familiar items.

Chance analyses (out of 4 trials) revealed that all children performed well on all trials, except the 3-year-olds on the endorse and judgment trials (see Table 4). A 2 (age) x 3 (trials) repeated-measures analysis of variance (ANOVA) test compared the proportion of correct selective trust trial types (ask, endorse, and judgment trials) with age as a between-subjects factor; the ANOVA revealed main effects of trial types (F(2, 174) = 10.58, p < .001, η_p^2 = 0.11), with children performing better on the ask (t(87) = 4.19, P_{holm} < .001) and judgment (t(87) = −3.75, P_{holm} < .001) trials when compared to the endorse trials. A main effect for age was also significant (F(1, 87) = 20.36, p < .001, η_p^2 = 0.19), with 5-year-olds outperforming 3-year-olds (t(87) = −4.51, P_{holm} < .001). The interaction between selective trust and age (3 and 5 year-olds) was not significant (F(2, 174) = 1.31, p = .27, η_p^2 = 0.02). Independent t-tests revealed that 5-year-olds outperformed 3-year-olds on the ask (t(87) = −2.66, p = .009, d = −.57; *Mann-Whitney* = 751.00, p = .03, d = −.24), endorse (t(87) = −3.25, p = .002, d = −.69), and judgment (t(87) = −3.94, p < .001, d = −.84) trials. As in Study 1, there was no difference in children's endorsement ratings of the robot from test endorse trial number 1 to 3 (First trial (twine): M = .61, SD = .49, Third trial (funnel): M = .56, SD = .50; t(88) = 0.78, p = .44, d = 0.08).

Table 4. Mean scores and chance analyses per age for the selective trust task.

Selective Trust Trial	n	Age	Mean	SD	Chance Analysis
Ask	43	3	2.05	1.07	t(42) = 0.93, p = .002, d = 1.92**
Ask	46	5	2.54	0.66	t(45) = 10.78, p < .001, d = 1.59***
Endorse	43	3	1.51	0.83	t(42) = 0.09, p = .93, d = 1.83
Endorse	46	5	2.11	0.90	t(45) = 4.59, p < .001, d = 0.68***
judgment	43	3	1.21	0.89	t(42) = 1.55, p = .13, d = 0.22
judgment	46	5	1.78	0.42	t(45) = 12.73, p < .001, d = 1.88***

The ask and endorse trials were scored out of /3. The judgment trial was scored out of /2. *** Indicates significance below p < .001. ** Indicates significance below p < .01.

Table 5. Mean scores and chance analyses per age for the naïve biology task.

Naïve Biology Domain	n	Age	Mean	SD	Chance Analysis
Animal	43	3	2.42	0.91	$t(42) = 3.03$, $p = .004$, $d = 0.46$**
Animal	46	5	3.83	0.08	$t(45) = 21.74$, $p < .001$, $d = 3.21$***
Artifact	43	3	2.05	0.93	$t(42) = 0.33$, $p = .74$, $d = 0.05$
Artifact	46	5	3.59	0.10	$t(45) = 16.50$, $p < .001$, $d = 2.43$***
Robot	43	3	1.23	0.81	$t(42) = 1.88$, $p = .07$, $d = 1.52$
Robot	46	5	1.81	0.47	$t(45) = 12.24$, $p < .001$, $d = 1.80$***

The animal and artifact trials were scored out of /4. The robot trials were scored out of /2. *** Indicates significance below $p < .001$. ** Indicates significance below $p < .01$.

Naïve biology

Chance analyses (out of 4 trials) revealed that all children performed well on all trials, except the 3-year-olds on the artifact and robot trials (see Table 5). A repeated-measures analysis of variance (ANOVA) test compared the proportion of correct trials (animal, artifact, and robot) with age as a between-subjects factor and testing language entered as a covariate. Mauchly's test of sphericity indicated that the assumption of sphericity was violated ($p > .05$). Therefore, a Greenhouse-Geisser correction was applied to this analysis. The ANOVA revealed a main effect of trial ($F(1.84, 158.32) = 41.61$, $p < .001$, $\eta_p{}^2 = 0.33$), with artifacts ($t(87) = -12.41$, $P_{holm} < .001$) and robots ($t(87) = -14.10$, $P_{holm} < .001$) being rated as more mechanical than animals. A main effect of age ($F(1, 86) = 17.71$, $p < .001$, $\eta_p{}^2 = 0.17$) and an interaction between trial and age ($F(1.84, 158.32) = 52.41$, $p < .001$, $\eta_p{}^2 = 0.38$) were also found, with 5-year-olds outperforming 3-year-olds on the animal ($t(87) = 8.84$, $p < .001$, $d = 1.87$), artifact ($t(87) = -9.13$, $p < .001$, $d = -1.94$), and robot ($t(87) = -4.41$, $p < .001$, $d = -0.94$) trials.

There was no significant difference between children's ratings of the robot before or after the selective trust task ($t(42) = -0.27$, $p = .79$, $d = -0.04$ for 3-year-olds, $t(45) = -1.77$, $p = .08$, $d = -0.26$ for 5-year-olds). Finally, the robot trials were not significantly correlated with the endorse, ask, or judgment trials (all correlations $r(87) < .12$, $p > .18$).

Child prosocial behavior questionnaire (CPBQ)

Five parents failed to fill out the CPBQ form ($n = 84$ parental responses). The 3-year-old children's average score on the CPBQ was 3.63 ($SD = 0.55$). The 5-year-old children's average score on the CPBQ was 3.72 ($SD = 0.41$). For 3-year-olds, no significant correlations were found for any of the selective trust trials (ask, endorse, or judgment) and the CPBQ score. For 5-year-olds, only the judgment trials positively correlated with the CPBQ score ($r(42) = .40$, $p = .007$). When the 3- and 5-year-old samples from Study 2 were combined, no significant correlations emerged.

Children's social understanding scale (CSUS)

A total of two parents did not complete the CSUS ($n = 87$ parental responses). The 3-year-old children's average overall CSUS score was 2.99 out of 5 ($SD = 0.36$). The 5-year-old children's average overall CSUS score was 3.47 out of 5 ($SD = 0.25$). As expected, Theory of Mind improved with age. For 3-year-olds, no correlational links were found between any selective trust trials (ask, endorse, or judgment) and the CSUS score. The same was found for the 5-year-olds. When the 3- and 5-year-old samples were merged, however, the ask score was trending towards positive significance with the CSUS score ($r(85) = .21$, $p = .06$).

Cross-robot comparisons

Children's naïve biology and selective trust scores were compared for the humanoid robot Nao versus the non-humanoid robot Cozmo across the two studies. A repeated measures ANOVA examined children's selective trust performance (endorse, ask, and judgment) with robot type (Cozmo or Nao) entered as a between-subjects factor and found no main effect of robot type ($F(1, 182) = 0.01$, $p = .93$, $\eta_p^2 = 0.00$) and no significant interaction between selective trust trials and robot type ($F(2, 364) = 0.49$, $p = .62$, $\eta_p^2 = 0.003$). Another repeated measures ANOVA was also run to examine children's naïve biology performance (animal, artifact, and robot) with robot type (Cozmo or Nao) entered as a covariate. Mauchly's test of sphericity indicated that the assumption of sphericity was violated ($p > .05$). Therefore, a Greenhouse-Geisser correction was applied to this analysis. This ANOVA also found no main effect of robot type ($F(1, 182) = 0.09$, $p = .76$, $\eta_p^2 = 0.00$) and no significant interaction between naïve biology and robot type ($F(1.74, 315.70) = 0.87$, $p = .41$, $\eta_p^2 = 0.01$). When both samples of the two studies are combined, the correlation between the robot score (both robot naïve biology trials) with the endorse selective trust trial became significant ($r(182) = .18$, $p < .02$). This effect is likely driven by age. Importantly, the ask and judgment trials still do not significantly correlate with the robot trials. No significant correlations between CPBQ and selective trust emerged either when the two samples were grouped together by age or when all four samples were combined together ($r(173) < .09$, $p > .24$). When the 3-year-old samples from both studies were merged for the CSUS analyses, no significance was found. However, the analysis of the two merged 5-year-old samples revealed a marginally positive correlation between the ask score and the CSUS ($r(84) = .20$, $p = .06$). When both studies and both ages are combined for analyses, weak correlations emerged between both the endorse ($r(176) = .19$, $p = .01$) and the judgment ($r(176) = .18$, $p = .02$) trials and the CSUS scores.

Overall model. To investigate if any ToM or prosociality effects survive in an overall study model, a stepwise linear regression was run with the endorse trials as the outcome measure on the combined Studies 1 and 2 datasets. Age was entered into model 1, overall naïve biology score in model 2, and both questionnaires (CPBQ and CSUS) in model 3. The first model was significant ($F(1, 170) = 17.21$, $p < .001$), with age accounting for 9% of the variance in the endorse scores ($R^2 = .092$). Naïve biology, as entered into Model 2, proved insignificant ($F(1, 169) = .58$, $p = .45$), explaining only a further .003% of the variance ($R^2 = .095$). Model 3 was not run due to the non-significant effects of both the CSUS and CPBQ in explaining any variance. Therefore, the variance in the endorse score in our sample is mostly explained by age.

Structural equation modeling (SEM) using Mplus (Muthén & Muthén, 1998–2017) was run after the Linear Regression to investigate any potential indirect effects of the variables mediating the association between age and the trust scores. Results showed a significant direct association between age and endorse ($\beta = .30$, $p < .001$) and judgment ($\beta = .21$, $p < .001$) but not on the ask trials ($\beta = .09$, $p = .17$). Additionally, age was significantly associated with the CSUS ($\beta = .20$, $p < .001$), but not robot type ($\beta = -.02$, $p = .56$) or the CPBQ ($\beta = -.02$, $p = .67$). All mediation analyses were observed to be not statistically significant (all $p > .21$).

Discussion

This second study investigated whether human morphology plays a role in 3- and 5-year-olds' choice of an informant in the selective trust paradigm. Despite manipulating human morphology by using a non-human-looking robot, the findings of Study 2 mirror those of Study 1. Children competently knew to ask the robot for help in learning novel object labels, and they responded correctly (knew who was right versus wrong) on the familiarization judgment trials. Despite Cozmo's lack of human appearance, the 3-year-old children in our sample still readily endorsed Cozmo's labels during half of the test trials. This suggests that the agency characteristics of the robot (speech, goal-directness), not its human appearance, were most likely the key characteristics guiding 3-year-olds evaluations of the informants. Importantly, the 5-year-olds, like in Study 1, continued to endorse the accurate agent, providing an even more conservative test of epistemic trust.

The 3-year-olds were not accurate at categorizing Cozmo's internal properties, although they tended towards assigning more mechanical insides than biological insides to Cozmo. However, as this result is only trending and the scores do not differ significantly from those for a humanoid robot, Nao, human morphology does not seem to be a main criterion guiding children's decision-making on whether a robot is either mechanical or biological. In contrast, the 5-year-olds correctly assigned a mechanical inside to Cozmo, like they did with Nao in Study 1. Interestingly, naïve biology was found to predict selective trust performance, specifically on the endorse trial, when the samples of Study 1 and Study 2 were combined. So, while small in effect, there does seem to be a connection between the performance on the two tasks. Better categorization of robots as mechanical artifacts seems to slightly better predict learning from a competent robot. However, this effect is most likely driven by age, as competence increases on both tasks from 3 to 5 years.

Regarding the parental report measures, the CPBQ was again found to have little effect on children's selective trust performance. Even with a large, combined sample, only correlations between the judgment trials and prosociality were observed. Important to note is that this effect did not hold in either of the general models. A stronger correlation was found between the selective trust trials (ask, endorse, and, judgment) and the CSUS. However, this relationship does not survive in the SEM model. Therefore, only a very weak positive correlation can be claimed, with greater ToM skills related to better learning from the robot.

General discussion

A recent meta-analysis based on a large body of studies on selective trust has found that the effects of informants' epistemic characteristics are moderated by children's age, with children beginning to prioritize epistemic (e.g., expertise, accuracy) over social (e.g., speech, familiarity) characteristics around the age of 4 years (Tong et al., 2019). The main goal of the current set of studies was to examine the robustness of epistemic trust by pitting a competent robot informant against an incompetent human informant. By doing so, we tested Canadian children's reliance on a key social characteristic (in-group membership, "like me" status) against competency.

Trust and informants' characteristics

To our knowledge, this is the first study to directly compare a human informant to a robot informant using the trust paradigm. As predicted, 5-year-old children chose to learn from a competent robot over an incompetent human. In contrast, our results showed that the 3-year-old children trusted both informants (human and robot) equally. This pattern of results held whether the robot informant was morphologically similar to a human or not. Of note, the human informant was Caucasian, making it an in-group member for most of our sample. As such, the current design provided a conservative test of the ability to attend to epistemic cues in the trust paradigm. In the present work, whom children chose to trust may be explained by the fact that the robot displayed characteristics of a social agent in both studies. For example, both Cozmo and Nao spoke with intonation, pointed to the objects as they were being labeled, engaged in turn-taking, and moved autonomously. In addition, Nao also stood upright and possessed human-like features (e.g., eyes, head). A recent study demonstrated that 3-year-olds consider Nao a psychological agent (e.g., Nao can think for itself) when displaying the same agency characteristics as in the present work (Brink & Wellman, 2020). Thus, for 5-year-olds, the competent informant displayed both epistemic and social characteristics, so the decision of whom to trust was straightforward. In contrast, because younger children are unable to prioritize epistemic characteristics, their decision was challenging as both informants possessed social characteristics that children consider when making such a determination (e.g., in group membership for the person and agency characteristics for the robot).

The finding that the absence of human morphology did not affect 3-year-old children's trust judgments was unexpected, given previous work that shows that children prefer to interact with agents similar to themselves, including robots (van Straten, Peter, & Kühne, 2020) and that morphology affects children's perceptions of robots (Fong, Nourbakhsh, & Dautenhahn, 2003). However, in the context of word learning, goal-directedness and speech may be the most important characteristics for 3-year-olds to consider when deciding which informant to trust. This finding becomes especially salient when one considers that the present studies were conducted online with pre-recorded videos. The fact that the two robots, Nao and Cozmo, greatly differed in size and appearance further validates our test of epistemic trust as conservative. Interestingly, previous research on ToM has shown that agency cues are powerful in guiding the attribution of mental states in children as well as in adults (Klin, 2000). For example, infants react similarly to a human agent and a mechanical crane in tests of false belief understanding (Burnside, Severdija, & Poulin-Dubois, 2019).

It is not possible to conclude with certainty whether children selected the robot because it was a novel and unusual informant or because they truly judged the robot as being more competent. We believe the first interpretation is unlikely for several reasons. First, if novelty was driving young children's responses, 3-year-olds would have overwhelmingly endorsed the robot, given their reported limited exposure to robots. Second, we believe that the variable performance on the ask versus endorse trials suggests that novelty is an unlikely strategy in this context. Both age groups performed well on the ask trials, but only the 5-year-olds endorsed the competent robot informant. Thus, it's possible that the ask trials may reflect a novelty bias for the robot, whereas the endorse trials are targeting learning and trust judgment. Specifically, the ask questions ("who do you want to ask what this is called?") is not measuring any learning from the informants. In fact, children could have interpreted this question as simply selecting which informant they want to ask for more information or which informant they wanted to interact with. This could be driven by curiosity or novelty rather than competency or accuracy. In contrast, the endorse questions clearly ask the child to endorse the competent informant ("what do you think this is called?"). In other words, there is less ambiguity and fewer ways to interpret the endorse question.

The present findings confirm that children can learn from inanimate social agents like robots. Robots occupy an interesting intermediate position between biological and mechanical entities (van Straten et al., 2020). Specifically, though not alive (i.e., a biological entity), robots have characteristics of both biological and mechanical objects. Like in the present studies, robots often look and act like social agents (e.g., speaking, gesturing), so they are conceptualized as depictions of social agents (Clark & Fischer, 2022). This appears to be the case regardless of the appearance of the robot, as shown by the fact that the 3-year-olds treated both robots as equally trustworthy. One novel way to measure children's conceptualizing of robots was to administer a naïve biology task that requires children to infer the inside of novel animals and artifacts. When shown a static picture of the robot, children were asked whether something biological (e.g., heart) or mechanical (e.g., gears) belonged inside. This naïve biology task has revealed a progression with age in inferring the parts that belong to unfamiliar artifacts and animals (Gottfried & Gelman, 2005). Important to note is the fact that we replicate the results of Gottfried and Gelman (2005) for animals and artifacts, confirming the validity of the task in this study. With age, we predicted that children would become better at categorizing the robot as mechanical, and the results support this prediction. Although the 3-year-olds associated both Nao and Cozmo with mechanical or biological insides equally, 5-year-olds overwhelmingly associated both robots with mechanical insides. It is worth noting that in both experiments, 5-year-olds classified the robot as mechanical but still chose to learn from it over an incompetent human. This finding confirms the robustness of the bias for epistemic characteristics at 5 years of age, as outlined in Heinrich and Broesch (2011), and provides evidence that children at this age perceive the robot as a depiction of a social agent, much like adults do (Clark & Fischer, 2022). Furthermore, children's ratings of the robot as mechanical correlated positively with children's performance on the selective trust task. With age, children got more competent at both tasks, and children's categorization of the robot weakly predicted better selective trust performance. Interesting to note, however, is the fact that age still only accounts for 9% of our variance, as shown by the linear regressions. Therefore, factors we did not measure, such as parenting style or school/daycare attendance, may further explain this shift from social to epistemic trust. This is an area to explore in future research. What, besides age, contributes to this shift?

Exploratory analyses

For our exploratory goals, we aimed to identify individual differences in socio-cognitive skills that could predict epistemic trust. Specifically, we investigated prosocial and ToM skills using parental report measures, the CPBQ and CSUS, respectively. We expected that individual variability in the tendency to choose the incompetent human informant would be explained by stronger social affiliation whereas ToM skills would contribute to the successful identification of the competent informant. Across both studies, however, only weak, and inconclusive, correlational links were found. Due to the inconsistency and lack of statistical strength found in the correlations, we ran two overall models: a linear regression and a structural equation model. We ran these models in the hope of clarifying our correlational findings and investigating the strength of the effects found through correlations between the selective trust task and the CSUS or CPBQ. No links survived in the overall models run. One reason for these null results might be the use of parental reports. Although a well validated measure of theory of mind, the CSUS has so far yielded only a weak or no link with performance in the selective trust paradigm (Brosseau-Liard et al., 2015; Dutemple, Hakimi, & Poulin-Dubois, 2022; Resendes et al., 2021). A replication of the present study with a direct measure of theory of mind would be beneficial. With regard to the measure of social affiliation, the CPBQ may not have been the best measure to use, as it is validated for age 3, but not for age 5. While the CPBQ is a reliable measure of prosociality, it lacks questions broadly measuring social affiliation, which may have been helpful in explaining children's trust decisions in the above-described studies. For example, a child might display low prosociality but still prefer interacting with agents more like them (people), as opposed to robots or other technological devices. Future studies will be needed to explore this issue more directly, including direct measures of in-group biases as well.

Given the absence of link between theory of mind and epistemic trust, one might wonder if children who preferred to learn from the robots perceived it as sentient. We believe so. There is ample evidence to support children's attributing mental states to robots. For example, Manzi et al. (2020) found that 5-year-olds attribute mental states (i.e., emotions, perceptions) to the Nao robot. Therefore, we are confident that 5-year-old children learned from the robot because they were guided by epistemic trust, and, in turn, the children viewed this robot informant as a depiction of a social agent.

Limitations and future directions

The present work has several further limitations that future research can address. One of the limitations was that online testing sometimes made it more difficult to control for interferences and distractions in the testing environment. To control for this potential confounding variable, distracted children were excluded from our sample. One way to address this limitation would be to conduct future work in the laboratory to maximize attentiveness and minimize technical difficulties. Replicating the present work in the laboratory would also increase the ecological validity. Most of the time, children interact with social robots like Cozmo or Nao in person and not through online videos and computer screens. The morphological features of the robots would also be more visible in person. Nonetheless, there are also some advantages to online testing, such as a faster data collection process, the ability to reach a greater range of families resulting in a more diverse sample, and making it easier for families to participate in research. Using pre-recorded videos ensured internal consistency as each child saw the exact same videos, and the informants behaved in the exact same way, reducing experimenter error. However, if administered live, it is possible the 3-year-olds would have learned more from the human speaker Ina rather than the robot. As the present work featured a competent robot and an incompetent human, an interesting follow-up study would be to examine children's trust judgments when both the human and the robot behave accurately. We would predict that younger children would learn more from the human due to its familiarity and the impact of in-group bias in previous research on selective trust, whereas older children would be expected to learn equally from both informants if epistemic cues guide their decision-making.

Future research should focus on manipulating the types of social cues informants display during social interactions. In the present set of studies, except for animacy, the two informants exhibited the same types of agency characteristics. Both the human informant Ina and the robot informants (Nao in Study 1, Cozmo in Study 2) spoke with intonation, pointed to the objects as they labeled them, and engaged in turn-taking (i.e., not speaking over one another). Having one informant display many agency characteristics while the other displays fewer could help tease out what role they play in younger children's decisions about whom to learn from. For example, future work could eliminate speech, which is a powerful agency characteristic, by having the robot informant show competence in performing actions (e.g., building a tower) or by showing more reliability in a communicative context (e.g., pointing to the correct location in a hiding game). Future work could also administer an interview to older children, comparing their choice of agent or inside with their verbal description and categorization of the robots. This would allow us to contrast two tasks of categorization (naïve biology task and interviews).

In conclusion, the present work contributes to the current literature by being the first study to compare a human to a robot informant, as most prior work has only tested selective trust with two robots (Breazeal et al., 2016; Brink & Wellman, 2020) or two human informants (Tong et al., 2019). Moreover, the present study examined trust with two different robots that varied in their human appearance. These findings demonstrate that young children can identify the competence of both human and non-human informants by 5 years of age. These findings have important implications for the use of robots in educational settings. As children's exposure to robots is increasing (de Jong, Peter, Kühne, & Barco, 2021), it is beneficial to examine how children learn from robots and understand what characteristics children prioritize when choosing the best informant.

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Data availability statement

Both studies were pre-registered. The pre-registrations can be found here:
Study 1: https://osf.io/u7nma
Study 2: https://osf.io/5cgp3

The combined dataset for both studies can be found here:
https://osf.io/nt785/files/osfstorage/63e6a9fecb544b012c9e6dda

The materials for both studies can be found here:
Study 1: https://osf.io/nt785/files/osfstorage
Study 2: https://osf.io/2mq87/files/osfstorage

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This article has earned the Center for Open Science badges for Open Data, Open Materials and Preregistered. The data and materials are openly accessible at https://osf.io/nt785/files/osfstorage/63e6a9fecb544b012c9e6dda, Study 1: https://osf.io/nt785/files/osfstorage, Study 2: https://osf.io/2mq87/files/osfstorage and Study 1: https://osf.io/u7nma, Study 2: https://osf.io/5cgp3

Ethics approval statement

Ethical approval to conduct the studies was granted by Concordia University's Human Research Ethics Committee (#10000548). Written informed consent to participate in this study was provided by the participant's legal guardian before the study began.

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