People do not always know best:
Preschoolers’ trust in social robots versus humans

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Thesis Abstract

People do not always know best: Preschoolers' trust in social robots versus humans

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The main goal of my thesis was to investigate how 3- and 5-year-old children learn from robots versus humans using a selective trust paradigm. Children's conceptualization of robots was also investigated. By using robots, which lack many of the social characteristics human informants possess by default, these studies sought to test young children's reliance on epistemic characteristics conservatively.

In Study 1, a competent humanoid robot, Nao, and an incompetent human, Ina, were presented to children. Both informants labelled familiar objects, like a ball, with Nao labelling them correctly and Ina labelling them incorrectly. Next, both informants labelled novel items with nonsense labels. Children were then asked what the novel item was called. Children were also asked what should go inside robots, something biological or something mechanical. Study 2 followed the same paradigm as Study 1, with the only change being the robot used, now the non-humanoid Cozmo. Eliminating the human-like appearance of the robot made for an even more conservative test than in Study 1. Both studies 1 and 2 found that 3-year-old children learned novel words equally from the robot and the human, regardless of the robot's morphology. The 3-year-old children were also confused about both robot's internal properties, attributing mechanical and biological insides to the robots equally. In contrast, the 5-year-olds in both studies preferred to learn from the accurate robot over the inaccurate human. The 5-year-olds also learned from both robots despite understanding that the robot is different from themselves; they attributed mechanical insides to both Nao and Cozmo over biological insides.

Study 3 further investigated 3-year-olds ambivalence regarding their trust judgements, that is, who they choose to learn from. Instead of word learning, the robot demonstrated competence through pointing. The robot would accurately point at a toy inside a transparent box, and the human would point at an empty box. Next, both informants pointed at opaque boxes and the child was asked where the toy was located. Neither informant demonstrated the ability to speak, as speech is a salient social characteristic. 3-year-olds were still at chance, equally endorsing the robot and the human's pointing. This suggests that goal-directedness and autonomous movement may be the most important characteristics used to signal agency for young children. The 3-year-olds were also still unsure about the robot's biology, whereas they correctly identified the human as biological. This suggests that robots are confusing for children due to their dual nature as animate and yet not alive. This thesis shows that by the age of 5, children are willing and able to learn from a robot. These studies further add to the selective trust literature and have implications for educational settings.

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Contributions of Authors

This dissertation consists of two manuscripts as well as a general introduction and discussion.

Chapter 1: General Introduction

Anna-Elisabeth Baumann wrote this section, with feedback provided by Diane Poulin-Dubois.

Chapter 2: Manuscript 1

Anna-Elisabeth Baumann and Diane Poulin-Dubois conceived of and designed the studies. Anna-Elisabeth Baumann performed a literature review. Anna-Elisabeth Baumann set up the study documents and launched the study. Anna-Elisabeth Baumann, Aymée Bray Le Métayer, and Alexandra Meltzer tested study participants. Anna-Elisabeth Baumann performed statistical and data analyses, with assistance from Ryan Persram running the structural equation model. Anna-Elisabeth Baumann drafted the manuscript with assistance from Elizabeth Goldman. Elizabeth Goldman and Diane Poulin-Dubois provided feedback on the manuscript.

Chapter 3: Manuscript 2

Anna-Elisabeth Baumann, Elizabeth Goldman, and Diane Poulin-Dubois conceived of and designed this study. Anna-Elisabeth Baumann performed a literature review with assistance from Aymée Bray Le Métayer. Anna-Elisabeth Baumann set up the study documents and launched the study. Anna-Elisabeth Baumann and Maria Minuche tested study participants. Anna-Elisabeth Baumann performed statistical and data analyses. Anna-Elisabeth Baumann drafted the manuscript with assistance from Elizabeth Goldman. Elizabeth Goldman and Diane Poulin-Dubois provided feedback on the manuscript.

Chapter 4: General Discussion

Anna-Elisabeth Baumann wrote this section, with feedback provided by Diane Poulin-Dubois.

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Chapter 1: General Introduction

When I was in elementary school 20 years ago, the technology in my classroom consisted of overhead projectors and CRT TV's. Yet technology is moving forward at an astoundingly fast rate, and classrooms today look recognizably different. Though it may be hard for us to imagine, robots are increasingly becoming classroom tools, serving as teachers aids and learning guides. In fact, the Nao robot, created by Softbank Robotics, is currently already deployed in 6000 academic institutions, in over 70 countries, teaching thousands of students (Sood, 2020). But how do children react to robot teachers? Are they excited? Nervous? Uncertain? Are they willing to learn from robots as they learn from humans? These questions underlie the basis of my thesis, which studied how young children selectively learn from robotic versus human informants.

As humans, starting in early childhood, we choose to learn information from some individuals more than others. This process is known as epistemic trust or selective trust (Harris & Corriveau, 2011; Mills, 2013; Poulin-Dubois & Brosseau-Liard, 2016; Sobel & Finiasz, 2020). We do this because some informants are better teachers, are nicer, or are more familiar to us (Tong et al., 2019). Children start to learn selectively starting in infancy (Brooker & Poulin-Dubois, 2013; Chow et al., 2008; Schieler et al., 2018), and are well-established at doing so by their preschool years (Harris & Corriveau, 2011; Mills, 2013; Poulin-Dubois & Brosseau-Liard, 2016; Sobel & Finiasz, 2020). Generally, children trust others by considering their social (i.e., language, benevolence, in-group status, contingency) and epistemic (i.e., accuracy, competency, reliability) characteristics.

One of the main theories guiding this thesis is Henrich and Broesch's (2011) two-stage theory of transmission. This theory posits that the success of humanity is, in large part, due to our ability and willingness to learn from others. Younger children aged 3 years or less tend to rely more on the information provided to them by familiar informants and in-group members, like their families. This reliance on familiarity helps children form a social network and successful social connections. As children age, they start to rely more and more on epistemic characteristics like accuracy, expertise, and reliability. While 3-year-old children tend to rely on social and epistemic characteristics equally when they are pitted against one another, children over the age of 4 prioritize epistemic characteristics like competency over traits such as social affiliation (Tong et al., 2019).

All three studies in this thesis ask children to respond to questions about who they wish to learn from or affiliate with. Questions are an important part of learning and are inherently social. Children ask questions in order to explore their surroundings, learn about the world around them, and seek other's knowledge (Fitneva et al., 2013). Questions are also a large part of social learning. Another theory directing this thesis is Albert Bandura's social learning theory (Bandura 1977). This theory states that humans learn new information through imitation and observation. Information can be learned both through direct instruction and through self-exploration. Social learning theory posits learning as a cognitive process that is influenced by the cultural and social contexts in which it occurs. For the purposes of this thesis, children learned new information from informants through observation of the informant's actions and, beyond that, learning the information provided by the informants.

Selective social learning

The main focus of this thesis concerns the cognitive abilities driving selective social learning. As a phenomenon, social learning has been widely studied in the literature (Rendell et al., 2011). Social learning is defined as the skill of learning from another through observation or interaction (Gariépy et al., 2014). It encompasses many different domains and occurs in many species besides humans. For example, a wide variety of non-human primates engage in specific social and cultural behaviours, such as nest building, grooming, or other connective rituals. Like humans, other primates selectively learn from their elders starting in infancy (Watson et al., 2018). Even birds have been shown to learn acts socially, as in the case of wild New Caledonian crows creating tools (Hunt & Gray, 2003). Yet there is still something different about the way humans learn from others.

Indeed, while social learning does occur in other animals, humans are considered to be an "ultra-social, cooperative animal." An animal that works with others and sometimes acts as a collective whole, bringing to the forefront an inherent sense of interpersonal connection in humanity (Tomasello, 2014). The cognitive abilities our species possess can be attributed, at least in part, to our tremendous ability to learn from, interact, and cooperate with others (Poulin-Dubois & Brosseau-Liard, 2016). Humans engage in a process known as *selective* social learning, also known as selective trust or epistemic trust. Epistemic trust is defined as the ability to selectively trust some information and informants over others based on social interactions (Poulin-Dubois & Brosseau-Liard, 2016).

Even in infancy, the selective learning strategies children use change situationally. They prefer to learn from accurate informants (Brooker & Poulin-Dubois, 2013; Koenig & Woodward, 2010; Sobel & Finiasz, 2020), from conventional informants (Zmyj et al., 2010), and from experts over novices (Stenberg, 2013). Infants have been shown to be attentive and to react toward inappropriate emotional expressions (Chow et al., 2008; Chiarella & Poulin-Dubois, 2015). As children age, their selective learning strategies also grow and change. With time, children start to become more active in their own learning. By age 4, children's selective trust expands to include more than just "accuracy." Children take into account both the knowledge of the informant and the informant's accuracy. For example, 4- and 5-year-old children are more likely to ask informants for help if they previously answered without aid rather than an accurate informant who always relied on another individual's help previously (Einav & Robinson, 2011). Children also start to think about outcome versus intention at this age, with children aged 3 and 4 years endorsing and imitating the actions of a successful but unconventional informant over a conventional, unsuccessful informant (Scofield et al., 2013). In another study, 5- and 6-year-old children trusted those who helped others more than hinderers. However, these children, overall, trusted accurate informants more than inaccurate informants, regardless of their intention (Liu et al., 2013). This suggests that preschool-aged children weigh multiple characteristics when deciding whom to trust. In this instance, children weighed the informant's accuracy against their mental states (Liu et al., 2013).

While selective trust has been widely studied in many different nuanced ways, one of the main tasks used to investigate selective trust is the classic trust paradigm invented by Koenig and Harris (2004). In this paradigm, two informants label common objects, such as a ball, during a familiarization phase. In this phase, one informant will label the object correctly, calling it a ball and the other informant will label the ball incorrectly, calling it, for example, a shoe. As a result, one informant has been established as accurate, and one as inaccurate. In the test phase, children are then presented with novel items, such as the top of a turkey baster. Both informants label this novel item with nonsense labels, such as a 'fep' or a 'dax.' Children are then asked what the novel object is called, effectively forcing children to endorse one label over another and choose to trust one informant over another. Using this or similar paradigms, many scenarios have been tested, including the impact of familiarity (Corriveau & Harris, 2009a), language (Corriveau et al., 2013; Kinzler et al., 2011), conventionality (Diesendruck et al., 2010), and more (Tong et al., 2019).

Beyond word learning

For most people, much of our daily communication occurs through verbally expressed information. Many studies have investigated how children learn information verbally (Corriveau et al., 2011; Corriveau & Harris, 2009b; Einav & Robinson, 2011; Koenig et al., 2004; Koenig & Harris, 2005a; Stephens et al., 2015). However, humans also transmit information non-verbally through gestures, postures, movements, or facial expressions. When children learn, they learn through both verbal and non-verbal modalities. Even infants can learn non-verbally. Fusaro and Harris (2013) found that 24-month-old infants accepted information more readily if a third party nodded their head in consensus versus shaking their head no. By the age of 4, preschoolers endorsed the novel names provided by an informant who had received bystander assent over those provided by an informant who received dissent (Fusaro & Harris, 2008). Children have also been shown to attend to referential cues, being able to distinguish accurate and inaccurate looks towards one of two possible hiding locations containing a prize (Yow & Li., 2021), and children attend to the visual access of hidden objects when learning about the object's visual identity (Brosseau-Liard & Birch, 2011).

Pointing can also be used as a powerful knowledge transmission tool. Palmquist and Jaswal (2015) found that preschoolers favored accurate pointers over inaccurate pointers. First, they showed children two informants pointing at clear plastic boxes, with one informant accurately pointing at the box containing a toy and the other informant pointing at an empty transparent box. Then, children were shown the same two informants pointing at opaque boxes and were asked where the toy is located. Children endorsed the location pointed at by the previously accurate pointer, suggesting children learned this accuracy non-verbally, similar to the way they learned accuracy using a verbal paradigm in Koenig and Harris (2004). Overall, preschool-aged children are able to learn new information both verbally and non-verbally, and competency can be demonstrated in both modalities.

Selective social learning, Theory of Mind, and prosociality

Previous research has often investigated the relationship between selective trust and Theory of Mind. Theory of Mind is the ability to attribute mental states, such as knowledge or beliefs, to others (Poulin-Dubois et al., 2020; Wellman, 2014). In a social learning paradigm, one informant demonstrates some knowledge: competency, accuracy, and reliability. Because of this demonstrated knowledge, a child with a well-developed understanding of Theory of Mind may attribute other mental states to knowledgeable informants (Poulin-Dubois & Brosseau-Liard, 2016). Therefore, higher mental state attribution through a well-developed Theory of Mind may lead to better performance in selective trust tasks (i.e., learning more from the accurate informant). Indeed, many studies have found such a link (DiYanni et al., 2012; Lucas et al., 2013). During the preschool years, Theory of Mind development has been shown to predict better selective trust performance (Brosseau-Liard et al., 2015; Crivello et al., 2017; DiYanni & Kelemen, 2008; Fusaro & Harris, 2008; Lucas et al., 2017; Palmquist & Fierro, 2018; Resendes et al., 2021). Complicating this link, other studies have failed to replicate this correlation (Pasquini et al., 2007; Souza et al., 2021). A secondary goal of this thesis was to investigate to which extent social learning is driven by social characteristics versus epistemic knowledge versus increasing cognitive abilities (like Theory of Mind) with age. This was investigated by administering a parental report measure of Theory of Mind, the Children’s Social Understanding Scale (CSUS), in all 3 studies.

Another influence on selective social learning is social affiliation, of which prosociality is a large part. Social affiliation can be defined as associating positively or cooperatively with another, often due to likeness or resemblance (APA Dictionary of Psychology). Prosociality is defined as behaviours that benefit others such as helping, comforting or sharing (Brazzelli et al., 2018). Previous research has found that children aged 5 selectively trust prosocial agents (Isella et al., 2018; Margoni et al., 2022). Other studies have found that children, starting from age 2, are more prosocial towards ingroup members over outgroup members (Dunham et al., 2011; Hilton et al., 2021, McGuire et al., 2018; Moore 2009). Following this research, if a child is more prosocial, perhaps they would feel a greater need to affiliate with those more 'like them' and learn more from the human. On the other hand, perhaps a more prosocial child would be more willing to interact with various sources of information and learn more from the robot. To explore this potential link, the Child Prosocial Behavioural Questionnaire (CPBQ), a parental report measure of prosociality, was administered in studies 1 and 2.

Robots as tools for learning

The main tools my thesis used to study selective learning are robots. Robots could be rather confusing for children to understand. They possess some qualities of agency and animacy, such as the ability to speak, to move autonomously, and to perform actions. Yet they are not actually alive, at least for now. Robots are made of plastic or metal and are programmed by humans to perform certain actions that demonstrate animacy. This makes them difficult for children to comprehend, much like plants which are alive but not animate (Goldman et al., 2023a; Hatano et al., 1993). While children can correctly categorize animals, mechanical artifacts, and robots by the age of 5 (Goldman et al., 2023a), they struggle to identify plants as living up until the age of 10 (Leddon et al., 2009). This suggests that characteristics of animacy, rather than the actual biological status, matter more to children when categorizing informants. This is supported by adults' behaviour as well; adults know that robots are not living, but they nonetheless treat robots as depictions of social informants and are willing to interact with and even learn from them (Clark & Fischer, 2022). It is possible that children view robots in similar ways (Goldman et al., 2023b).

Children have been shown to anthropomorphize robots and sometimes attribute mental (i.e., talk, think) as well as biological (i.e., alive, eating) states to them. Previous research shows that children attribute fewer mental states to a robot that does not look human, versus a humanoid robot (Goldman et al., 2023a; Manzi et al., 2020). Generally, younger children tend to anthropomorphize robots more than older children (Goldman & Poulin-Dubois, 2023; Manzi et al., 2020). Another study found that 3-year-old children attributed biological properties to a robot whereas 5-year-old children attributed psychological qualities after a social interaction with said robot (Okanda et al., 2021). Children aged 5-16 have been shown to attribute cognitive and behavioural characteristics, such as memory, to a robotic arm (Beran et al., 2011). With age, children become better at classifying robots correctly, with 5-year-olds correctly assigning a mechanical inside to robots but 3-year-olds failing to classify the robot as either mechanical or biological (Goldman et al., 2023a). My thesis also sought to investigate if children are willing to learn from and trust robots if, or once, even if they understand that robots are biologically different from themselves. As such, this provides a conservative test of epistemic trust.

Due to their nature, robots provide an excellent way to study young children's social cognition. Unlike human informants, the specific animacy characteristics a robot displays can be manipulated. A robot can be programmed to behave in a very socially contingent manner, taking turns, following eye gazes, and gesturing, or it can be programmed to seem socially ignorant.

While a human's behaviour inevitably varies, a robot can act in the exact same way across multiple social interactions with multiple children. A robot's morphology can also be manipulated. Robots can look human, with limbs and facial features, like Nao from Softback Robotics, or they can look very mechanical and/or amorphous, like Dash from Wonder Workshop or Cozmo from Digital Dream Labs. Importantly, even a non-human-looking robot can act socially, still speaking, gesturing, and conveying information. The same cannot be said for non-human-looking biological creatures. For example, scientists have not yet managed to get a fly to convey social information to children.

The impact of morphology, social affiliation, and exposure

Physical appearance, or morphology, affects children's perceptions of informants. Generally, children prefer to interact with, and learn from, informants who speak the same way they do (Buttelmann et al., 2013; Kinzler et al., 2009), and who look more like them in terms of gender or race (Bar-Haim et al., 2006; Fishbein & Imai, 1993; Kelly et al., 2007; Kinzler et al., 2009; Ramsey, 1991; Ramsey & Myers, 1990). For example, children prefer to be friends with same-gender playmates (Fishbein & Imai, 1993). Infants as young as 3 months old have been shown to prefer same-race faces over different-race faces (Bar-Haim et al., 2006; Kelly et al., 2007). While infants already show this preference, it does not seem to affect social preferences until about 3 to 5 years of age, when it starts to impact sharing behavior. By the age of 5, children prefer to give toys to same-race over different-race individuals, something that was not found in younger age groups (Kinzler & Spelke, 2011). Also found at age 5, children prefer to learn a new action from an informant with a native accent over a non-native accent. However, this finding was mediated by certainty, with children preferring to learn from a certain over an uncertain informant regardless of accent (Wagner et al., 2014). Children exposed to more racial diversity have been found to be less biased (Gaias et al., 2018; Killen et al., 2022; Shutts et al., 2011). This suggests intergroup contact is an excellent strategy that can be used to reduce 'like-me' bias.

Findings have revealed that the morphological features robots display matter in a variety of ways. van Straten (2020) found that the robot features which mattered most in trust interactions were inconsistent across studies. It was found that robot characteristics such as responsiveness and expressiveness were more important, over physical attributes. Anthropomorphism and perceived empathy also played a role. However, boys did prefer robots that look male to robots that look female (van Straten et al., 2020). In another study, Barco et al. (2020) found that children rated an anthropomorphic robot as more socially present, animate, and more like them when compared to a zoomorphic robot. Tung (2016) has shown that children aged 8 to 14 prefer a moderately human robot over a highly human-looking robot and found that the uncanny valley effect is present in children. This effect was moderated, however, by the social cues displayed by the robot. Robots who displayed social cues were rated as more attractive by the children (Tung, 2016). Finally, children have been shown to interact with a robotic dog differently than they interact with a humanoid robot (Fong et al., 2003). While the evidence is mixed and, at times, unclear, the morphology of the robot does seem to play a role in children's categorization and trust in robots. Like with different ethnicities, increased exposure to robots could diminish or at least clarify the effects of morphology.

Selective trust in robots

Some studies have investigated children's selective trust in robots. Yet these studies have only pitted a robot against another robot or used one robot at a time (Breazeal et al., 2016; Brink & Wellman, 2020; Meltzoff et al., 2010; O'Connell et al., 2009 Oranç & Küntay, 2020). Brink &

Wellman (2020) found that children aged 3 prefer to learn from an accurate robot over an inaccurate robot. Children pay attention to a robot's previous accuracy and previous errors to decide how much trust to place in the robot (Geiskkovitch et al., 2019). Furthermore, Breazeal and colleagues (2016) showed that children aged 3 to 5 also pay attention to the social characteristics displayed by robots, with children preferring to learn new information from a socially contingent robot over a socially incontingent robot. Contingency was demonstrated through gaze following (Breazeal et al., 2016).

Some studies have investigated children's inherent propensity to learn from robots versus humans, without displays of accuracy. When presented with either a robot or a human agent, one study found that 4- and 5-year-old children preferred to learn novel word labels for novel objects from a human over a robot (Moriguchi et al., 2011). In contrast, Westlund and colleagues (2017) found that children learned novel animal names equally well from robots and humans, and even stated that they preferred to learn from the robot. In both of these studies children were presented with one informant at a time and were not asked to directly choose between informants. Generally, children seem to learn from robots and humans in similar ways. For both types of informants, children use epistemic characteristics, like previous accuracy, and social characteristics, like contingency or appearance, to guide their trust judgements (Stower et al., 2021; Tong et al., 2019).

The present studies

Study 1

In Study 1, the Koenig, Clément & Harris (2004) trust paradigm was administered to 3- and 5-year-old children. The children were presented with a competent social humanoid robot named Nao and an incompetent human named Ina. The robot demonstrated competence, an epistemic characteristic, while the human displayed more social characteristics and was more familiar to children. In this way, we were able to directly pit social versus epistemic characteristics to examine the weight that young children give to each type of characteristics. By using a robot, which was unfamiliar and less like them than a human informant, we could conservatively test 5-year-old children's reliance on epistemic characteristics over social characteristics. The robot was accurate and novel, but the human was much more socially and morphologically similar to the child.

During the familiarization trials, the robot labelled familiar objects, like a ball, accurately. The human would label these same objects with incorrect labels, calling the ball a shoe. After 3 familiarization trials, 3 test trials were administered. During the test trials, 3 novel objects were presented to children and both the robot and the human labelled these objects with nonsense labels (i.e., toma, mido). Children were asked 3 types of questions, who they wished to ask for help labelling the novel objects (ask trials), what the object was called (endorse trials), and who told them 'right' or 'wrong' information (judgement trials). We predicted that the 5-year-old children would successfully learn from the robot, that is endorse the label provided by the robot, but that the 3-year-old children would learn more from the inaccurate human considering Nao's novel and unfamiliar nature.

We also administered a naïve biology task to the child, based on Gottfried and Gelman's (2005) design. This study was the first to administer this naïve biology task with robots. Children were asked if something biological (heart) or mechanical (gears) should go inside four unfamiliar animals, mechanical artifacts, and the robot Nao. This task sought to investigate if children knew the robot is inanimate, made of mechanical parts, and whether this knowledge would affect their trust judgements. We predicted that 5-year-old children would successfully categorize the robot as mechanical but that the 3-year-old children would struggle with understanding the robot's physiology. Finally, the potential impact of prosociality and theory of mind on selective learning was studied through parental report surveys as an exploratory goal.

Study 2

Study 2 followed the same procedure and administered the same tasks as Study 1. The only difference being the robot informant that was used. In Study 2, the robot Cozmo was used instead of Nao. Cozmo is non-humanoid in appearance, lacking many of the morphological characteristics Nao displayed. This design allowed us the investigate the possible effects human morphology may have on children's learning from robots. We predicted that the lack of human appearance might make Cozmo easier to classify for children, resulting in a greater attribution of mechanical insides to Cozmo. Using a non-human-looking robot made our test of epistemic trust even more conservative. Altering the features of the robot was also done in order to clarify the ambivalence of 3-year-olds trust judgements found in Study 1.

Study 3

Finally, Study 3 investigated children's learning through a non-verbal communicative gesture, pointing. Adapting Palmquist & Jaswal's (2015) pointing paradigm, children were presented with an accurate, non-humanoid, non-verbal robot, Cozmo, and an inaccurate, non-verbal human. During the induction trials, the robot accurately pointed at a transparent box containing a toy, whereas the human pointed at an empty box. For the test trials, both informants pointed at opaque boxes. Children were asked who they wished to ask for help finding the toy (ask trials), which box they believe the toy to be located in (endorse trials), and who pointed at the toys (judgement trials). A naive biology task was also administered in study 3. Children were asked if a biological organ or a mechanical part belonged inside the robot Cozmo and the human informant's body. Finally, children were asked who they liked better, the robot or the human, and if the informants were 'alive.' We predicted that the lack of speech would drive 3-year-olds towards learning from the human informant, as the robot now displayed no social characteristics besides goal-directedness and autonomous movement.

Taken together, this thesis aimed to contribute to the selective trust literature and clarify how children learn from different types of informants. The developmental shift towards prioritizing epistemic characteristics was investigated between the ages of 3 and 5. The studies contained in this thesis provide novel contributions to the field, being the first published study to directly pit a robotic informant against a human informant using a selective word learning task (studies 1 and 2) and a non-verbal pointing task (Study 3). These studies are also unique in their design, directly comparing the importance of social versus epistemic cues and investigating these effects with more than one type of agent, and even with multiple robots. studies 1 and 2 have been published in the *Journal of Cognition and Development* and Study 3 is under revision in the *Journal of Experimental Child Psychology*.

Chapter 2: People do not always know best: Preschoolers' trust in social robots

Baumann, A.-E., Goldman, E. J., Meltzer, A., & Poulin-Dubois, D. (2023). People do not always know best: Preschoolers' trust in Social Robots. *Journal of Cognition and Development*, 1–28. https://doi.org/10.1080/15248372.2023.2178435

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 (Koenig et al., 2004). 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 et al., 2018; Koenig & Harris, 2005a&b). 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 non-human informants (Tong et al., 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 et al., 2020; Wellman, 2014). A large body of work has revealed a link between ToM skills and performance in the selective trust task (Brosseau-Liard et al., 2015; Crivello et al., 2017; DiYanni & Kelemen, 2008; Fusaro & Harris, 2008; Lucas et al., 2017; Palmquist & Fierro, 2018; Resendes et al., 2021). However, a few studies have failed to find such a link (Pasquini et al, 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 et al., 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 et al., 2015; Wang et al., 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 et al., 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 et al., 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 et al., 2019; Okita et al., 2006; Somanader et al., 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 et al., 2023a). 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.

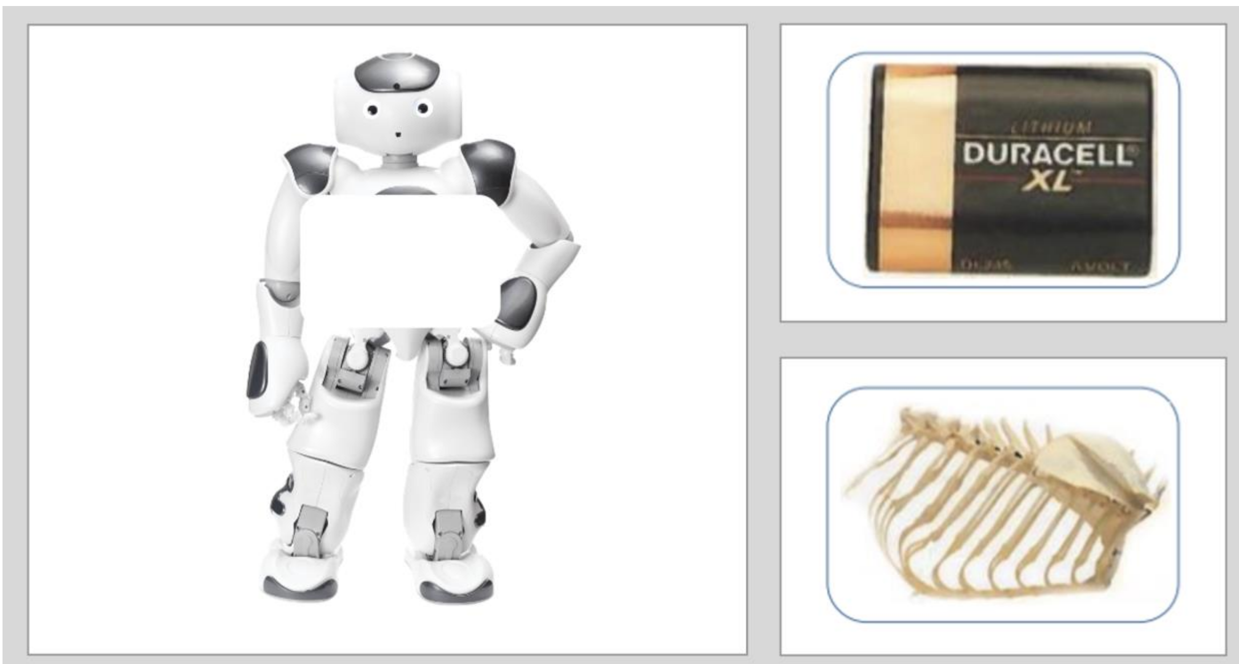
As in the training trials, the missing piece was indicated by a white rectangle. The unfamiliar images (i.e., animals, artifacts, Nao) were presented one at a time. For every trial, one of four biological insides (i.e., muscle, lungs, heart, bone) and one of four mechanical insides (i.e., gears, circuit, 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 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).

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).

Selective trust task

The standard selective trust task originally designed by Koenig and colleagues (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 labelled 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.

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).

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).

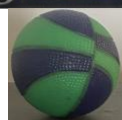
Figure 2

Still frame of the video setup for the selective trust task

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.

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		

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 for each 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 et al., 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 for each 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., 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), 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.

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 judgement 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 judgement), 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 judgement 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).

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	$t(44) = 3.85$, $p < .001$, $d = 0.58$***
Judgement	50	3	1.36	0.72	$t(49) = 3.53$, $p < .001$, $d = 0.50$***
Judgement	45	5	1.62	0.49	$t(44) = 8.51$, $p < .001$, $d = 1.27$***

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

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 ($p > 0.05$). Therefore, a Greenhouse-Geisser correction was applied to this analysis. The ANOVA 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.

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	$t(49) = 1.19$, $p = 0.24$, $d = 0.17$
Robot	45	5	1.82	0.44	$t(44) = 12.49$, $p < .001$, $d = 1.86$***

Note. 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 $p < .05$.

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 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 nonsignificant ($F(1, 85) = 0.06$, $p = .81$), 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 nonsignificance, 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 were 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 three-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 videoconference 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 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.

Figure 3

Still frame of the selective trust video setup in Study 2

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 ($F(1.84, 158.32) = 3.60$, $p = .03$, $\eta_p^2 = 0.04$), 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 judgement 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 ($F(2, 174) = 10.58$, $p < .001$, $\eta_p^2 = 0.11$), with children performing better on the ask ($t(87) = 4.19$, $P_{holm} < .001$) and judgement ($t(87) = -3.75$, $P_{holm} < .001$) trials when compared to the endorse trials. A main effect for age was also significant ($F(1, 87) = 20.36$, $p < .001$, $\eta_p^2 = 0.19$), with 5-year-old 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 ($F(2, 174) = 1.31$, $p = .27$, $\eta_p^2 = 0.02$). 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 judgement ($t(87) = -3.94$, $p < .001$, $d = -.84$) 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	$t(45) = 4.59$, $p < .001$, $d = 0.68$***
Judgement	43	3	1.21	0.89	$t(42) = 1.55$, $p = .13$, $d = 0.22$
Judgement	46	5	1.78	0.42	$t(45) = 12.73$, $p < .001$, $d = 1.88$***

Note. The ask and endorse trials were scored out of /3. The judgement trial was 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 ($p > 0.05$). 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.

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	$t(45) = 12.24$, $p < .001$, $d = 1.80$***

Note. 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 $p < .01$.

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 judgement 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 judgement) 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 ($p > 0.05$). 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 judgement 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 judgement ($r(176) = .18$, $p = .02$) 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 modelling (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 an 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 judgement 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 judgement) 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 et al., 2020) and that morphology affects children's perceptions of robots (Fong et al., 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 et al., 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 question ("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 Tong et al., 2019, 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 et al., 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 judgements 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 display 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 et al., 2021), it is beneficial to examine how children learn from robots and understand what characteristics children prioritize when choosing the best informant.

Chapter 3: Do preschoolers trust a competent robot pointer?

Baumann, A. Goldman, E. Cobos, M. Poulin-Dubois, D. (2023). Do preschoolers trust an accurate pointer when it is a social robot? *In Press, Journal of Experimental Child Psychology*. Preprint: https://psyarxiv.com/gpfhk

Abstract: How young children learn from different informants has been widely studied. However, most studies investigate how children learn verbally conveyed information. Furthermore, most studies investigate how children learn from humans. This study sought to investigate how 3-year-old children learn from, and come to trust, a competent robot versus an incompetent human when competency is established using a pointing paradigm. During an induction phase, a robot informant pointed at a toy inside a transparent box, whereas a human pointed at an empty box. During the test phase, both agents pointed at opaque boxes. We found that young children asked the robot for help to locate a hidden toy more than the human (ask questions), and correctly identified the robot to be accurate (Judgment Questions). However, children equally endorsed the locations pointed at by both the robot and the human (endorse questions). This suggests that 3-year-old children are sensitive to the epistemic characteristics of the informant even when its displayed social properties are minimal.

Introduction

Most species tend to learn from others as opposed to only learning independently. Humans are particularly prone to engage in social learning, defined as the ability to learn through observation or interaction with another individual (Gariépy et al., 2014). Learning from others comes with certain risks, as some informants can teach incorrect or misleading information, either by accident or on purpose. Thus, learners are faced with the challenge of deciding who to trust and who to learn from. From a very early age, children do not learn from all teachers equally, selecting some over others. This selectivity is called selective social learning, that is, the ability to select whom to trust as a reliable source of new information based on these interactions (Poulin-Dubois & Brosseau-Liard, 2016). Previous research has shown that preschoolers are selective in choosing whom to learn from (Harris & Corriveau, 2011; Mills, 2013; Poulin-Dubois & Brosseau-Liard, 2016; Sobel & Finiasz, 2020). In fact, some form of selective trust seems to emerge already in infancy (Brooker & Poulin-Dubois, 2013; Chow et al., 2008; Schieler et al., 2018).

The present study used a social robot as one of the informants to investigate children's development of selective trust. Social robots are ambiguous and challenging for children, and sometimes even adults, to comprehend and categorize. On one hand, they tend to act like human agents. They can move, speak, and may even look like humans despite being artifacts made of metal or plastic. Some prior work has shown that children perceive robots as social agents and interact with and learn from them (Breazeal et al., 2016; Brink & Wellman, 2020; Stower et al., 2021). However, the extent to which children are willing to interact with and learn from robots versus humans remains unclear. For example, children imitate robots' actions, but less so than they do humans (Fong et al., 2021; Sommer et al., 2019). Children share resources with robots, especially with ones that act prosocially, and tend to ascribe some mental states to them (Kahn et al., 2012; Peter et al., 2021). Children even attribute a certain level of free will to robots (Flanagan et al., 2021). Thus, the ambiguity of robots makes them valuable tools for studying the strategies that young children use when deciding whom to learn from and trust. More specifically, the anthropomorphic characteristics of robots, such as a human morphology and contingency, can be manipulated to study developmental changes in the robustness of epistemic trust.

Developmental shift in epistemic trust

From an early age, children rely on a variety of characteristics of the informant when choosing whom to learn from. Decades of research have examined which characteristics lead to informants being endorsed. More specifically, when choosing whom to trust, children consider the epistemic (e.g., accuracy, reliability, competency) and the social (e.g., benevolence, language, or in-group status) characteristics of an informant. Which characteristics children utilize when selecting informants depends largely on age. Overall, 3-year-old children rely on both social and epistemic characteristics, while children over the age of 4 years have been shown to prioritize epistemic characteristics over social characteristics (Tong et al., 2020). This developmental shift is supported by Henrich and Broesch's two-stage theory of transmission (Henrich & Broesch, 2011). This theory states that during the first years of life, children rely more on social characteristics as they prefer to trust information communicated to them by familiar others (e.g., those "like them," their in-group, those who speak the same language or have the same skin color). This reliance on familiarity helps children navigate the world and adapt to a variety of social interactions. Once children have acquired these social connections and formed a wider net of potential teachers, they tend to rely less on social characteristics and prioritize epistemic ones, preferring to learn from the more accurate or competent informant (Tong et al., 2020).

However, 3-year-old children do prioritize social characteristics over epistemic ones in certain circumstances. For example, 3-year-old children prefer to learn from an inaccurate familiar teacher over an accurate unfamiliar teacher (Corriveau & Harris, 2009a&b), trust an informant labeled as a "teacher" with a small and homogenous sample over an informant labeled as a "child" with a large and diverse sample of information (Lawson, 2018), and trust a nice informant with no expertise over a mean informant with expertise (Landrum et al., 2013). On the other hand, 3-year-olds have also been shown to prioritize epistemic characteristics, preferring to endorse and imitate an unconventional but successful agent over a conventional, unsuccessful agent (Scofield et al., 2013). Despite this mixed evidence, most studies find that 3-year-old children rely on social and epistemic characteristics equally when they are in conflict (Corriveau et al., 2013; Elashi & Mills, 2014; Schillaci & Kelemen, 2014). At this age, children's reliance on one type of characteristic over another seems to be fragile and only discernible in specific scenarios. For example, Johnston et al. (2015) found that 3-year-olds endorsed the labels of a mean agent over a nice agent if the mean agent is described as smart. However, 3-year-olds equally endorsed the mean and nice agent when competency was displayed through a description of prior behavior instead of inherent traits, like intelligence (Johnston et al., 2015). This study aimed to test 3-year-old children to further investigate their ambivalence between social and epistemic characteristics reported in previous research (see metanalysis by Tong et al., 2019).

Furthermore, the developmental shift from social to epistemic characteristics may also be driven by the maturation of cognitive skills, particularly Theory of Mind (ToM), between the ages of 3- to 5-years. Theory of Mind is the ability to attribute mental states, such as beliefs, to others (Poulin-Dubois et al., 2020; Wellman, 2014). Previous literature has found that ToM can predict or correlate with performance on epistemic trust Tasks, such as competency (Brosseau-Liard et al., 2015; Crivello et al., 2017; DiYanni & Kelemen, 2008; Fusaro & Harris, 2008; Lucas et al., 2017; Palmquist & Fierro, 2018; Resendes et al., 2021). However, some studies have failed to find a link between ToM and the ability to selectively learn from competent informants (Pasquini et al., 2007; Souza et al., 2021). As an exploratory goal, the present study administered the Children's Social Understanding Scale (CSUS), a measure of ToM, to parents to investigate this link further.

Robots as informants

Social robots have been used as a conservative test of epistemic trust as their animacy characteristics (e.g., morphology, social contingency) can be manipulated. A large body of research has been conducted with robot informants who have displayed either epistemic or social (or both) characteristics. Most studies to date were conducted either with a single robot agent (Meltzoff et al., 2010; O'Connell et al., 2009 Oranç & Küntay, 2020) or with two robot agents pitted against one another (Breazeal et al., 2016; Brink & Wellman, 2020). For example, Brink and Wellman (2020) found that 3-year-olds were more likely to learn the names of novel objects from a previously accurate humanoid robot than from a previously inaccurate one. These findings are consistent with past studies that have revealed children's preferences to learn from an accurate social robot over an inaccurate one (Geiskkovitch et al., 2019; Stower et al., 2021). These outcomes are also consistent with past literature that suggests that children prefer to learn from an accurate human over an inaccurate human (see Tong et al., 2019).

In another study, Breazeal and colleagues (2016) introduced two anthropomorphic robots to 3 to 5-year-olds who learned information about unfamiliar animals from the robots. One of the robots demonstrated social contingency (i.e., gaze following) while the other robot did not. The results showed that children treated both robots as informants from whom they could learn new information. However, children were more likely to learn from the robot that demonstrated a greater non-verbal contingency (Breazeal et al., 2016). This body of literature provides evidence that children learn from human and non-human agents in similar ways, evaluating the teacher's level of sociability and competency (Stower et al., 2021).

How children learn from a robot *versus* a human has only been recently investigated. Baumann et al. (2023) tested children's prioritization of social versus epistemic characteristics in learning from an accurate robot versus an inaccurate human. The aim of this research was to test children's reliance on social characteristics (in-group membership, "like me" status) against epistemic characteristics like competency, demonstrated through correctly verbally labeling familiar toys. Furthermore, unlike previous research, this study provided a more conservative test of the developmental shift in children's trust judgments by pitting a human and a robot agent against one another, therefore directly pitting epistemic characteristics against sociability characteristics. Children's selective social learning was tested using a selective word-learning Task developed by Koenig and colleagues (2004). First, the robot labeled familiar things, like a shoe, accurately, while the human labeled them inaccurately. Then, both agents labeled novel items with nonsense labels like a 'toma' or a 'mido.' Children's trust was tested with two different types of robots: a robot that looks like a human, Nao (Study 1), and a robot that looks non-human, Cozmo (Study 2). The findings revealed that 5-year-old children preferred to learn novel words from both a competent humanoid (Nao, Study 1) robot and a competent non-humanoid (Cozmo, Study 2) robot over an incompetent human. In contrast, 3-year-old children were unsure about whom to trust, equally endorsing the labels of the robot and the human. This suggests that the morphology or physical appearance of the robot is not a major factor in children's selective learning strategies in these studies. This suggests that other characteristics, such as speech or autonomous movement, might be more important than appearance for young children when evaluating informants. In the present study, how children learn to trust non-verbal informants, both robot and human, was investigated. By comparing the results of this study to previous work (Baumann et al., 2023), the impact of speech on children's decisions about whom to trust can be investigated.

While children learn a vast amount of information through verbal testimony, they also learn through non-verbal channels, such as facial expressions or gestures. Most of the studies on epistemic trust have tested children's trust using informants who provided information through verbal testimony, such as labels or facts (Corriveau et al., 2011; Corriveau & Harris, 2009a,b; Einav & Robinson, 2011; Koenig et al., 2004; Koenig & Harris, 2005; Stephens et al., 2015). In their seminal study, Koenig and colleagues (2004) showed 4-year-olds an informant who labeled familiar objects accurately and another informant who labeled them inaccurately. The results revealed that children were more likely to endorse new labels for novel unfamiliar objects provided by the previously accurate informant over the previously inaccurate informant. Given that informants also use other means to convey information (e.g., gestures, eye gaze, and autonomous movement), Palmquist and Jaswal (2015) investigated children's inferences about informants based on their pointing accurately to hidden objects. The researchers empirically tested whether 4-year-olds would distinguish between an accurate and an inaccurate pointer and whether they would later prefer information from a previously accurate pointer over a previously inaccurate pointer. They found that 4-year-olds favored a previously accurate pointer over a previously inaccurate one, demonstrating similarity between children's trust decisions using verbal and non-verbal modalities (Palmquist & Jaswal, 2015). Other studies using non-verbal information have shown similar results (Brosseau-Liard & Birch, 2011; Yow & Li, 2021). However, it has not been studied how children can learn non-verbally from robotic informants.

Children's perception of robots

How do children perceive robots? Given that the level of anthropomorphism displayed by a robot informant can influence if and how children learn from it (Fong et al., 2003; Tung, 2016; van Straten, 2020), it is crucial to know how children perceive social robots. Prior work has suggested that children may treat robots as social agents or as depictions of social agents (Clark & Fischer, 2022; Goldman et al., 2023b). Generally, children aged 3 years are confused about whether robots have biological or mechanical insides. In contrast, by 5 years of age, children know that something mechanical should go inside robots (Baumann et al., 2023; Goldman et al., 2023a).

Children have been shown to attribute mental states to robots, such as the ability to feel or think. For example, 5-year-old children have been shown to attribute psychological qualities to a robot after a naturalistic interaction, whereas 3-year-old children attributed biological qualities to the robot (Okanda et al., 2021). Another study found that 5-year-olds were more likely to anthropomorphize robots than older children but that older children (aged 7 and 9) attributed more mental states to a humanoid robot over a non-human-looking robot (Manzi et al., 2020). Finally, Goldman et al. (2023a) found that 5-year-olds attributed more animacy (e.g., biological insides such as a heart) to a human-looking robot over a non-human-looking robot. This suggests that while children, with age, learn that robots are different from themselves, they still view robots as animate and are willing to interact with them and even learn from them. Will children choose to learn from a robot teacher, even if they realize this teacher is not like them?

To study how children categorize the robot compared to the human, we asked children if either informant was alive and also tested their knowledge of the animacy of robots with a naïve biology Task (inside Task). For the purposes of this study, we tested children's animacy judgments about robots with the attribution of biological properties (e.g., internal organs).

The present study

The current study aimed to further investigate the characteristics driving 3-year-olds' trust judgments. Following up on the results of Baumann et al. (2023), 3-year-old children's trust in robots was tested using a selective trust paradigm based on the transmission of episodic information. Our main objective was to decrease the human-like characteristics displayed by the robot informant by measuring the impact of the removal of speech on children's selective trust. Speech is considered to be a salient social characteristic that transmits a wide range of social and epistemic information (Kinzler, 2021). In the present study, children learned from both a non-humanoid robot agent (Cozmo) and a human agent. The robot was consistently accurate, and the human was consistently inaccurate. Using an adapted version of Palmquist & Jaswal's (2015) pointing paradigm, the robot demonstrated competency by pointing at boxes that contained toys. Through this Task, we explored 3-year-old children's trust in a robot versus a human when neither communicated verbally, but the robot was still competent.

In previous studies using the Koenig and colleagues (2004) paradigm, agents usually label novel objects while also gesturing or pointing towards them. While pointing is inherently social and communicative, it is very often a communicative gesture that accompanies and reinforces speech (Kita & Özyürek, 2003). In the previous studies conducted by Baumann et al. (2023), both the robot and the human agent pointed alongside their verbal labels. In the current study, by eliminating speech and manipulating pointing, we sought to make the robot display as few social characteristics as possible. The only social characteristics the robot exhibited were the ability to understand direction, goal-directedness, and autonomous movement via pointing (essential for establishing competency). In decreasing the robot's sociability, our goal was to make the robot's competence as salient as possible, in contrast to an incompetent social human. In this way, we sought to directly pit and compare the impact of social and epistemic characteristics on 3-year-old children's learning and trust judgments.

An adapted version of Gottfried and Gelman's (2005) naïve biology Task was also administered to assess the animacy status of the robot. Gottfried and Gelman (2005) tested children's knowledge of the internal parts of animals, plants, and mechanical objects. Similarly, Baumann et al. (2023) and Goldman et al. (2023a) used a modified version of this Task to test children's knowledge of whether something biological (e.g., lungs) or something mechanical (e.g., gears) belonged inside robots, animals, and mechanical objects (artifacts). At 3 years of age, children could categorize what should go inside animals and artifacts but were confused about what should go inside the robot. Children also did not classify robots as 'alive' at 3 years of age (Goldman et al., 2023a). In the present study, we asked children what should go inside both agents (the human and the robot). We also asked the children if both the robot and the human were alive. Both Tasks were administered to investigate how children categorize the robot. If children choose to learn from the robot while recognizing the robot as an artifact that is different from themselves, this provides a conservative test of children's reliance on epistemic characteristics.

Assuming that a key social cue such as speech production played a vital role in children's trust in previous studies (see Baumann et al., 2023), we predicted that children would choose to learn from an incompetent human agent over a competent robot with very limited social characteristics once speech and human appearance is removed. Furthermore, we predicted that we would replicate Baumann et al. (2023)'s findings with children of that age being ambivalent about what should go inside a robot, something biological or something mechanical. We hypothesized that children would correctly attribute a biological inside to the person and that the performance on the naïve biology Task would mirror the alive question, with children answering that the human is alive but being unsure about the robot's animacy status. Finally, we wished to further investigate the link, or lack thereof, between ToM performance and higher scores for the competent robot on the Selective Trust Task. A recent study has found only a very weak effect, or no effect at all, between trust and ToM when using a robot and a human as the informants (Baumann et al., 2023). Therefore, attributing mental states to a robot may be harder for children than attributing mental states to someone more like them, a human. This study seeks to build upon the results of Baumann et al. (2023). In sum, this study sought to explore the role of both social and epistemic characteristics on 3-year-olds' selective trust. This was done by using non-human agents like robots who taught information to the child episodically.

Methods

Participants

The sample consisted of 45 3-year-old children living in a large Canadian metropolitan city (M_{age} = 41.78, *SD* = 2.72, 28 males, range = 36 to 46 months). Participants were recruited from a database of past participants and from social media advertisements. An a priori G*Power 3.1 analysis (Faul et al., 2007) was run to determine the appropriate sample size for a one-sample case difference from constant t-test. Our goal was to obtain .95 power to detect a moderate effect size of .5 at the standard .05 alpha error probability. The analysis revealed a minimum needed sample size of 45. Therefore, our final sample size of 45 is sufficient for the desired analyses.

Children were tested in a small laboratory room. The testing session was conducted in either English (n = 25) or French (n = 20), reflecting the dominant languages spoken by the local population. Prior to their participation, parents filled out a consent form and a demographics form about their children. As compensation, parents received a $25 gift card to a local bookstore, and children received a Concordia University certificate of merit for their participation. All children included in the sample had no known developmental delays or hearing problems. Parents were asked about their children's exposure to robots, and any child who regularly interacted with robots was excluded (n = 3). A total of 16 additional children were tested but excluded because of parental or sibling interference (n = 3), the child's refusal to participate or not finishing the Task (n = 6), or experimenter error (n = 7). The participants in the final sample were mainly Caucasian (51.11%) and the rest of our sample identified as Asian, African, or South American (28.89%) or Mixed ethnicity (20%). Our sample was generally comprised of high SES families, with 66.67% earning above $100,000 dollars per year and another 20% earning above $50,000 dollars a year.

Materials

A robot, Cozmo, developed by Digital Dream Labs, was used. Cozmo is a non-humanoid, autonomous, and programmable robot that is 2.5 inches wide and tall and 4.25 inches long. A desktop computer (27-inch iMac) with Microsoft PowerPoint (PPT) installed was used to administer the Selective Trust Task to the child. A total of two 8.5 x 11-inch letter-size laminated cards were used for the naïve biology Task to show the pictures of the robot and the human with a missing internal part. For the alive interview question, an additional two laminated cards were used to show pictures of the robot and the human without a missing part. Small, laminated cards (1.5 x 2.5 inches) were used to show pictures of the mechanical and biological internal parts.

Procedure

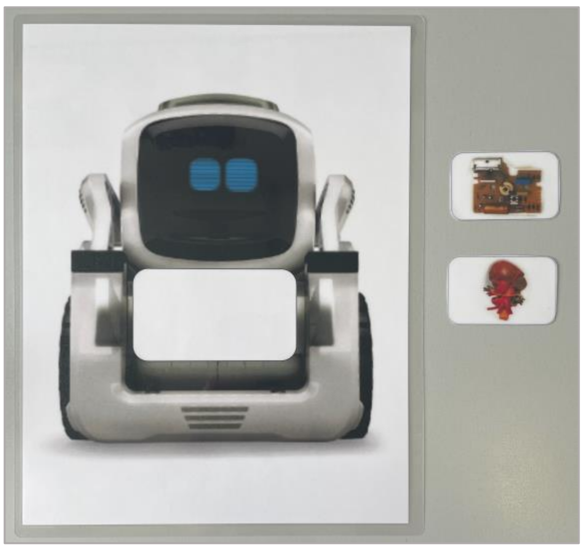
Parents were first contacted by email and telephone to determine if they wished their child to participate in the study. Before the testing session began, the parents were briefed on the purpose of the study and filled out a consent form on behalf of their child. A demographics questionnaire and the CSUS were also filled out by the parents, either before or after the testing session. The child was seated in front of the computer at a desk while the parent was seated behind the child. In some cases, the child was seated on the parent's lap at the desk. The participants then completed the naïve biology Task and the Selective Trust Task. Which Task was completed first was counterbalanced. After completing the study, parents were debriefed, informed of the study's goals, and presented with a certificate of merit for their child and a twenty-five-dollar gift card to a local bookstore to thank them for participating. The parent also had the opportunity to ask any questions. The testing session was recorded, with videos being stored afterward on a secure university server.

Naïve biology Task

The Naive Biology Task was adapted from Gottfried and Gelman (2005). Children were presented with standard letter-size laminated cards depicting either a robot, Cozmo (Digital Dream Labs), or a person. Both agents were missing a center piece represented by a white rectangle. Children were also presented with smaller cards of pictures of mechanical or biological internal parts, i.e., the potential "missing" parts (see Figure 4). Four Trials were administered per agent. In each trial, one potential mechanical inside (i.e., gears, circuit, batteries, wires) and one potential biological (i.e., muscle, lungs, heart, bone) inside was shown to the child. For each trial, children were asked, "What goes inside of here?" while the experimenter pointed to the missing piece of either the robot or the person. Children were then told to place the internal part they believed to be correct into the missing white rectangle. The experimenter never labeled the robot or the person as such. The experimenter also did not label the potential internal parts, referring to them simply as "that one" or "this one." Which mechanical inside was presented with which biological inside was yoked and whether the biological or the mechanical inside was placed on the bottom was counterbalanced. The order of which agent (robot or person) was presented to the child first was also counterbalanced across participants.

Figure 4

A Naïve biology trial with the robot



After the four naïve biology Trials had been administered for either agent, the experimenter would ask the child, "Is the robot/person alive?" The child either responded verbally with "yes" or "no," or responded with a shake or nod of their head.

Selective Trust Task

The Selective Trust Task was split into three phases, with four Induction Trials, followed by four Test Trials, and finally, two Catch Trials.

Introduction phase. Before the Task began, children were shown a screenshot of the setup used in the selective trust videos (see Figure 5). The experimenter introduced three agents: the hider in the middle, as well as a robot, and a person. Children were told that the hider would hide some toys in either a green box or a yellow box and that they would then be asked who pointed at the toys, the person, or the robot. The boxes were transparent, with the backsides lined with green or yellow felt. Before moving on, the experimenter asked the children to point to the boxes where the toys would be hidden so that children were familiarized with the boxes as the target locations of the hiding game. If the child pointed at only one box, the experimenter reiterated that the toys could be hidden in either box.

Figure 5

Screenshot of the display used during the introduction phase of the Selective Trust Task

Induction Trials. There were four Induction Trials presented via a series of videos using a PowerPoint show. In the first induction trial, the hider introduced the scene and labeled the two boxes (green and yellow), an animal toy, and the two agents (one robot and one person). Which box and which agent was introduced first was counterbalanced. Next, the hider confirmed that both agents were watching. Induction Trials 2 through 4 did not feature the introduction section of the video and started right before the hiding event occurred (when the hider proclaimed both agents to be watching). Then, the hider pulled an opaque curtain across the screen, which resulted in both boxes being occluded from the view of the child. Both agents were still visible to the child and could be seen watching, even when the curtain was pulled. The hider then hid an animal figurine (cheetah, deer, seal, and pig) in one of the two transparent boxes, lifted both boxes up with one hand, and hid the toy in one of the boxes with the other. The child could not tell which box the toy had been hidden in at this point in time. Then, the curtain was drawn back. Since the boxes were transparent, children could now see in which box the toy had been hidden. Next, the hider proclaimed that it was time to see where the toy was, and children watched as the two agents (the person and the robot) pointed simultaneously. To point, the robot would move towards the box, turn towards it, and then lift its mechanical arm (see Figure 6). The robot consistently pointed at the correct box, which contained the toy, and the human agent consistently pointed at the incorrect, empty box (see Figure 8 in supplementary materials). After each induction trial, the child was asked, "Where is the toy?" (Induction Endorse Trials). Following the last induction trial, the child was asked, "Who pointed at the toys? The person or the robot?" (Induction Judgment Trial).

Figure 6

Screenshot of the robot and human informants pointing during a test trial

Test Trials. Four Test Trials were conducted directly after the Induction Trials. The videos and procedure were identical to the Induction Trials except for two key differences. Instead of transparent, the boxes were now opaque and either red or blue in color (see Figure 9 in supplementary materials). Therefore, the "true" location of the toy was never confirmed for the child. Furthermore, after the hider had hidden the animal figurines (lioness, sealion, bear, and cow) but before the agents pointed, the children were asked, "Who can help you find the toy?" (Ask Trials). Four test endorse questions were asked after each pointing event ("Where is the toy?"), and the Test Judgment Question was again asked at the end of the four Test Trials ("Who pointed at the toys?").

During the Induction Trials and the Test Trials, the children were shown the stimuli (animal figurines) in the same order. However, who was introduced first (i.e., the robot or the person) and which box was labeled first (green or yellow in Induction Trials; blue or red in Test Trials) was counterbalanced across the conditions. Furthermore, which side of the screen the robot was on (left or right) was also counterbalanced. Additionally, which Task was administered first (the Naïve biology Task or the Selective Trust Task) was counterbalanced. The preference question was always asked at the end of the testing session.

Catch Trials. As in the original procedure (Palmquist & Jaswal, 2015), two other videos were presented to children at the end of the Selective Trust Task, using both the same display and the two opaque boxes (red and blue). First, the hider introduced a new toy: a piece of fruit (a plastic pear or strawberry). Then, the person turned around. The hider then remarked that the person could no longer see but that the robot was still watching. The hider then pulled the curtain, lifted both opaque boxes up, and hid the fruit under one. The curtain was pulled back, and then the experimenter asked the child, "Who can tell you where the fruit is, the person or the robot?" In the second video, the robot turned around and could not see (see Figure 10 in supplementary materials). Which agent turned away in the first trial and which fruit was presented first (pear or strawberry) was counterbalanced. These Catch Trials served as a check of Task comprehension as well as an attention check. Previous research has shown that by the age of 4 years, children can recognize an informant's knowledge based on whether the informant had seen an event occur (Pratt, 2022). Therefore, children should be able to identify which agent saw the piece of fruit as it was hidden in one of the two opaque boxes.

Preference question

At the very end of the testing session, after both Tasks had been completed, the child was asked, "Who do you like better, the person or the robot?" This question served to identify a potential bias towards either the robot or the human agent.

Children's Social Understanding Scale (CSUS)

The children's social understanding scale (CSUS) was filled out by the parents either before or after the testing session. The CSUS measures Theory of Mind in children aged 2 to 7 years. Theory of mind is the ability to attribute mental states, beliefs, and thoughts to others (Wellman, 2014). It includes 42 questions and statements that parents respond to on a 4-point Likert scale ranging from "definitely untrue (1)" to "definitely true (4)." Parents could select "don't know" as an option if they were unsure of their child's behavior for that item. The CSUS covers six domains, with seven questions/statements asked per domain: emotion, intention, desire, perception, knowledge, and belief. For each child, a mean score out of 4 was determined by averaging their scores across the six domains (Tahiroglu et al., 2014). The CSUS was translated into French and validated by Brosseau-Liard et al. (2019).

Scoring and data analysis

As shown in Table 6 (see supplementary materials), there are 4 Induction Trials and 4 Test Trials, resulting in Ask and Endorse scores out of 4 in total. For the Induction Trials of the Selective Trust Task, children received a score out of four, one point for each correct identification of the box that contained the toy (Endorse Trials), and a score out of 1 for the Judgment Trial (i.e., which agent pointed at the toys). For the Test Trials, children received a score out of four for the Ask Trials (i.e., whom they wanted to ask for help), a score out of four for the Endorse Trials (i.e., in which box they believe the toy was located), and a score out of one for the test Judgment Trial (i.e., which agent pointed at the toys). The induction and test Judgment Trials were combined for some analyses to form a total judgment score out of 2. A point was awarded each time the child chose to ask the robot for help finding the toy, endorsed the box the robot was pointing at, or judged the robot to have pointed at the toys. For the Catch Trials, the child received a point, scored out of 2, for stating that the agent who was watching could tell them where the fruit was hidden. The child received one point (out of 4) each time they correctly assigned the inside of both the robot and the human (i.e., the mechanical inside to the robot and the biological inside to the human). The "alive" question was scored the same way, with children receiving a score of 1 (out of 1 trial) for the correct response (i.e., saying that the human was alive, and that the robot was not alive). Finally, the preference question was scored out of 1, with 1 indicating a preference for the robot. For the purposes of cross-Task analyses, scores were turned into proportions (see Table 1 in supplementary materials).

Results

Data cleaning and transformation

All participant videos were live coded by the experimenter, with data entry being completed immediately after the testing session concluded. All responses were checked by an independent coder, who verified the data entry. Nine cases of disagreement occurred (out of a total of 1404 Trials), where a child's response on a specific trial was not clear. In these nine cases, a third coder broke the tie. When a child's response differed between modalities (i.e., pointing at one box but verbally saying the color of the other box), the verbal response was taken as the final score. If a child switched their answers back and forth, the child's final response was used. For 47 Trials (out of a total of 1404 Trials), the child's responses could not be checked by the second coder due to technical failure. An additional 6 Trials are missing due to experimenter error ($n = 4$) or the child's refusal to answer ($n = 2$).

A small number of participants did not have scores for individual Naïve biology or Selective trust Trials ($n = 6$ Trials) due to experimenter error or the child's refusal to answer. These cells were left blank in the data analyses and treated as missing data points. All data were checked for normality. If a deviation from normality was found, the appropriate corrections were applied, and nonparametric tests were run. If a change in significance was found because of the applied correction (i.e., a finding became insignificant or trending), that change is reported below. All analyses were checked for interactions between gender (male or female) and testing language (French or English) on both Tasks (Selective trust and Naïve biology), but no significant interactions with the Tasks were found. Thus, the gender and language variables 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 analyses across trial types or Tasks.

Preference

At the end of the testing session, children were asked, "Who do you like better, the person or the robot?" Most of the children responded that they preferred the robot over the human (*Prop* = .78, binomial test, $p < .001$, 95% CI [0.63,0.89]).

Selective Trust Task

The Selective Trust Task consisted of three phases. Each phase of the Selective Trust Task was analyzed independently.

Induction Trials

Recall that toys in the Induction Trials were hidden in transparent boxes. At the end of each of the four Induction Trials, after the agents had pointed at the boxes, the child was asked, "Where is the toy?" Children performed well, correctly identifying the box the toy was hidden in ($M = 3.20$, $SD = 1.42$; $t(44) = 5.65$, $p < .001$, $d = 0.17$). At the end of the fourth and final induction trial, children were asked, "Who pointed at the toys? The person or the robot?" Children overwhelmingly said the robot had pointed at the toys (*Prop* = .82, binomial test, $p < .001$, 95% CI [0.68,0.92]).

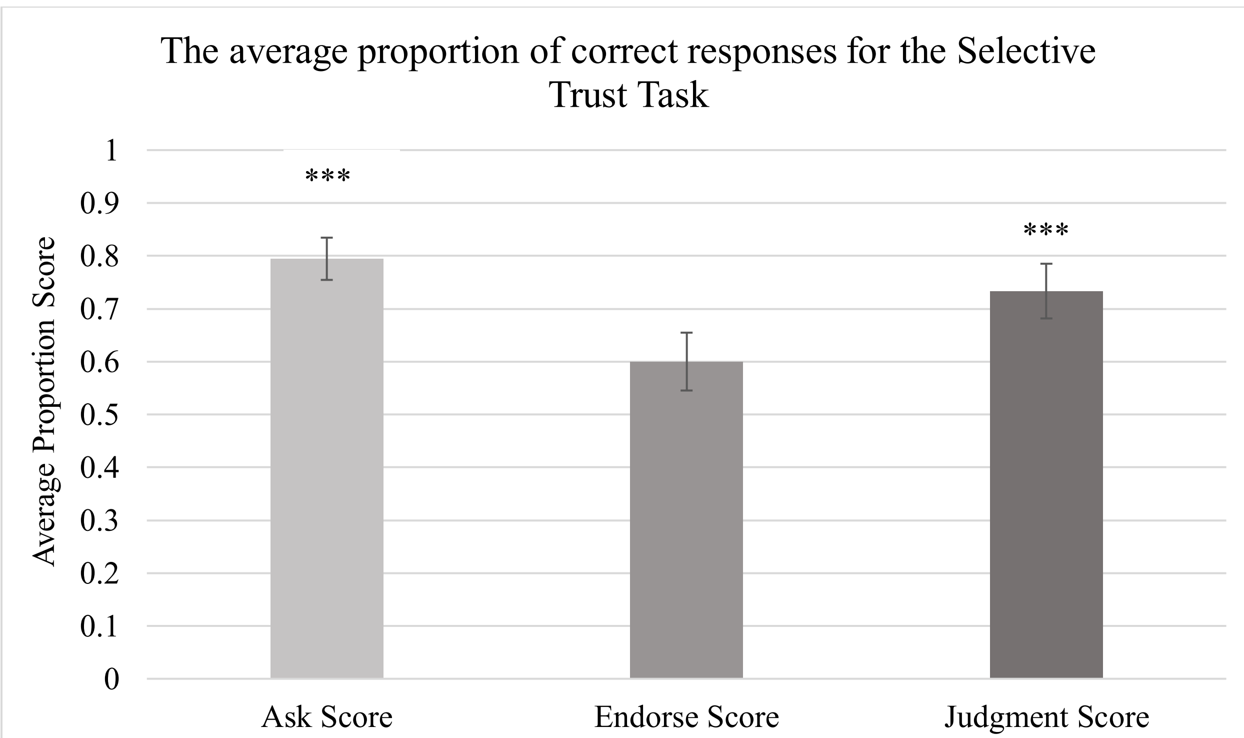
Test Trials

In the Test Trials, children responded to the ask question, "Who can help you find the toy?" after the toy had been hidden but before the agents pointed. Overall, most children did well on the ask question and said the robot could help them find the toy ($M = 3.18$, $SD = 1.07$; $t(44) = 7.37$, $p < .001$, $d = 1.10$). After the fourth test trial, children were asked the judgment question, "Who pointed at the toys? The person or the robot?" Although more children responded correctly that the robot had pointed at the toys, this was not a significant difference (*Prop* = .64, binomial test, $p = .072$, 95% CI [0.49,0.78]). After each test trial, children were asked to respond to the endorse question, "Where is the toy?" Children performed at chance level ($M = 2.40$, $SD = 1.47$;

$t(44) = 1.83$, $p = .074$, $d = 0.27$). However, children were trending towards endorsing the location the robot had pointed at. When the induction and test judgment scores were combined, children performed well, responding that the robot had pointed at the toys significantly more often (M = 1.47, $SD = 0.69$; $t(44) = 4.51$, $p < .001$, $d = 0.67$). See Figure 7 for children's performance on the Ask, Judgment, and Endorse questions.

Figure 7

The average proportion of correct responses for the Selective Trust Task Trials



Note. The bars represent standard error. *** represents significance of p < .001

Since 78% of children preferred the robot, a correlation was run between the Selective Trust Task scores and children's preference choice for either the robot or the human. This was done to rule out the possibility that children's selective trust performance was mainly driven by their preference toward one informant or the other. No significant correlation emerged between children's preference choice and their ask, endorse, or judgments scores (all $r(44) < .21$, $p > .17$), suggesting children's selective trust choices were not influenced by their preference.

Catch Trials

Following the Test Trials, children completed two Catch Trials. The children were asked, "Who can tell you where the fruit is, the person or the robot?" Recall that children only passed the Catch Trials if they answered both Trials correctly. Most children failed the Catch Trials (*Prop* = .89, binomial test, $p < .001$, 95% CI [0.76,0.96]). In terms of preference, 29 out of 45 children chose the robot for both Catch Trials, whereas 4 out of 45 children chose the human for both. We examined whether children's preference for one agent over the other could have contributed to children's failures in the Catch Trials. A majority of the children (64%) picked the agent (the robot or the person) they had indicated they preferred on the preference question ("Who do you like better, the person or the robot?") for both Catch Trials. A one-sample t-test indicated this finding was trending on significance ($M = 0.64$, $SD = .48$; $t(44) = 2.00$, $p = .052$, $d = 0.30$). Consequently, most children received a score of 1 out of 2 on the Catch Trials, given that which agent saw the hiding event switched from trial 1 to trial 2. Only 6 children answered both Catch Trials incorrectly, picking the informant who had turned around in both Trials. Children's performance on the Catch Trials (pass or fail) did not affect their performance on the Endorse Trials ($t(43) = -0.97$, $p = .34$, $d = -0.46$).

Naïve biology Task

A paired samples t-test compared the naïve biology scores by trial type (person versus robot). The t-test revealed no main effect of trial type ($t(44) = -1.00$, $p = .32$, $d = -0.15$), with children performing statistically similarly on the robot and person Trials overall. Children did well on the person naïve biology Trials, correctly attributing biological internal parts to the person (*M* = 2.31, *SD* = 1.02; *t*(44) = 2.05, *p* = .046, *d* = 0.31). In contrast, children performed at chance on the robot Trials of the naïve biology Task, assigning mechanical and biological parts equally (*M* = 2.10, *SD* = 1.13; *t*(44) = 0.53, *p* = .599, *d* = 0.08). A correlation between children's Naive Biology scores for the robot and the endorse question in test was run. No significant correlation was found between these Trials (*r*(44) = -.008, *p* = .957).

Interview

Very few children were able to correctly judge that the robot was not alive (*Prop* = .14, binomial test, *p* < .001, 95% CI [0.05,0.28]). Therefore, most children (86%) judged the robot to be alive. Most of the children also knew the person was alive (*Prop* = .84, binomial test, *p* < .001, 95% CI [0.69,0.93]).

Children's Social Understanding Scale (CSUS)

One parent failed to complete the CSUS. Children's overall CSUS score was 3.04 out of 4 (*SD* = 0.41). Our sample's overall score is in line with previous research that has administered the CSUS (Tahiroglu et al., 2014). The overall CSUS score, and subscale scores were not found to be correlated to any scores on the trust Task, either the ask, judgment, or endorse question scores (all *r* < -.281, *p* > .081). Apart from one likely spurious correlation between the judgment question and the intention CSUS subscale (*r*(44) = -.31, *p* = .037).

Discussion

The main goal of the present study was to investigate whether 3-year-old children prefer to learn from a non-verbal, non-human-looking competent robot over an incompetent human. Specifically, by removing speech as a characteristic of the model, we reduced the robot's agency to goal-directedness and autonomous movement, both of which were necessary to demonstrate communicative competence. To date, this is the first study to compare children's learning between human and non-human informants using a non-verbal paradigm, adapted from Palmquist and Jaswal (2015). A recent meta-analysis concluded that, at the age of 3, children weigh social and epistemic characteristics equally in their trust judgments (Tong et al., 2019). This study sought to further clarify if both social and epistemic characteristics are truly equal to 3-year-old children when the sociality of one of the informants is significantly reduced.

Social trust

Two previous studies have supported Tong's meta-analysis findings using a similar design to our own. When a competent robot is pitted against an incompetent human using a verbal selective learning Task, 3-year-olds are split in their trust decisions and learn equally from both informants. In contrast, 5-year-olds prefer to learn from the competent robot. Importantly, the children learned equally from a robot that looked more like a human and a robot that looked less human-like. In other words, the 3-year-olds remained ambivalent, regardless of the robot's morphology (Baumann et al., 2023). This suggests that morphology may not be a key characteristic driving 3-year-old children's learning from non-human informants. Since the characteristics driving these decisions remained unclear, the current study hoped to clarify the findings by investigating the effect of speech, a very salient social characteristic and important communicative tool. We predicted that, without speech, the 3-year-olds may overlook the robot's competence and shift towards learning more from the inaccurate human informant who is more "like them." This hypothesis was not supported. Our findings suggest that removing speech did not alter children's trust judgments of a non-humanoid robot as they remained ambivalent about which informant to trust. We conclude that, since 3-year-old children consider both types of characteristics (social and epistemic), they are unwilling to completely overlook social cues no matter the circumstance.

It appears that goal-directedness and autonomous movement are sufficient, and potentially the most crucial, social characteristics needed to trigger social affiliation in young children. Goal-directedness can be interpreted by infants as young as 6 months of age, even when it is exhibited by non-human agents (Johnson et al., 2007; Király et al., 2003). By 16 months of age, infants attribute false belief to a toy crane when it moves in a goal-directed manner (Burnside et al., 2020). Furthermore, both self-propulsion and goal-directness have been associated with children's attribution of animacy to agents (Biro et al., 2007). Infants seem to categorize non-human agents (e.g., boxes, geometric shapes, robots) that display animate motion patterns as human-like (Baillargeon et al., 2016). By age 5, children have been shown to attribute both biological and physiological characteristics ("aliveness") to a blob that moves autonomously in a goal-directed manner (Johnson et al., 1998; Opfer, 2002). Since autonomous movement and goal-directedness, in tandem, are salient cues of animacy, the 3-year-old children in the current study may have still treated the robot as an unfamiliar social agent.

Another possibility is that children trusted both the robot and the human at equal rates because both informants shared information and followed the instructions of the hider. While we tried to make the robot as socially unrelatable as possible, the robot was shown to understand, and respond to, human speech. When asked, both informants readily pointed at one of the boxes, endorsing a location and transmitting knowledge through a non-verbal communicative signal. This intentional sharing may have triggered the same level of social affiliation as a speaking robot did. To speculate further, perhaps both informants were viewed as alive by children because of this behavior. Children may have assumed that agents who share information or have goals/intentions are alive. Important to note, however, is that the informants never directly shared information with the child, and neither informant spoke. Rather, they responded to a prompt given to them by the hider. Children watched this take place through a series of videos.

Although the robot informants in our study displayed agency characteristics (e.g., verbal comprehension, goal-directedness, and autonomous movement), the human stranger was, by default, more social than the robot. Therefore, we expected children to preferentially socially affiliate with the human and ask them for help. Yet we found the opposite, with children preferring to ask the robot for help over the human. One possibility is that the novelty of the robot biased the children, as suggested by the answers on the Ask Trials, where children selected to ask the robot for help finding the toy more often than the human. This bias is further confirmed by the preference interview question, with children significantly preferring the robot over the human. It is important to note, however, that the robot's previously demonstrated accuracy may have influenced the preference shown by children towards the robot.

Interestingly, children performed well on the Judgment Trials, knowing that the robot was correct, that is, that the robot had pointed at the box with the toys. Thus, this indicates that they had properly encoded the information during the induction phase. While children failed the Catch Trials, this finding also suggests that our sample understood both the videos shown to them and the Task in general. Children's performance on the Judgment Trials can lead us to conclude that it is not a lack of knowledge that guided children's responses during the Endorse Trials, as children knew that the robot was correct. However, they could not yet apply this knowledge to their own decisions about whom to endorse and whom to learn from. This suggests a dissociation between the children's knowledge and the children's trust decisions at this age. While they prefer to ask the robot for help and know the robot is accurate, they are not yet capable of endorsing the location provided by the accurate robot. Supporting previous findings in the literature, this present work indicates 3-year-old children's reliance on both social and epistemic characteristics when these characteristics are conflicting (Tong et al., 2019). Even when the robot informant was much more morphologically similar to the child and more social by speaking to the child, children were still torn between learning from the robot and the human (Baumann et al., 2023). Interesting to note, however, is that children's endorse trial scores were trending towards significance and towards greater endorsement of the robot's boxes. This suggests that the age of 3 years might be a transitory period where children start to shift to epistemic characteristics more than social ones when deciding whom to trust (Tong et al., 2019). This is further supported by the fact that the children in our sample attended to epistemic characteristics and did not overwhelmingly choose the human informant, even when the robot lacked many social characteristics. Our results match the results of a previous study (Baumann et al., 2023), where the robot was more human-like and revealed its competence through verbal testimony.

Surprisingly, most of the children failed the Catch Trials. They could not tell which agent could provide them with information about a hidden fruit toy's location when one agent watched the toy being hidden and one agent was turned away. When this Task was done as a memory check with two human agents, 4-year-old children had less trouble correctly answering. However, 27% still failed the Catch Trials even with an older sample and a design that featured two human agents (Palmquist & Jaswal, 2015). Potentially, our slightly younger 3-year-old sample was simply confused by this Task and unable to understand it. Since children performed well on both the induction Endorse Trials and the judgments Trials, we have no concerns that children did not understand the Task in general. We believe that our catch trial results may reflect a preference bias, that is, children choose whomever they preferred in both Catch Trials.

For example, a child who preferred the robot may have answered 'robot' for both Catch Trials. Indeed, this is what we observed in most of our sample. At age 3, children seem to conflate the Catch Trials with more of an 'ask' than an 'endorse' question. Since the informants did not point at either box, we asked the child, "Who can tell you where the fruit is?" This wording is quite similar to the ask question and may therefore reflect that same novelty bias instead of depicting a knowledge/no knowledge difference as we had predicted. In future studies, the Catch Trials procedure should be altered to more closely match the Endorse Trials than the Ask Trials by including a pointing phase and an endorse question. Furthermore, the general preference shown by children for the robot over the human may have been biased by the robot's previous accuracy. The preference question was always asked at the end of the study after children had seen the robot accurately point to boxes. This was done to avoid biasing the children before the Selective Trust Task had been administered. Future studies should counterbalance all Tasks and questions asked and compare the results when a preference question occurs at the beginning of the study.

Children's anthropomorphism of the robot

When 3-year-old children learn from robots, do they understand that robots are artifacts and not like them? In the current study, did they treat the robot as they would treat a self-moving box? We attempted to clarify this issue by administering a Naïve biology Task and an interview question. When asked what should go inside the agents, 3-year-old children correctly identified that something biological should go inside the human. However, they were confused about what should go inside the robot, equally attributing mechanical and biological insides. This result replicates previous studies, which have shown that 3-year-old children accurately categorize unfamiliar animals and artifacts but are confused about robots, regardless of their appearance. By the age of 5 years, children know something mechanical should go inside robots. However, children still choose to learn from the robot because competence trumps animacy by the age of 5 (Baumann et al., 2023; Goldman et al., 2023a). It is possible that what explains 3-year-old children's reluctance to learn from the robot stems from their confusion about its animacy status. Robots are inherently confusing. They are not actually alive and are made of metal or plastic. Yet they can act very much like a human, moving, speaking, or pointing. Therefore, children are unsure if this machine, made of metal, but acting human in some ways, is like them. Can such an agent be trusted?

In contrast to our Naïve biology Task, children overwhelmingly thought that both the robot and the human were alive. This finding contradicts some previous work that found that 3-year-old children do not think a robot is alive (Goldman et al., 2023a; Saylor et al., 2010). However, other studies have found aliveness attribution to robots at age 3, matching the present work (Kim et al., 2019, Okita et al., 2006). Since the findings are mixed, it suggests a general confusion among 3-year-olds about the concept of life. The significant difference between the interview and the Naïve biology Task may be explained by the interview question being a forced response paradigm of either 'yes' or 'no.' Children may have been biased to answer positively, given their difficulty in understanding the word alive. In contrast, the Naïve biology Task is more interactive and contains multiple Trials. Furthermore, the biological and mechanical internal parts are not valanced the same way 'yes' or 'no' might be. Different studies finding contradictory results may also indicate young children's lack of understanding when being asked interview questions (Goldman et al., 2023a; Saylor et al., 2010). Interactive non-verbal Tasks may better assess younger children's thoughts about animacy. Furthermore, future research using interviews should feature open-ended follow-up questions, such as "Why do you think the robot is alive?" to clarify and justify children's responses while providing context.

Children's anthropomorphism of the robot Cozmo was somewhat unclear, given their conflicting responses on the two tasks assessing its animacy status (i.e., Alive Question versus Naïve Biology Task). Children thought the robot was alive when asked explicitly ("Is the robot alive?") but did not attribute more biological insides than mechanical insides to the robot in the Naïve Biology Task. Which Task better reflects their anthropomorphism of the robot? Given that the children in our sample performed well when asked about the insides of a person, we believe that their poor performance reflects an incomplete knowledge about the animacy of social robots. Nevertheless, children still saw Cozmo as a social, sentient agent whom they wished to ask for help in the object search Task and to whom they correctly attributed competence in locating objects. Children aged 3 are therefore willing to treat a very non-social and unfamiliar agent, like a non-humanoid robot, as a sentient agent. However, they are still developing the ability to trust such agents.

Theory of mind and selective social learning

Previous research has found a link between Theory of Mind and selective trust when tested with human agents (Brosseau-Liard et al., 2015; Crivello et al., 2021; DiYanni et al., 2012, Palmquist et al., 2022). This suggests that children are more likely to favor competence over other characteristics as a function of their theory of mind skills, as measured with laboratory-based Tasks. However, some studies have also failed to replicate this link (Pasquini et al., 2007; Souza et al., 2021). The present study found no correlations between a parental report measure of ToM, the CSUS, and children's performance on the Selective Trust Task. This result again matches the findings of two previous experiments conducted using a robot informant, which found no links among 3-year-olds and only weak links in samples including older children aged 5 (Baumann et al., 2023). Potentially, this link can only be detected when tracking performance with growing age because Theory of Mind is not sufficiently developed to guide selective trust at age 3. Some studies have found a link between 3-year-olds' selective trust and ToM (Brosseau-Liard et al., 2015; DiYanni et al., 2012), but these studies used in-person tests of ToM. It is possible that the link between ToM and selective trust can only be detected when the robot exhibits higher levels of animacy or anthropomorphism or interacts more naturalistically with the child than it does in the current study. This matches with other previous studies that have found only weak or no links between the CSUS and selective trust with human agents (Brosseau-Liard et al.,2015; Dutemple, Hakimi, & Poulin-Dubois, 2022; Resendes et al., 2021). Future studies should aim to investigate the potential link further using in-laboratory Tasks.

Limitations and future directions

The present work has several limitations that need to be addressed in future studies. One of the limitations was that the selective learning Task was administered using pre-recorded videos. Since both the human agent and the robot agent were presented to the children on a screen, the children may not have affiliated with them in the same way they would have if the agents had been physically present in the room with them. This screen-disconnect may have led children to view the agents as depictions instead of as 'real.' Children may affiliate more with agents that they can physically see and interact with live. Future research should replicate the present work by performing the selective learning Task with live agents in the laboratory. Administering the Tasks live instead of using pre-recorded videos would also increase the ecological validity of the study since children usually interact with social robots in person and not through pre-recorded videos or through a computer screen. A live demonstration may also help children view the robot and its features more clearly, potentially eliminating some of the confusion surrounding its internal parts. However, using pre-recorded videos does help with internal consistency as all children watched the Task performed by the robot and the person in the same way, thereby limiting experimenter error.

Future studies should also use a variety of robots in similar paradigms, varying in human appearance. This would increase generalizability and ecological validity. The robot used in this study, Cozmo, was very small and did not have an arm or a hand. Instead, Cozmo pointed using a mechanical tread, while the human pointed using their hand. Due to its size, Cozmo also had to move forwards before pointing, whereas the human remained stationary. These differences in how the human versus the robot pointed are a further limitation of this study and may have affected children's responses or perceptions. Children did appear to comprehend the pointing of both informants since they deemed the robot to have correctly pointed at the toys. Yet still, perhaps children would endorse the robot's information about location more often if the robot and the human were of a more similar size and the robot's pointing was demonstrated differently. On the other hand, Cozmo's pointing did have advantages as well as it helped further limit Cozmo's social characteristics and reduce social affiliation since the robot pointed mechanically.

The present study pitted a competent robot against an incompetent human to provide a strict test of epistemic trust, but future research should test 3-year-old's trust decisions when a competent robot is pitted against a competent human. This experimental design would inform about any initial biases towards either the robot or the person. When both informants show competency, it is likely that young children would choose to affiliate with the human and learn from them. However, older children may choose to learn from the robot, which is more novel and perhaps more intriguing. The impact of episodic versus semantic information could also be directly studied instead of across studies, as done here. For example, future work could have the human informant label the objects, whereas the robot points to the object. This would further widen the social gap between the agents. Another potential future avenue would be to perform a cross-cultural study between countries differing in their level of societal robot integration. Children in Japan, for example, might be better at categorizing robots at an earlier age than children from Europe due to a higher amount of robot exposure in a country like Japan (Haring et al., 2014). Considering in-group biases, future research could also select a human from a different race or gender to be pitted against the robot informant. This would allow us to assess if children would be more likely to learn from the human with additional cues to in-group bias.

Conclusions

In conclusion, the present study adds to the existing literature by providing evidence that both speech and morphology are not the main social characteristics driving 3-year-old children's trust judgments. Our findings establish that even when very few social characteristics are exhibited by both informants, 3-year-old children still consider both social and epistemic characteristics when selecting from whom to learn new information. As children are increasingly exposed to robots in educational settings, it is important to understand what characteristics children rely on most when they choose which informant to trust. Therefore, this study has practical implications for using robots in educational settings and provides guidance on what characteristics matter most when building a robot that can serve as a child's teacher.

Supplementary Materials

Figure 8

The Induction trials of the Selective Trust Task

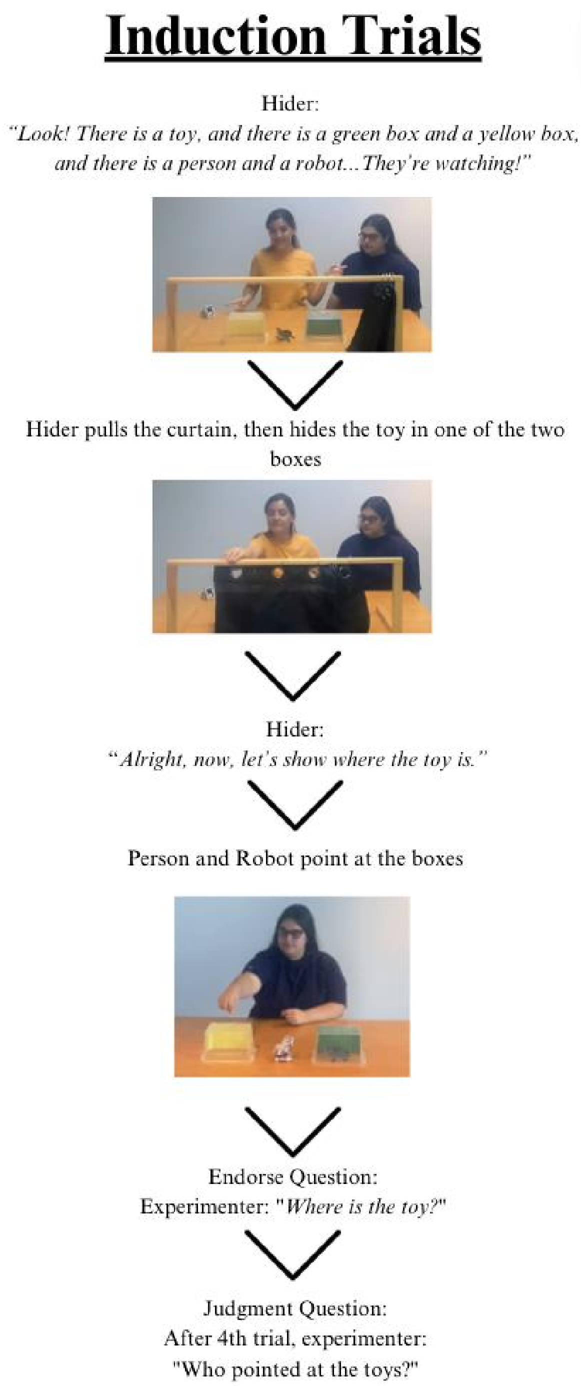


Figure 9

The Selective Trust Task procedure for the Test trials

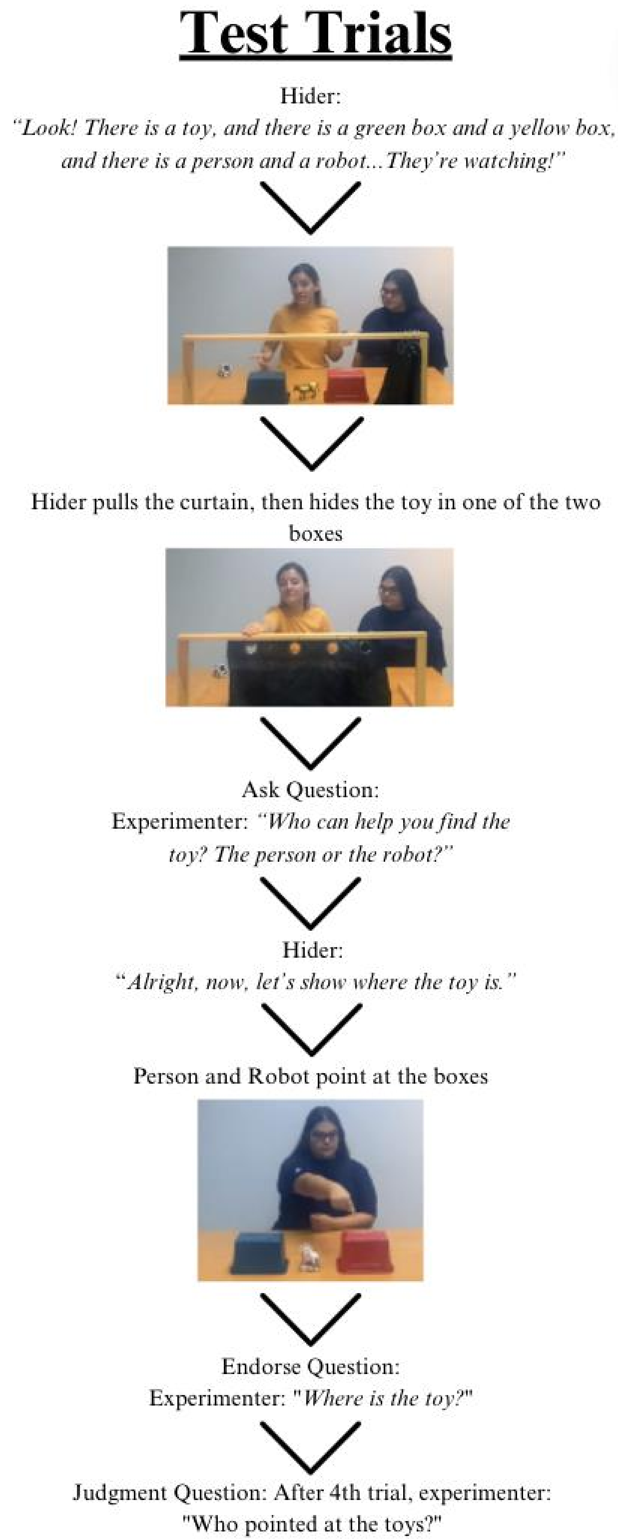


Figure 10

The catch trials of the Selective Trust Task

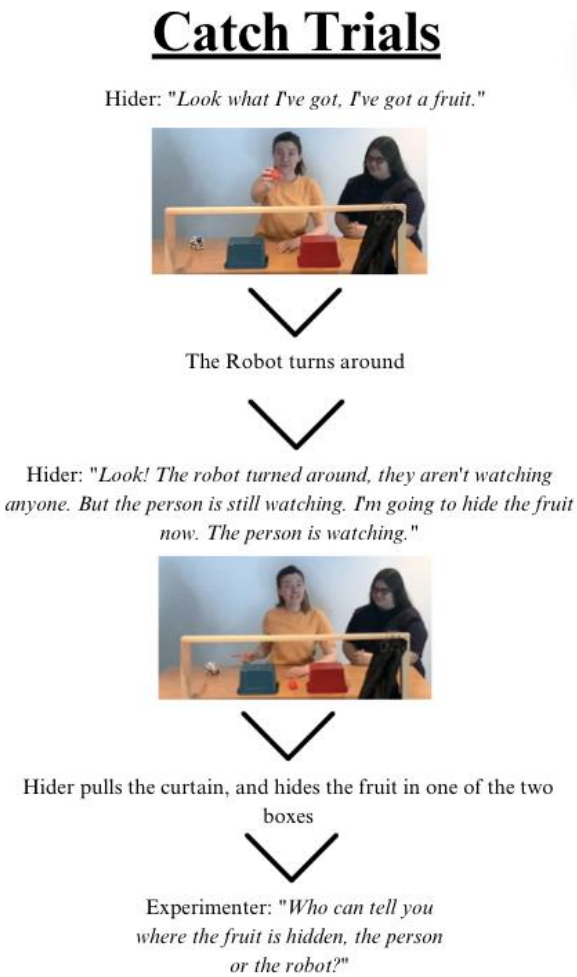


Table 6

The scoring procedures used for the testing procedure

Task	Trial	Correct response	Scored out of
Naïve biology	Robot trials	Number of mechanical responses	4
	Human trials	Number of biological responses	4
Interview	Robot alive question	'No' response correct	1
	Human alive question	'Yes' response correct	1
	Preference question	Robot	1
Selective trust	Ask Trials	Asking the robot for help	4
	Endorse Trials	Endorsing the robot's box	4
	Judgment Trials	Judging the robot to have pointed at the boxes	1
	Catch trials	The agent who watched can find the fruit	2

Chapter 4: General Discussion

This thesis sought to investigate if 3- and 5-year-old children prioritize social or epistemic characteristics when making trust judgements. This was done in order to better understand how the cognitive abilities underlying children's selective learning strategies change with age. The main goal was to test children's reliance on epistemic characteristics using a non-human agent whose social characteristics could be manipulated, altered, and diminished; thereby creating a conservative test of children's reliance on epistemic characteristics by age 5. An unfamiliar informant was used as the competent informant, specifically a social robot. The use of a robot allowed us to test a new variable in the study of epistemic trust and its potential impact on children's trust decisions, that of animacy. Throughout three experiments reported over two manuscripts, the impact of novelty, morphology/appearance, and speech on 3- and 5-year-old children's trust judgements was investigated.

This set of studies is unique in that it is, to our knowledge, the first to directly compare how children learn from a robot versus a human informant when forced to choose between them and also the first to administer a naïve biology paradigm to children with robots. This was investigated using both a word learning paradigm in a semantic context (studies 1 and 2) and using a communicative gesture, pointing, in an episodic context (Study 3). As an exploratory goal, this thesis also investigated if the link that has been reported between Theory of Mind and selective trust (Theory of Mind predicting selective trust performance) could be replicated when one of the informants is an unfamiliar robot. Finally, the potential link between prosociality and selective trust was also explored.

Selective trust

Using a conservative test of epistemic trust, this thesis studied if 3- and 5-year-old children would prefer to learn from an accurate robot over an inaccurate human. It was a conservative test in that it required children to overlook a salient characteristic of one the informants, an in-group member (human) to focus on the knowledge or competence displayed by the out-group, novel informant (robot). In Study 1, the robot Nao was pitted against a human informant using a word-learning task. In Study 2, the same procedure was followed; however, the robot used was a non-human-looking robot, Cozmo. In Study 3, Cozmo was again pitted against a human, but this time neither informant demonstrated the ability to speak, and competence about episodic information (location of an object) was manipulated through a communicative gesture (pointing) paradigm. Across all three studies, 3-year-olds equally learned from both the human and the robot, regardless of the robot's appearance (human-looking or non-human-looking) whereas the 5-year-olds always learned more from the accurate robot. In other words, the 3-year-old children equally endorsed the labels or location provided by the robot and the human, whereas the 5-year-old children endorsed the information from the robot significantly more than the human.

Overall, the results of all three studies fit into the general developmental pattern reported in the literature. When social and epistemic characteristics are in conflict, 3-year-old children generally weigh both types of characteristics equally when making their trust judgements. For example, 3-year-old children are unsure of whom to learn from when an in-group member is inaccurate, and an out-group member is accurate (Elashi & Mills, 2014). In another study, 3-year-olds preferred native speakers over foreign accent speaker. However, when a native speaker was inaccurate and a foreign accent speaker was accurate, the 3-year-olds learned equally from both speakers (Corriveau et al., 2013). In contrast, by 5 years of age, children prioritize epistemic characteristics like competency or expertise over social characteristics like benevolence (Tong et al., 2019). In the work by Corriveau and colleagues (2013), for instance, the 5-year-olds preferentially learned from the accurate informant, regardless of accent. In our studies, the human was the socially familiar informant, whereas the robot was epistemically competent. We observed confusion in both 3-year-old samples, who learned equally from the robot and the human, but not the 5-year-old sample, who preferentially learned from the robot. Therefore, our findings converge with those of other studies, suggesting that children treat a robotic informant similarly to a human one. Trust in both types of informants, human and robot, seems to be driven by the informant's displayed sociability and competency (Tong et al., 2019; Stower et al., 2021).

In contrast to their endorsement and learning, children across all three studies preferred to ask the robot for help labelling or finding a toy over the human, no matter their age. Thus, children at any age understood that the robot was previously accurate. This knowledge was also demonstrated by their competency when answering the judgement trials ("who was right/wrong?"), and therefore a better choice to ask for help. Considering 3-year-olds ambivalence on the endorse trials, it is somewhat surprising that they did not feel a stronger need to socially affiliate with the human informant and choose to ask them for help. Their preference to ask the robot may be explained by the fact that children were shown pre-recorded videos of the human and the robot and did not actually interact with either or meet them in real life. Perhaps children would have asked the human for more help had the procedure been demonstrated with live informants. Our findings for the ask questions do not fit into some the past literature, as other studies have found that 3-year-old children do not prefer either a social or an epistemic informant when the two characteristics are in conflict. In contrast, 5-year-old children prefer to ask the competent informant regardless of their displayed social characteristics

(Corriveau et al., 2013; Corriveau & Harris, 2009a). This difference may be due to children's bias towards the robot. The robot was novel for all children included and was, therefore, perhaps more 'exciting' to learn from than the human. Children may have selected the robot because they wished to further interact with it. Indeed, this has been shown in other studies as well. For example, when asked who they wish to learn from, 5- to 6-year-old children were significantly more likely to choose Amazon Echo over a human informant. However, children did not trust the information provided by Echo any more or less than the information provided by the human (Wojcik et al., 2022). This finding therefore mirrors our own finding in 3-year-olds, showing an ask bias towards the robot but no learning or endorsement preference towards either informant.

In both studies 1 and 3, both age groups were able to correctly identify that the robot was accurate (judgement question). In Study 2, only 5-year-olds were able to do so. Overall, most children were able to accurately identify the correct informant, both after the demonstration of accuracy in the familiarization/induction trials and after the test trials. This suggests that, while fragile, even the younger 3-year-old children have an understanding of epistemic characteristics. A majority of our participants assigned competency to the correct informant. This is reassuring, as it suggests that children of both age groups understood the task and encoded the displays of competency. Therefore, children's trust decisions during the endorsement trials were not due to a lack of knowledge or comprehension. Children recognize the robot's accuracy but are still somewhat pulled towards the human, whether due to social considerations or simply the expectation of learning from a human over a robot. While the transition is complete at age 5, by age 3, children are still struggling between their desire to socially affiliate with the human that is more like them and their desire to learn from competent informants, even if they are robots.

Manipulating animacy: Morphology and speech

Neither manipulating morphology (Study 2) nor speech (Study 3) affected children's trust judgements of the robot and the human. Our findings remained very consistent across all 3 studies. Children of both ages learned words or locations equally well or equally poorly from a human-looking robot (Nao) and a non-human-looking robot (Cozmo). Results also did not differ whether the robot established its competency using verbal labels or non-verbal pointing. The contingent behavior of a robot seems to matter more to children than its morphological appearance or other such characteristics (Tung, 2016; van Straten et al., 2020).

Our results suggest that social characteristics other than morphology or speech production may be more important in guiding children's trust judgements. The only social characteristics being displayed by Cozmo in Study 3 were the ability to understand and respond to directions, goal-directedness and autonomous movement. Both goal-directedness and autonomous movement have been shown as being crucial markers that indicate animacy to children (Biro et al., 2007). Moving autonomously towards a goal has been associated with children attributing characteristics of life to informants by the age of 5 (Johnson et al., 1998; Opfer, 2002). Starting in infancy, children categorize many informants other than humans, such as shapes, boxes, or robots, as human-like, as long as said informants move animatedly (Baillargeon et al., 2016; Burnside et al., 2020). This salience may overarch any other characteristic. Perhaps children treat any type of informant that is moving purposefully as animate, and as a potential teacher, no matter what other characteristics are absent or missing. Furthermore, the fact that the robot responded to the hider's verbal instructions (i.e., pointing when being told it is time to point), also made the robot more social by demonstrating some form of language comprehension.

Perception of robots

To investigate children's perception of robots, we asked children what should go inside the body of a robot, something mechanical or something biological. If children understand the robot's mechanical nature but still choose to learn from the robot, then our test of epistemic trust is confirmed as conservative. Our studies, as well as previous work (Gottfried & Gelman, 2005), have confirmed that children rate animals and humans as biological. Therefore, if children rate robots as mechanical, they realize that robots are inherently different from themselves. Across all three studies, a developmental shift was found. The 5-year-old children correctly categorized both a human-looking and a non-human-looking robot as mechanical. In contrast, the 3-year-olds assigned mechanical and biological insides to the robot equally, suggesting they are confused about the robot's internal properties. Since all the children were unfamiliar with the robots presented to them, categorizing these objects becomes even more of a challenge.

Children's categorization of robots did not differ based on the robot's morphological appearance, human or non-human. We predicted that a non-human-looking robot might be easier for children to categorize and comprehend as unlike them, being mechanical. However, this was not observed, suggesting both humanoid and non-humanoid robots are confusing for young children to classify, especially if they act competently.

Furthermore, children's categorization of the robot did not differ after they had seen the robot behave competently. The younger children were confused about a robot's internal properties no matter their behavior, whereas, by age 5, children were always confident about what ontological category it belonged to. This demonstrates that the 5-year-old children were willing to learn from a robot, despite realizing its status as different from themselves, that is, realizing the robot is a mechanical artifact and not biological. This willingness demonstrates 5-year-old children's robust reliance on epistemic characteristics over social ones.

Interestingly, both age groups were competent at categorizing other items. In studies 1 and 2, both 3- and 5-year-olds correctly categorized animals as biological. In Study 1, both age groups also correctly identified mechanical artifacts as mechanical. In Study 2, only the 5-year-olds correctly identified the mechanical artifacts. Lastly, in Study 3, the younger children, aged 3, correctly identified a human as biological. Therefore, we can conclude that children are competent at categorizing biological entities like themselves from an early age and possess an understanding of naïve biology. Similarly, mechanical artifacts are also relatively easy for children to classify, even if unfamiliar robots, being both animate and mechanical, are more challenging for children to categorize. Of note is that this finding contradicts the original study done by Gottfried & Gelman in 2005, which found competence in this task starting from age 4. However, it replicates more recent work done with the naïve biology task (Goldman et al., 2023a).

Robots as depictions of social agents

A recent paper by Clark & Fischer (2022) posited that adults treat robots as depictions of social agents. In other words, adults realize that robots are not human, and not alive, yet still willingly and even eagerly interact and engage with robots in a variety of ways (Clark & Fischer, 2022). But how do children view robots? The results of the current studies show that by the age of 5, children, like adults, are willing to learn from robots even if they recognize robots as mechanical in nature. While 5-year-old children and adults recognize robots as mechanical, humans of all ages still often attribute mental states, like thinking, seeing, or feeling, to robots (Thellman et al., 2022). If children comprehend that robots are different from themselves but are still willing to learn from them, and anthropomorphize them with mental states, this suggests that children view robots as depictions of social agents (Goldman et al., 2023b). Others have argued that children do not view robots as depictions of social agent, but rather as ‘real’ social agents. Since children learn from robots and interact with them in similar ways to humans, Haber & Corriveau (2023) argue that children treat social robots as more than interactive toys, specifically as social learning partners and valuable teachers. Similarly, Girouard-Hallam & Danovitch (2023) theorize that children view social robots as a social agent belonging to a unique ontological category, somewhere in between a machine and a human in their level of animacy. This view fits in with our Naïve Biology findings, which showed that children at both 3 and 5 years of age classify the robot as having biological insides somewhere between the rates of a mechanical artifact and an animal. Others argue that even adults view robots as true social agents during a live interaction. While adults may distinguish between real and not real when asked about robots theoretically, Eng and colleagues (2023) argue that robots become very real to humans when in the midst of a social exchange. I would argue that younger children, below the age of 5, likely view robots as “real” or at least as highly complex and confusing, as shown by their confusion about whom to learn from and what should go inside of the robot. Older children, from 5 years of age onwards, understand that robots are artifacts and different from themselves. However, they still view robots as valuable informants, confederates, and teachers. Whether children view robots as depictions or as ‘real’ agents when in the middle of a robot-child interaction is an interesting theoretical debate, yet either viewpoint leads to the same end goal, a child’s learning from a non-human, social robot.

Exploratory measures: Theory of Mind and prosociality

Contradicting previous work (Brosseau-Liard et al., 2015; Crivello et al., 2021; DiYanni et al., 2012, Palmquist et al., 2022), the studies included in this thesis found either only a very weak link or no link at all between Theory of Mind (measured through a parental report survey, CSUS) and selective trust. Theory of Mind did not reliably predict selective trust toward the robot in any of our samples. The past work (Brosseau-Liard et al., 2015; Crivello et al., 2021; DiYanni et al., 2012, Palmquist et al., 2022) investigating this link has mostly been done using human informants, so it is possible that using a robotic informant, which is more ambiguous, complicated the picture. The robots in these studies exhibited both characteristics of animacy (such as goal-directedness and autonomous movement, speech in studies 1 and 2) and characteristics of artifacts (not alive, made of plastic or metal and programmed to act as they do). Perhaps robots, given their ambiguous animacy status, are harder for children to attribute mental states to in comparison to humans. A longer interaction with the robot in a more naturalistic setting may be needed to properly investigate the predictive power of Theory of Mind to children's selective trust in robots. Future work is needed to investigate how children attribute mental states to robots. Future studies should also investigate the potential correlation between selective trust and Theory of Mind using an in-laboratory measure of Theory of Mind, instead of a parental report survey. For example, ongoing work in our laboratory investigates children's attribution of mental states to robots versus humans using the interactive Wellman and Liu Scale (Wellman & Liu, 2004) and interviews such as the Attribution of Mental States Questionnaire (Miraglia et al., 2023).

A more prosocial child may be more socially biased towards other humans than robots, which are more difficult to affiliate with. Alternatively, a more prosocial child may act more prosocially towards any agent that displays characteristics of animacy, even robots. The potential relationship between prosociality and selective trust was investigated in the first two studies using a parental report questionnaire of prosociality. No correlation was found between prosociality, as measured by the CPBQ, and selective trust.

Instead of investigating only prosociality, future work should test a broader measure of social affiliation and in-group bias. Prosociality and social affiliation are related but distinctly different concepts. Prosociality must actively benefit others (Pfattheicher et al., 2022), whereas social affiliation is any formed social relationship (Feldman, 2014). Children who are more biased towards others like themselves (in terms of language spoken, race, gender, or other characteristics) may be less willing to learn from a robot. Future studies could investigate how children's friendship judgements (i.e., preference for same-race, same-language, or same-gender friends) effects their willingness to learn from robots. This could be done using an adapted version of Kinzler and colleagues (2007) child friendship choice procedure. Will a child who prefers a friend of their own race or their own sex learn less from the robot since the robot is a member of an out-group? Will a child be more inclined to learn from the human informant if the informant's gender or race matches their own?

Limitations and future directions

The three studies contained within my thesis are not without limitations. Due to the Covid-19 pandemic, the first two studies were conducted online over the Zoom video conferencing platform. While some studies have found that children learn equally well online compared to in-lab (Bambha & Casasola, 2021; O'Doherty et al., 2011), there was a greater chance of distractions, such as sibling interference, occurring in the home environment. We could not control the testing environment as we can in lab. To eliminate this potential issue as much as possible, all videos were checked for attentiveness and potential environmental interferences. With the drawbacks to online testing also come advantages. Online testing allowed us to reach a more diverse sample, collect data faster, and allowed children to be more comfortable in the familiar surroundings of their own homes during testing. Some studies work equally well online and in-person, others do not. We believe our tasks worked well in both modalities. We found similar results between studies 1 and 2 (online) and Study 3 (in-person), suggesting that both the selective trust tasks and the naïve biology task worked equally well across all 3 studies and across different experimental designs.

Another limitation is that fact pre-recorded videos of the informants were used for all three studies. This was done for practical reasons, as live informant presentations would require at least three experimenters at each testing session. Pre-recorded videos were also used due to COVID-19 constraints and to limit experimenter error and increase internal consistency. Important to note is that many other studies have used pre-recorded video stimuli as well when administering a selective trust task to children, including the original Koenig, Clément & Harris (2004) study (Brink & Wellman, 2020; Koenig & Harris, 2005a; Liu et al., 2013; Palmquist & Jaswal, 2015). Since both the human and the robot were presented through videos instead of live, children may have felt disconnected from them both, viewing them as depictions and not as real potential teachers or social agents. Future work should strive to replicate these studies using a live informant paradigm. When investigated in adults, participants have been shown to cooperate with robots both virtually and live, but fulfilled more unusual requests for the robot if it was presented in-person (Bainbridge et al., 2010).

When conducted with live agents in-person instead of over zoom, children would be able to see the informants more clearly and interact with them more personally. A live informant paradigm would also more closely match how children interact with robots in their everyday lives, at school, for example. Especially the 3-year-old children may learn more from the human when the human is presented as a live informant rather than a video. The need to socially affiliate with the human informant would likely increase if the human informant was actually in the room with the child, watching them make their choices. Children, even at age 3, may understand that there is only a limited, if any, benefit to affiliating socially with a character shown on a video screen. A live agent, however, can be a beneficial social ally in a variety of circumstances.

While widely used, the classic trust paradigm employed by Koenig, Clément & Harris (2004) has also been criticized as being not ecologically valid. It has a training phase that requires one informant to blatantly label familiar things inaccurately while otherwise behaving in a socially contingent manner (speaking in turn, gesturing, following eye gaze). These informants also inherently violate the social convention of truth-telling (Koenig & Sabbagh, 2013). A child might wonder if this informant is truly incompetent or simply deceptive or silly. We believe that the children do understand and believe in the informant's incompetence and inaccuracy, as demonstrated by their proficiency in answering the judgement questions. Furthermore, all the children tested in the studies were attentive to the task and did not express any humorous comments towards the human's inaccuracy. Nonetheless, future work should aim to investigate how children learn from robots versus humans when accuracy is demonstrated differently.

Accuracy could be demonstrated through facts the child knows to be true or false, such as, "Plants are alive." This would, however, likely require an older age group and perhaps a training phase where the facts are learned by the child. This may be a more ecologically valid design as it is arguably more naturalistic than the word learning paradigm. While humans are often wrong about certain facts, not many humans label familiar objects, such as cups, inaccurately in real life. Competency could also be demonstrated more naturalistically, with children interacting with two separate informants several times, during which time one informant successfully completes a number of tasks while the other agent fails to succeed (i.e., opening a box or completing a puzzle). This type of demonstration would be complicated, however, when using a robot, due to the robot's limited range of movement. Finally, expertise could be used as a different way to establish epistemic reliability. For example, the robot could be established as an expert in history to the child, whereas the human is introduced as knowing nothing about history. Then, the child could listen to history facts told to them by both the robot and the human and be asked which is the correct fact.

Another way to increase the robustness of the selective trust design would be to run a longitudinal study, in which the (in)accuracy of the agents is demonstrated to the children in a variety of ways over multiple weeks. Children would be familiarized with both agents so neither would be novel, and would be very aware of both agents' strengths, behaviours, and levels of competence. Then, the test trials could be run in a different session from the familiarization trials to confirm the robustness of learning from one agent over another and rule out the possibility of a simple memory effect. This design would also control for a potential novelty bias seen in children's responses, especially in the ask trials.

This research opens the avenue for a number of potential future studies. The generalizability and applicability of the results that can be drawn from the current set of studies is limited due to the fact that the interaction between animacy and competence could not be fully investigated as the design was limited to a single condition (competent robot vs incompetent human). To best compare and contrast results, future work should investigate if children would prefer to learn from the robot or the human when both informants are competent or incompetent. This study would also help identify any inherent bias or preference towards either the robot or the human. Future work should also investigate who children would choose to learn from if the robot is inaccurate and the human is accurate to help set a baseline of learning from both agents and help rule out novelty confounds. Furthermore, future studies should present not only forced-choice paradigms (i.e., choose either the human or the robot) but ask follow-up questions. This would provide more context and justification for children's responses and increase generalizability even further.

Finally, an interesting avenue to explore would be cross-cultural studies using a robot in a selective trust paradigm. In some countries, individuals have higher levels of robot exposure, such as in Japan (Haring et al., 2014). Some studies have investigated the effects of culture on children's interactions with robots. For example, Shahid et al (2014) found that collectivistic Pakistani children were more expressive in their interactions with a social robot over individualistic Dutch children. Chen and colleagues (2023) found that repeated exposure to a robot strengthened children's rapport with said robot. Will a child who is more familiar with social robots integrated into society be more willing to learn from a robot at a younger age? If children are familiar with robots, a robot may become a part of their in-group, therefore increasing its social affiliative status with the child.

Conclusions

The studies reported in this thesis directly pitted an accurate robot against an inaccurate human using two different selective learning paradigms. We found that there was a preference towards learning from the more accurate robotic informant among the 5-year-olds but not the 3-year-olds, who learned equally from the robot and the human. We investigated which characteristics are most important to children when they decide whom to trust and found that goal-directedness and autonomous movement matter more to children when selecting informants from whom to learn, over morphology and speech. Finally, we found that 5-year-old children can learn from a robot, even while recognizing the robot as inherently different from themselves. In real life, the types of interactions humans will have with robots will be much more cooperative than competitive, as they were presented in these studies. The current findings do not allow us to conclude that human teachers should be replaced with robotic ones, rather it hopes to further suggest robots as a tool through which human instructors can teach children more effectively. Robots could make for particularly engaging, instructive, and stimulating assistants to teachers because of their novel nature, distinctive appearance, and behaviours (Mubin et al., 2013). Robots also allow us to test selective trust in unique and novel ways, manipulating the level of animacy in ways not possible for human informants. Overall, I believe that the findings reported in this thesis make a significant contribution to the selective trust literature and contribute novel findings, being the first to directly pit a robot against a human using a selective learning paradigm and being one of the first to test children's naïve biology of robots.

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Appendix A: Recruitment Materials

English Recruitment Letter – Study 1 and 2

French Recruitment Letter – Study 1 and 2

English Recruitment Letter -Study 3

French Recruitment Letter – Study 3

Dear parent(s),

The Cognitive and Language Development Laboratory, which is part of the Centre for Research and Human Development at Concordia University, is presently conducting an **online** study over **zoom** to **examine how children interact with social robots.** This project is part of Anna-Elisabeth Baumann's PhD dissertation. Our research has been funded by federal and provincial agencies for the past twenty-five years and our team is internationally recognized for its excellent work on early child development. Our articles are frequently published in prestigious journals, such as "Infancy" and "Developmental Science." You also might have heard about our studies on national radio or on the *Discovery Channel*. If you participated in a study in the past, we would like to thank you for your enthusiasm and commitment to research.

For the present study, we will conduct a **Zoom Video Communications session**, in which your child will have the opportunity to play some games (for example, watch some videos and label some objects) with an experimenter and a robot and answer questions based on what they have seen. You will also need to complete some online questionnaires, including a demographic questionnaire. To join the zoom session, you will require access to a computer or iPad.

The Zoom session will be recorded, and all the information obtained in this study, including the video footage, will be treated in the strictest of confidentiality. Overall, your participation will involve **one 20- to 30-minute Zoom session with the researcher.** Appointments can be scheduled at a time which is convenient for you, including weekends. Upon completion of the study, a **Certificate of Merit** for Contribution to Science will be mailed to your child, as well as a **$20 gift card** for participating. A summary of the results of our study will also be mailed to you once it is completed.

For the purposes of this study, we are looking for children who are between **3 and 5 years of age**, who hear English or French at home or at preschool, and who do not have any visual or hearing difficulties. We are also looking for children who are not exposed to robots with a human-like appearance on a regular basis. **If you are interested in having your child participate in this study, please visit https://cldlab.simplybook.me/v2/#book/count/1/ and select *Online Study on Robot Sociability* to participate. If you have any questions or would like any further information, please contact us at 514-848-2424 ext. 2279 or by email at cldlab@**concordia**.ca.** For more information on our studies, visit our website: www.concordia.ca/artsci/psychology/research/cognitive-language-development-lab.html.

We are looking forward to hearing from you.

Sincerely yours,

Diane Poulin-Dubois

Diane Poulin-Dubois, Ph.D.
Professor of Psychology

Anna Baumann

Anna-Elisabeth Baumann
PhD Student

Université Concordia University

Cher(s) parent(s)

Le Laboratoire de Recherche sur le Développement de la Cognition et du Langage, qui fait partie du Centre de Recherche en Développement Humain de l'Université Concordia, mène actuellement une étude **en ligne** qui a pour but **d'examiner comment les enfants interagissent avec les robots sociaux.** Ce projet fait partie de la thèse de doctorat de Anna-Elisabeth Baumann. Nos recherches sont subventionnées depuis près de 25 ans par des organismes fédéraux et provinciaux, et notre équipe de recherche est internationalement reconnue pour son excellent travail sur le développement des jeunes enfants. Nos articles sont souvent publiés dans des revues prestigieuses telles que *Infancy* et *Developmental Science*. Vous avez peut-être aussi entendu parler de nos études à la radio ou sur la chaîne de télévision *Discovery Channel*. Si vous avez participé à l'une de nos études dans le passé, nous vous sommes très reconnaissants de votre enthousiasme et de votre engagement envers la recherche.

Pour la présente étude, nous vous rencontrerons sur la **plateforme de vidéoconférence Zoom**. Pendant cette rencontre, votre enfant aura l'occasion de jouer quelques jeux (par exemple, regarder des vidéos et étiqueter des objets) avec une expérimentatrice et un robot et de répondre à des questions sur ceux-ci. Vous devrez également compléter quelques questionnaires en ligne, incluant un questionnaire démographique. Pour rejoindre la session zoom, vous aurez besoin d'un accès à un ordinateur ou un iPad.

Les réactions de votre enfant pendant la séance Zoom seront enregistrées et les informations obtenues lors de la session Zoom et des questionnaires en ligne seront traitées de façon strictement confidentielle. La participation à l'étude comprend **une session d'environ 20 à 30 minutes sur la plateforme de vidéoconférence Zoom**. Vous pourrez prendre rendez-vous à un moment qui vous convient, incluant la fin de semaine. À la suite de sa participation, votre enfant recevra par la poste un **Certificat de Mérite** ainsi qu'un **certificat-cadeau de 20$** pour sa contribution à la science de l'Université Concordia. Un compte-rendu des résultats vous sera aussi posté dès que l'étude sera terminée.

Pour cette étude, nous recherchons des enfants qui sont âgés entre **3 et 5 ans**, qui entendent le français ou l'anglais à la maison ou à la garderie, et qui n'ont aucun problème auditif ou visuel. Nous recherchons également des enfants qui n'ont jamais été exposés à des robots d'apparence humaine auparavant. Si vous souhaitez que votre enfant participe à cette étude, veuillez visiter notre site de réservation cldlab.simplybook.me/v2/ et sélectionner *Étude en ligne sur la socialité des robots.* Si vous avez des questions, vous pouvez nous contacter par courriel à cldlab@concordia.ca ou par téléphone au 514-848-2424 poste 2279. Pour plus d'informations sur nos études, visitez notre site web :www.concordia.ca/artsci/psychology/research/laboratoire-de-recherche-developpement-de-la-cognition-et-langage.html.

Recevez l'expression de nos sentiments distingués,

Diane Poulin-Dubois

Diane Poulin-Dubois, Ph.D.
Professeure Titulaire

Anna Baumann

Anna-Elisabeth Baumann
Doctorante

Dear parent(s),

The Cognitive and Language Development Laboratory, which is part of the Centre for Research and Human Development at Concordia University, is presently conducting an **in-person** study at the **Concordia Loyola Campus in Montreal** to **examine how children interact with social robots.** This project is part of Anna-Elisabeth Baumann's Ph.D. dissertation. You are receiving this email because you responded to one of our social media ads or were already in our internal database of participants. Our research has been funded by federal and provincial agencies for the past twenty-five years and our team is internationally recognized for its excellent work on early child development. Our articles are frequently published in prestigious journals, such as "Infancy" and "Developmental Science." You also might have heard about our studies on national radio or on the *Discovery Channel*. If you participated in a study in the past, we would like to thank you for your enthusiasm and commitment to research.

In this study, your child will have the opportunity to play some games (for example, watch some videos and label some objects) with an experimenter and a robot and answer questions based on what they have seen. The present study will take place at the Concordia Loyola Campus on Sherbrooke Ouest. Parking will be provided. You will also need to complete some online questionnaires, including a demographic questionnaire.

The session will be recorded, and all the information obtained in this study, including the video footage, will be treated in the strictest of confidentiality. Overall, your participation will involve **one 30-minute session with the researcher.** Appointments can be scheduled at a time which is convenient for you, including weekends. Upon completion of the study, a **Certificate of Merit** for your Contribution to Science will be mailed to your child, as well as a **$25 gift card** for participating. A summary of the results of our study will also be mailed to you once it is completed.

For the purposes of this study, we are looking for children who are **3 years of age**, **who speak English or French at home or at preschool, and who are typically developing (i.e. no visual, speech, hearing, or cognitive difficulties)**. **If you are interested in having your child participate in this study, please visit https://cldlab.simplybook.me/v2/#book/count/1/ and select *Study on Robot Sociability* to participate. If you have any questions or would like any further information, please contact us at 514-848-2424 ext. 2279 or by email at dpdlab@gmail.com.** Testing is ongoing. For more information on our studies, visit our website: https://www.concordia.ca/artsci/psychology/research/cognitive-language-development-lab.html.

We are looking forward to hearing from you.

Sincerely yours,

Diane Poulin-Dubois, Ph.D., Professor of Psychology

Anna-Elisabeth Baumann, Ph.D. Candidate

Cher(s) parent(s)

Le Laboratoire de Recherche sur le Développement de la Cognition et du Langage, qui fait partie du Centre de Recherche en Développement Humain de l'Université Concordia, mène actuellement une étude **en présentiel au campus Concordia Loyola à Montréal** qui a pour but **d'examiner comment les enfants interagissent avec les robots sociaux.** Ce projet fait partie de la thèse de doctorat de Anna-Elisabeth Baumann. Vous recevez ce courriel parce que vous avez répondu à l'une de nos annonces dans les médias sociaux ou que vous étiez déjà dans notre base de données interne de participants. Nos recherches sont subventionnées depuis près de 25 ans par des organismes fédéraux et provinciaux, et notre équipe de recherche est internationalement reconnue pour son excellent travail sur le développement des jeunes enfants. Nos articles sont souvent publiés dans des revues prestigieuses telles que *Infancy* et *Developmental Science*. Vous avez peut-être aussi entendu parler de nos études à la radio ou sur la chaîne de télévision *Discovery Channel*. Si vous avez participé à l'une de nos études dans le passé, nous vous sommes très reconnaissants de votre enthousiasme et de votre engagement envers la recherche.

Pour la présente étude, votre enfant aura l'occasion de jouer quelques jeux (par exemple, regarder des vidéos et étiqueter des objets) avec une expérimentatrice et un robot et de répondre à des questions sur ceux-ci. Pour la présente étude, nous vous rencontrerons au **campus Loyola de Concordia sur la rue Sherbrooke Ouest**. Une place de parking sera prévu gratuitement. Pendant cette rencontre, vous devrez également compléter quelques questionnaires en ligne, incluant un questionnaire démographique.

Les réactions de votre enfant seront enregistrées et les informations obtenues lors de la session et des questionnaires en ligne seront traitées de façon strictement confidentielle. La participation à l'étude comprend **une session d'environ 30 minutes**. Vous pourrez prendre rendez-vous à un moment qui vous convient, incluant la fin de semaine. À la suite de sa participation, votre enfant recevra par la poste un **Certificat de Mérite** ainsi qu'un **certificat-cadeau de 25$** pour sa contribution à la science de l'Université Concordia. Un compte-rendu des résultats vous sera aussi posté dès que l'étude sera terminée.

Pour cette étude, nous recherchons des enfants sans **difficultés développementales de 3 ans (ex. pas de difficultés visuelles, auditives, vocales, ou cognitives), et qui entendent le français ou l'anglais à la maison ou à la garderie. Si vous souhaitez que votre enfant participe à cette étude, veuillez visiter notre site de réservation https://cldlab.simplybook.me/v2/#book/count/1/ et sélectionner *Étude en ligne sur la socialité des robots.* Si vous avez des questions, vous pouvez nous contacter par courriel à dpdlab@gmail.com ou par téléphone au 514-848-2424 poste 2279**. Les tests sont en cours. Pour plus d'informations sur nos études, visitez notre site web : https://www.concordia.ca/artsci/psychology/research/laboratoire-de-recherche-developpement-de-la-cognition-et-langage.html.

Recevez l'expression de nos sentiments distingués,

Diane Poulin-Dubois, Ph.D., Professeure Titulaire

Anna-Elisabeth Baumann, Doctorante

Appendix B: Consent Forms

Link to Sample English Consent Form – Study 1 and 2:

https://osf.io/cpd5y

Link to Sample French Consent Form – Study 1 and 2:

https://osf.io/xdwrv

Appendix C: Demographic Forms

Link to Sample English Demographic Form – Study 3:

https://osf.io/sbmuc

Link to Sample French Demographic Form – Study 3:

https://osf.io/n6tpa

Appendix D: Children's Prosocial Behaviour Questionnaire (CPBQ)

Link to English CPBQ:

https://osf.io/df8wm

Link to French CPBQ:

https://osf.io/w3hz2

Appendix E: Children's Social Understanding Scale (CSUS)

Link to English CSUS:

https://osf.io/ukjp4

Link to French CSUS:

https://osf.io/wx4dz

Appendix F: Internal Consistency of the CSUS and CPBQ

Parental Report Measure	Internal Consistency (Cronbach's alpha)	
	Validation Studies	**Study 1**
Children's Social Understanding Scale (CSUS)	α*s* = .94 (Tahiroglu et al., 2014)	α = .81
Children's Prosocial Behavioural Questionnaire (CPBQ)	α = .73 (Brazzelli et al., 2018)	α = .85