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DOES BEHAVIORAL SYNCHRONY EXTEND TO ROBOTS? CHILDREN'S SHARING, MENTALIZING, AND SOCIAL ATTRIBUTIONS TO SYNCHRONOUS OTHERS

By

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B.S. Psychology, Tennessee Technological University, Cookeville, TN, 2019

Thesis

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DOES BEHAVIORAL SYNCHRONY EXTEND TO ROBOTS?

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Does Behavioral Synchrony Extend to Robots? Children's Sharing, Mentalizing, and Social Attributions to Synchronous Others

Chairperson: Rachel L. Severson

Behavioral synchrony, or the act of keeping rhythm with others, has many implications on children's interactions with others, from prosocial behaviors to feelings of affiliation with synchronous people. However, little is known about how behavioral synchrony applies to non-human entities. From robots leading movement-based learning in classrooms or being engaged in cultural settings, a new series of questions arise for how children view synchronizing with non-human others. The current study aimed to investigate how broadly synchronization effects would extend in a child sample: Are behavioral synchrony effects limited to synchronizing with humans or do they extend to social agents (e.g., social robots) or any device that moves (e.g., metronome)? To address this question, this study employed a 3 x 2 design with agent (human, social robot, metronome) as a between-subjects factor and synchronization (synchronous, asynchronous) as a within-subjects factor. Participants (*N*=104; 5-8 years) were randomly assigned to an agent condition. In two test phases, participants played a clapping game in which they clapped with a 'partner' (agent) to the same (synchronous) or a different (asynchronous) beat (counter-balanced order). After each test phase, participants responded to questions (random order) assessing the child's ascription of mental states and sociality to the partner. Following both test phases, participants completed a sticker sharing task where they allocated an odd number of stickers between the synchronous and asynchronous partners. Results indicated that synchrony influenced children's sharing preferences, such that they gave more stickers to the synchronous human partner but asynchronous non-human partners. Regardless of synchrony, children attributed significantly more mental states to humans compared to the robot and metronome and significantly more sociality to the robot. Developmental differences emerged for sharing preferences, such that 7-year-olds preferred to share synchronously, whereas 5- and 6-year-olds preferred to share asynchronously. Additionally, 7-year-olds attributed less sociality overall. 6-year-olds attributed sociality more generously, and 5-year-olds were approaching significance for more generous attributions of sociality nearly on par with the 6-year-olds. Overall, behavioral synchrony impacted how children allocated stickers. That is, synchrony effects applied to all entities, but in different directions: Children preferred synchronous humans and asynchronous non-human entities.

Does Behavioral Synchrony Extend to Robots? Children's Sharing, Mentalizing, and Social Attributions to Synchronous Others

When choosing a dance partner, one may not immediately think to grab the nearest piece of technology as a companion. Yet, Huang Yi (2017) performed a lyrical dance with the robot, KUKA, programmed to perfectly move in time as a partner in the duet. Although robots may not be so prevalent that one would be a common choice to dance with, technology has an ever-increasing presence in social and educational spaces. In fact, children have demonstrated they will engage in dancing and rhythmic actions with robots (Michalowski et al., 2007), even in common everyday educational spaces (Tanaka et al., 2006). Social robots employed in classrooms which utilize movement to augment learning are thought to foster inclusivity for children with Autism or language barriers (Damiani & Ascione, 2017). As this demonstrates, the presence of social robots is increasing in society, and the use of these technologies to facilitate movement is encouraged to be utilized in cultivating opportunities for all children. The counterpart to this notion is the need to understand how children are perceiving such technologies. The current study aims to understand how synchrony may influence children's sharing, mentalizing, and social attributions, and how these tendencies may (or may not) differ when children move synchronously with a person, robot, or mechanical metronome.

From simple synchronized movements like waving to elaborate social dances, behavioral synchrony, or the act of keeping in time or rhythm with others, is linked to a broad range of positive social and personal outcomes. When participating synchronously rather than asynchronously with others, adults have shown higher scores of likability (Hove & Risen, 2009), improved facial recall (Macrae et al., 2008), increased rapport (Lakens & Stel, 2011), improved cooperation (Valdesolo et al., 2010; Wiltermuth & Heath, 2009), and increased self-esteem

(Lumsden et al., 2014). These benefits are not limited to adults but are evident across development. In children, partaking in synchronous actions with others promotes helping behavior (Kirschner & Tomasello, 2010; Tunçgenç & Cohen, 2018) and increases perceived similarity and closeness (Rabinowitch & Knafo-Noam, 2015). Thus, the synchronous movement appears to manifest a range of positive cognitive and social benefits.

What then would it signify if children are demonstrating the same patterns of sharing, mentalizing, and social attributions to synchronous robot partners analogous to synchronous human partners? One explanation draws on the connection between synchrony and theory of mind understanding (Baimel et al., 2015), as evidenced by joint attention – a foundation of theory of mind understanding (Sodian & Kristen-Antonow, 2015) and arguably the earliest synchronous action in infancy. Previous work has demonstrated that children think of robots in a distinctive way. The new ontological category hypothesis suggests that children may view social robots as a unique category of entities separate from "alive" or "not alive" (Kahn et al., 2004; Severson & Carlson, 2010). In addition, children do attribute mental states to robots (for a review, see Thellman et al., 2022). If there is an effect of synchrony on children's mentalizing and social attributions to robots, it would suggest synchrony is facilitating thinking about robots as social others, regardless of being pieces of technology.

Despite the prevalence of robots and use of synchronous action in society, little is known about how broadly children will apply the effects of behavioral synchrony. There is some evidence to suggest that children demonstrate less precision when synchronizing with a machine than a human partner (Kirschner & Tomasello, 2009), but precision does not identify the ways in which children will perceive synchronous non-human others. If synchrony influences children to perceive all synchronous agents the same way, we would expect this to be a low-level process including non-social others, such as a mechanical device. If children only demontrate a preference for synchronous agents limited to human others, it would seem that synchrony is a high-level process restricted to human-others. Social robots may create an in-between category, similar to the new ontological category hypothesis, such that synchrony effects apply to social agents including humans as well as social robots, even if to a lesser degree. All in all, there are important practical and theoretical implications to understanding the range of entities – from humans to mechanical devices – that may elicit a synchrony effect amongst children.

Emergence of Synchrony in Childhood

A sensitivity to synchrony appears to emerge early in childhood. Infants as young as 12 months old prefer social toys (e.g., teddy bears) that the infant rocked with synchronously. This preference for synchronous partners also extends to prosocial behavior toward others. Cirelli et al. (2016) investigated how synchronous movement might extend to affiliates of the synchronous partner. That is, infants were bounced (synchronously or asynchronously) with a researcher and then observed the researcher they bounced with interact with a new person (the affiliate). The results indicated that 14-month-old infants exhibited prosocial helpfulness toward the affiliate, but only when the researcher had previously bounced synchronously with the infant. Importantly, although 12- to 14-month-olds demonstrate preferences and prosocial behaviors towards others with whom they have moved in synchrony, infants at these young ages are not well-equipped to participate of their own accord in synchronous movements with others. In fact, Kirschner and Tomasello (2009) found that children could not accurately engage in synchronous movements on their own until about 2.5 years.

Synchrony, Cooperation, and Empathy

The simple action of synchronizing with others increases one's affinity and recall of their partner (e.g., Hove & Risen, 2009; Macrae et al., 2008; Tunçgenç et al., 2015). But do simple acts, such as moving together in time, yield more complex and sophisticated social behaviors? Looking at how synchrony impacts cooperation and empathy can help clarify the connection between mentalizing and viewing synchronous partners as social beings. The link between synchrony and cooperation has been examined in both adults and children, whereas the association between synchrony and empathy has been studied primarily in adults.

A common way to measure cooperation is by using economic games, such as the ultimatum game or dictator game. Güth et al. (1982) introduced the ultimatum game wherein in a dyad, one person proposes a split between an offer, and if the other person rejects that offer neither will receive any of the offers. A closely related method, coined the dictator game (Kahneman et al., 1986), also involves a dyad but does not depend upon the agreement between two partners; rather, giving part of the stake obtained is optional, and not as high-risk. In a series of three experiments that observed synchrony and economic games, Wiltermuth and Heath (2009) identified that acting synchronously with others increased future cooperation and feelings of connection. This increased cooperation was larger and continued longer throughout the economic game with synchronous dyads compared to asynchronous dyads. Subsequent studies have confirmed the finding that participating synchronously results in greater cooperation in economic games, and have further shown that groups who share a goal while synchronizing choose to cooperate even with risks (Reddish et al., 2013).

Not only does synchrony increase incentive-driven cooperation, but studies have shown that adult dyads partaking in movement synchrony more readily cooperate in future interactions than dyads that moved asynchronously. That is, when adult dyads are asked to jointly navigate a ball through a maze, those who had previously worked synchronously took less time to complete the task than those who had worked asynchronously (Valdesolo et al., 2010). To further examine potential downstream effects of synchrony, Reddish et al. (2014) conducted a series of studies on differences in prosocial behaviors following synchronous or asynchronous movement. Results from the first study indicated that synchrony did not result in differences in adults' willingness to help an individual between the synchronous or asynchronous condition, but adults in the synchronous condition were more likely to help than those who did not participate in any movement condition. Subsequently, in a second study, those who participated synchronously were more likely to split the reward with the puzzle group, suggesting that prosocial goals are supported by synchronous behavior (Reddish et al., 2014). Moreover, across synchronous and asynchronous groups, the extended in-group were more likely to receive help than the outgroup, but participants from the synchronous groups were more likely to help the outgroup than the asynchronous group (Reddish et al., 2016).

The assumption that synchrony positively influences prosocial behaviors to out-group members also applies to children. Tunçgenç and Cohen (2016) examined how children (7-11 years) engaging in synchrony bonded with out-group members. Children were assigned randomly to a synchronous or asynchronous group, with the synchronous group participating in a task with the same movements and tempo as their partners, whereas the asynchronous group engaged in different movements and tempi from their partners. Group bonding was assessed by pre-and post-test measures of in-group and out-group bonding. The results showed that children who participated in the synchronous condition were much more likely to bond with the out-group than those in the asynchronous conditions. However, partaking in the asynchronous action did not appear to hinder or bolster outgroup bonding, suggesting that asynchronous action had no detectable influence (positive or negative) on out-group bonding (Tunçgenç & Cohen, 2016). Kirschner and Tomasello (2010) further examined the impacts of synchronization (jointly singing and dancing) on cooperation amongst 4-year-olds. Those who participated in the joint music-making were more likely to help their partners and cooperate in solving a task than those who were in the non-joint music tasks. The authors concluded that participating in joint synchrony in music and dance increases social commitment (Kirschner & Tomasello, 2010).

Research with adults has begun to explore the relation between synchrony and empathy (Baimel et al., 2018; Koehne et al., 2016). Specifically, empathy tends to be higher after synchronous behavior, when compared to asynchronous groups (Baimel et al., 2018). Similarly, in a leader-follower dyad, Koehne et al. (2016) found that neurotypical adults participating in synchronous behavior led to higher cognitive empathy and speculated that behavioral synchrony provides a means to reason about the intentions of others. Moreover, previous studies have examined how synchrony may influence empathy and anthropomorphism, or the tendency to attribute human-like mental states (i.e., mentalize) to non-human entities. Although empathy increases in synchronous conditions, anthropomorphism was found to decrease with synchronous conditions when compared to control or asynchronous conditions (Baimel et al., 2018). These results suggest that synchronous movement with others *increases* the tendency to mentalize the partner, and *decrease* the tendency to mentalize others, including non-human others. Although there is a growing body of work documenting this relation with adults, I am aware of no studies that have examined this relation in children. However, previous research has found that children will attribute mental states to a robot, although not to the same degree as a person (Kahn et al., 2012).

Resource Allocation and Synchrony with Robots

As noted above, children will differentiate and share based on puppet preference (Chernyak & Sobel, 2016), illustrating that children will share to non-human entities. Recently, Nijssen et al. (2021) expanded on these findings by examining how preschoolers and second graders would preferentially share with robots that were programmed to express emotion. They manipulated the anthropomorphic appearance and affective states of humanoid and mechanical robots. Each participant saw a video of a robot expressing the ability to have emotions and a video of a robot without this ability. They then participated in either a costly or non-costly version of the dictator game in which they were given stickers to either keep or share with the robot. In the costly version, if they chose to share, children would be giving up their stickers. In the non-costly version of sharing, they were given an even number or an odd number of stickers to allocate to each robot without losing the stickers they had already received. In the costly trial, children were more likely to share their resource of stickers with the robot that displayed affect than the robot that did not display affect. However, in line with previous work on resource allocation (Chernyak & Sobel, 2016), in the non-costly trials, when children had an even number of stickers they split the resources evenly between the robots. When forced to split an odd number of stickers, the robot expressing affect received more stickers than the robot that did not express emotions (Nijssen et al., 2021). Therefore, children distribute more resources to a robot that expressed emotions than a robot that did not. Although these studies show children’s propensity to share with socially engaged non-human entities, the influence of synchronizing on sharing behavior with non-human entities has not been studied in children.

Notably, children’s accuracy in synchronizing is more sensitive to human partners compared to machine partners. Kirschner and Tomasello (2009) compared the influence of social and non-social conditions by having children synchronize by tapping a drum with a human, a machine mimicking a human hand, and just an auditory metronome beat. Children would synchronize with higher precision in the social condition (human partner) than the two non-social conditions (mechanical hand and metronome), and the researchers found no difference in the precision of synchronizing with a machine or metronome beat (Kirschner & Tomasello, 2009). What remains unknown is how children would respond to more social technologies, such as a social robot. Although they were not as likely to synchronize with a machine mimicking a hand, personified technologies, such as social robots, may yield a different outcome.

Recently, Heijnen et al. (2019) examined how synchrony with a robot influenced adult participants' anthropomorphism scores. Differences in state and trait anthropomorphism were measured across two sessions, one session participating in synchronous action with a robot and one session participating in asynchronous action with a robot. Participants also completed a dictator game with the robot as the opponent in each of the sessions. Participants were randomly assigned to one of two groups that differed in terms of who (or what) initiated the movement (participant or robot). If a participant initiated in the synchronous condition, the robot would match movements synchronously, but in the asynchronous condition, the robot and participant would not match movements. Ultimately, their study did not find any differences in anthropomorphism or the dictator game for any conditions (Heijnen et al., 2019). Although this study indicates adults do not anthropomorphize differently for synchronous or asynchronous robots, it is still possible that synchrony can influence the tendency to mentalize.

Current Study

The current study explored how partaking in synchronous and asynchronous movements with another may impact children's sharing, mentalizing, and social attributions to the partners, and if this differed depending on whether the child's partner was a human, robot, or metronome.

Children (5-8 years) interacted synchronously and asynchronously (counter-balanced) with either two human, robot, or metronome partners (randomly assigned). Participants completed three key measures: attribution of mental states social characteristics to both synchronous and asynchronous partners and a sticker distribution task between the two partners. In other words, participants only saw one type of agent (human, robot, or metronome, but all participants played the clapping game twice once with a synchronous partner and once with an asynchronous partner. The current study aimed to address the gaps in the literature regarding (1) children's behavioral synchronization with human and non-human others, (2) children's mentalizing, social attributions, and sharing decisions based on synchronous or asynchronous movement with their partners, and (3) potential differential synchronization effects in terms of children's mentalizing, social attributions, and sharing based on the type of entity (human, social robot, mechanical metronome).

Hypotheses

H1: Preferential sharing will be greater for synchrony, such that synchronous partners will receive more stickers.

H1A: If the synchrony effects on preferential sharing vary by entity, we expect to see differences between the human, robot, and metronome partners. Preferential sharing could differ by entity such that: (1) synchrony effects are limited to humans, such that preference to share with the synchronous human partner is greater than the asynchronous human partner, (2) synchrony effects apply more broadly to social agents, such that preference to share with the synchronous human and robot is greater than the asynchronous, but no differences for the metronome, (3) synchrony effects apply to any entity, including a mechanical device, such that preference to share with the synchronous human, robot, and metronome is greater than the asynchronous partners.

H2: Mentalizing others will vary based on synchrony, such that synchronous partners will be attributed a higher degree of mental states.

H2A: If the synchrony effects on mentalizing vary by entity, we expect to see differences between the human, robot, and metronome partners. Mentalizing could differ by entity such that: (1) synchrony effects are limited to humans, such that mentalizing the synchronous human partner is greater than the asynchronous human partner, (2) synchrony effects apply more broadly to social agents, such that mentalizing the synchronous human and robot is greater than the asynchronous, but no differences for the metronome, (3) synchrony effects apply to any entity, including a mechanical device, such that mentalizing with the synchronous human, robot, and metronome is greater than the asynchronous partners.

H3: Social attributions will vary based on synchrony, such that synchronous partners will receive a higher degree of social attributions.

H3A: If the synchrony effects on social attributions vary by entity, we expect to see differences between the human, robot, and metronome partners. Social attributions could differ by entity such that: (1) synchrony effects are limited to humans, such that social attributions for the synchronous human partner is greater than the asynchronous human partner, (2) synchrony effects apply more broadly to social agents, such that social attributions for the synchronous human and robot is greater than the asynchronous, but no differences for the metronome, (3) synchrony effects apply to any entity, including a mechanical device, such that social attributions with the synchronous human, robot, and metronome is greater than the asynchronous partners.

The study plan, main analyses[1], and hypotheses were preregistered through Open Science Framework (see link).

Method

Participants

Participants (*N*=104) included children ages 5-8-year-olds (*M*=7.09, *SD*=1.16; 53% female) with roughly equal number of children at each age (5-year-olds, *n*=23; 6-year-olds, *n*=25; 7-year-olds, *n*=27; 8-year-olds, *n*=29). Participants' parents (95.2%) self-reported their child's ethnicity as European (64.7%), multiple ethnicities (18.2%), Asian (4%), Latin, Central, or South American (3%), Middle Eastern (1%), Native American (1%), Caribbean (1%), and other ethnicities (7%) such as Egyptian, Greek, Inuit, and Jewish.

The age range was selected based on previous research indicating children 5-8 years are successful in synchronizing tasks (e.g., Kirschner & Tomasello, 2009; Rabinowitch & Knafo-Noam, 2015). The current sample is a partial data set (87%) of the intended sample size (*N*=120). An *a priori* power analysis (conducted in G*Power 3.1; Faul et al., 2009) indicated a total sample size of (*N*=114) would obtain sufficient power (80%) to detect effect sizes of Cohen's *f* = .2 or larger between synchrony and agent conditions (within-between interactions). A synchrony meta-analysis suggested synchrony effects are typically *r*=.2 (Mogen et al., 2017), which was converted into a Cohen's *f* for the present study's power analysis. Considering the counterbalancing for the design of the study, the intended sample size (*N*= 120) allows for an even number of participants in each version and age group, while also taking into account the power analyses' suggested sample size.

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[1] The sticker sharing analysis was preregistered as a multiple linear regression, but the analysis conducted and reported is a two-way ANOVA for the hypothesized differences and a linear regression for exploratory variables.

Participants were recruited through two primary recruitment strategies: Minds Lab's family registry and the University of Montana Living Lab. The Minds Lab family registry is operated out of the University of Montana Department of Psychology and includes families who have volunteered to be contacted when their child(ren) are eligible for a study in the Minds Lab. Families with eligible children (based on age) were invited to participate. In addition, families visiting the University of Montana Living Lab, located in the Missoula Public Library, were invited to participate if their child(ren) were between 5 to 8 years old. In both cases, parents were given information about the study to decide if they (and their children) were interested in participating.

Data collection occurred in the UM Living Lab. The UM Living Lab is a partnership between the University of Montana, Missoula Public Library, and the City of Missoula. It is funded through a Science Education Partnership Award through the National Institutes of Health to provide opportunities for the public to participate in research studies, learn about science activities, and host educational events. Study sessions were either scheduled in advance or occurred on a drop-in basis.

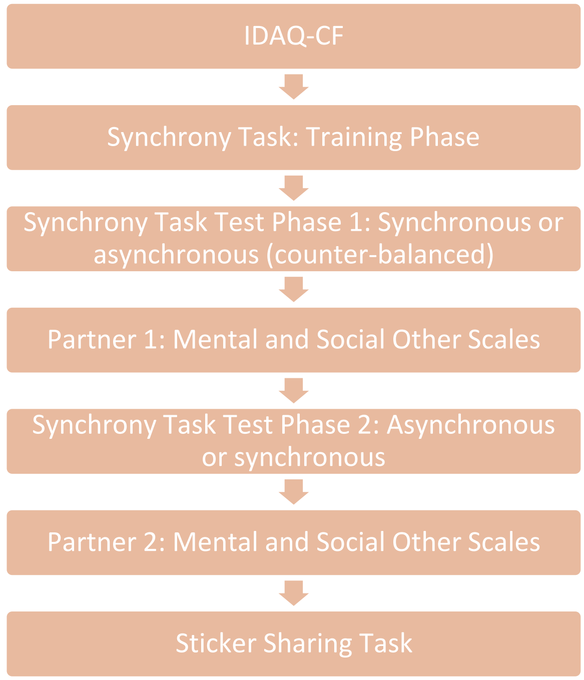
The study procedure was approved by the Institutional Review Board at the University of Montana. Parents of participating children provided written permission for their child's participation and child participants provided verbal assent to participate. Participants received a certificate, stickers (as described below), and a $5 Amazon gift card for their participation.

Procedures and Measures

Participants were assigned to either the human (n=40), robot (n=47), or metronome (n=17) condition. Each participant was individually administered the study procedure by a research assistant in a quiet alcove in the UM Living Lab. Each session lasted approximately 25 minutes and was video recorded (with parent permission). The study procedure was presented in a set order (see Figure 1).

Figure 1

Study Procedure



Anthropomorphism. Participants initially completed the Individual Differences in Anthropomorphism Questionnaire – Child Form (IDAQ-CF; Severson & Lemm, 2016). The IDAQ-CF consists of 12-items assessing children's tendency to anthropomorphize non-human entities (see Appendix A). The items on the IDAQ-CF consist of two subscales: technology-nature (e.g., "Does a robot know it's a robot"; "Does a tree think for itself?") and animals (e.g., "Does a turtle do things on purpose?"). For each question, participants were asked to respond with a "Yes" or "No," and if they said, "Yes" they were asked, "How much?" with answer options including "a little bit" (1), "a medium amount" (2), and "a lot" (3). Thus, IDAQ-CF was scored on a 4-point scale in which 0=Not at all and 3=A lot. The IDAQ-CF items were administered in random order. Average scores were computed for the overall scale and the two subscales.

Synchrony Task. Participants were first familiarized with clapping to an auditory metronome beat during a training phase. The researcher introduced the "clapping game" and invited the child to clap along with them to a 10-second audio recording of a metronome beat of 150 bpm (400 ms). Specifically, the researcher introduced the clapping game and training phase by saying, "We are going to play a clapping game! For this game, you have to clap along with a sound you hear. Let's practice clapping along to the sound together!" The participants practiced clapping to the beat a minimum of two times. If the child successfully clapped along to the beat (i.e., their claps matched the beat as assessed by the research assistant) after two training trials, the researcher moved on to the test phases. However, if the child was not successful in matching their claps to the beat, the researcher would move on to a third training trial in which they again clapped along to the beat with the child. Thus, the participating child was presented with a maximum of three training trials. All children successfully completed the training phase and continued with the study procedure.

Following the training phase, participants were shown a video presented on an iPad of a "partner" (either human, robot, or metronome, depending on the condition) clapping synchronously to the same beat the participating child heard (150 bpm) or asynchronously to a different beat from what the child heard (100 bpm). Partner (Human 1/Robot 1/Metronome 1; Human 2/Robot 2/Metronome 2) and synchrony (synchronous/asynchronous) order was counterbalanced across test phases 1 and 2 resulting in four versions for each of the human and robot conditions and two versions of the metronome condition (see Table 1). Each test phase lasted approximately one minute. In the first test phase, the researcher instructed the participant to clap to the beat they hear, noting their partner may be listening and clapping to the same beat or a different beat. Across four 10-second trials, the participant was instructed to clap along to the beat they heard while watching a video of the partner clapping (synchronous or asynchronous with the beat the participant hears). Specifically, the researcher said, “Great job! Now you will be playing the clapping game with a [person/robot/sound machine] on a video. Remember, for this game you have to clap along to the sound you hear. The [person/robot/sound machine] might hear the same thing you hear, or they might hear something different. But you should clap along with what YOU hear. Okay? Are you ready to play the game?” In the second test phase, the synchrony task procedure was repeated with the second partner and the opposite synchrony pattern. Thus, in the synchronous test phase, there was no difference between what the

Table 1

Counterbalancing

Condition	Version #	Partner 1	Partner 2
Robot	Version 1	Robot 1 (SYNC)	Robot 2 (ASYNC)
	Version 2	Robot 1 (ASYNC)	Robot 2 (SYNC)
	Version 3	Robot 2 (SYNC)	Robot 1 (ASYNC)
	Version 4	Robot 2 (ASYNC)	Robot 1 (SYNC)
Human	Version 5	Human 1 (SYNC)	Human 2 (ASYNC)
	Version 6	Human 1 (ASYNC)	Human 2 (SYNC)
	Version 7	Human 2 (SYNC)	Human 1 (ASYNC)
	Version 8	Human 2 (ASYNC)	Human 1 (SYNC)
Metronome	Version 9	Metronome 1 (SYNC)	Metronome 2 (ASYNC)
	Version 10	Metronome 2 (ASYNC)	Metronome 1 (SYNC)

participant heard (auditory metronome beat) and what the participant saw (partner's clapping). However, in the asynchronous test phase, there was interference such that what the participant heard (auditory metronome beat) did not match what they saw (partner's clapping).

To create the synchronous and asynchronous robot stimuli, Choregraphe software was utilized to program the Nao robots (SoftBank Robotics, 2019). Two virtual Nao robots, a red Nao H25 (V50) and a grey Nao H25 (V6) were programmed to clap, and recordings were made of the virtual robots clapping in the Choregraphe window. The recordings were then edited to have a black background and put into iMovie to edit the speed of clapping to match 100 bpm and 150 bpm. Each Nao recording was reduced in speed to 86% (150 bpm) and 57% (100 bpm) of the original clapping speed programmed. This precision was confirmed by overlaying a metronome beat to make sure the claps aligned with the beat. In total, four videos of the virtual robots were created: red Nao 150 bpm (synchronous), red Nao 100 bpm (asynchronous), grey Nao 150 bpm (synchronous), and grey Nao 100 bpm (asynchronous). Although the video stimuli of the Nao robots was edited, the stimuli did not look unnatural or incomparable to the other stimuli. Two human actors were filmed clapping the rhythm of 150 bpm (synchronous) and 100 bpm (asynchronous). The actors were able to listen to the metronome beat in real time while clapping. Each actor was compensated. Finally, a mechanical metronome was video recorded while set to 150 bpm (synchronous) and 100 bpm (asynchronous). In total ten stimuli videos were created of the six partners (see Figure 2).

Figure 2

Synchrony Partner Stimuli

Robot 1 Robot 2 Human 1 Human 2 Metronome 1 Metronome 2

A research assistant (blind to condition and synchronous vs asynchronous test phases) is currently coding the video recordings of participants' sessions to assess whether or not each participant successfully clapped along to the beat they heard during the test phases. For each clapping round, the coder will answer four questions (see Appendix B) (1) Did the participant clap? (2) Was the clap synchronous with the sound? (3) What motion did they do when clapping? (4) Where did the participant look? The coder will answer the four questions for each of the partners four clapping trials. The video coding is on-going and therefore will not be included in the current analyses. However, the final analyses will include the coded video data once the full sample size is complete.

Mental Other Scale. After each test phase, the participating child was presented with five questions assessing the extent to which the child attributed mental states to their partner (see Appendix C). These questions included, "How much does this [robot/person/sound machine] think for itself?", "How much does this [robot/person/sound machine] have feelings, like happy and sad?", "How much does this [robot/person/sound machine] know that it is a [robot/person/sound machine]?", "How much does this [robot/person/sound machine] do things on purpose?", and "How smart do you think this [robot/person/sound machine] is?" The first four items were adapted from the IDAQ-CF (Severson & Lemm, 2016) described above, and focus on the specific robot, person, or metronome rather than entities in general. The final "smartness" item was adapted from previous studies assessing mental attributes to technologies (e.g., Kahn et al., 2012; Girouard-Hallam, Streble, & Danovitch, 2021). These items were measured on a 4-point Likert scale where (0) = "Not at all," (1) = "A little bit," (2) = "A medium amount," and (3) = "A lot." These questions were administered in a random order along with the items from the social other scale (described below).

Social Other Scale. After each test phase, the participating child was administered the Social Other Scale comprised of five questions assessing how participants ascribed sociality to each partner (person, robot, or metronome; see Appendix D). These questions evaluated friendship and likability (Birch et al., 2020), as well as whether the child would comfort or spend time with the partner (Kahn et al., 2012; Severson & Lemm, 2016), and how much the child enjoyed playing the clapping game with the partner. These items were measured on a 4-point Likert scale where (0) = "Not at all," (1) = "A little bit," (2) = "A medium amount," and (3) = "A lot." As noted above, these questions were presented in random order with the mentalizing questions.

Sticker Resource Allocation Task. After both synchronous and asynchronous partner trials, a sticker sharing task (modeled on Nijssen et al., 2021) assessed children's resource allocation to the synchronous and asynchronous partners. Chernyak & Sobel (2016) found that when preschoolers were given stickers to share with two puppets if the child is told one of the stickers is rare, they would split stickers equally but give the rare sticker to their preferred puppet. However, if the rare sticker is torn, they would not give the value-reduced rare sticker to their preferred puppet. Taken together, this suggests that stickers are considered a valuable resource for children's decision to distribute them to others, thus a practical item to utilize for children's resource allocation tasks.

Participants were presented with a variety of sticker sets (animal, space, or unicorn stickers) to choose from and given their preferred set. Each sticker set was comprised of seven stickers and given to the participant as a gift for participating in the study. Participants were informed that their partners in the clapping game would also receive stickers for playing the game. The researcher explained the participant had an identical set of seven stickers to share between the two partners they participated with. The researcher asked the child to distribute the seven stickers between the partners they participated with by providing boxes with the partner's image on the front for them to place the stickers so the recipients can be given the stickers later. The researcher said, "Thank you for playing the clapping game, you will get some stickers for playing! We have space stickers, animal stickers, or unicorn stickers, which type of stickers would you like? The [people/robots/sound machines] who played the clapping game with you will also receive stickers for playing. I have another set of the same stickers you chose. See these boxes with their pictures? Can you share the stickers with these two [people/robots/sound machines] while I set up the next game? You can give however many you want to each [person/robot/sound machine]. I will give them the stickers in their boxes later."

The decision to use an odd number of stickers for this task is based on previous research illustrating that children are likely to make an equal split between recipients (Chernyak & Sobel, 2016; Nijssen et al., 2021). To examine how participants allocate resources between synchronous or asynchronous agents, the use of an odd number of stickers alleviated the possibility of an equal split (except for n=2 ripping the stickers in half to make an even split). Participants received two boxes with images of each model on the outside for ease of knowing which box to place stickers in for that recipient. The researcher ostensibly busied themselves with paperwork, providing privacy for the child to decide how to distribute the stickers. After the session, the researcher measured resource allocation by counting how many stickers were given to each model. The stickers allocated to each agent were not counted until after the child completed the study session.

Manipulation Check. After the sticker allocation task, participants responded to a manipulation check (see Appendix E). The manipulation check assessed whether the participant could correctly identify the synchronous and asynchronous partners by asking, "Which partner do you think heard a different sound than you?" The question was asked after the sticker allocation task to not influence how the child would distribute resources.

Parent Questionnaire. While the child participated in the study, the parent or legal guardian was given the optional parent questionnaire administered through a Qualtrics form on an iPad. The questionnaire involved four parts: demographics, robot knowledge and interest, Children's Social Understanding Scale, and Children's Social Preference Scale. Questions were not forced choice and could be skipped if the parent preferred not to answer. Data collected from the parent questionnaire will be analyzed once the full sample has been collected.

Demographics. Parents or legal guardians accompanying the participating child completed a series of questions about demographics including the child's ethnicity, gender identity, and diagnosed or suspected developmental delays (see Appendix F). Additionally, questions asked about the parent or legal guardian's age, gender identity, educational level, occupational status, and relationship to the child.

Robot Interest and Knowledge Questions. Parents or legal guardians responded to 2-items about the participating child's interest or knowledge of robots (see Appendix G). These questions were measured from “no interest/knowledge” to “really interested/knowledgeable” on a 5-point scale.

Children’s Social Understanding Scale (CSUS). The Children’s Social Understanding Scale (CSUS) is a parent-report measure of children’s theory of mind tendencies (see Appendix H; Tahiroglu et al., 2014). Parents or legal guardians answered 18-items about individual differences in their child’s perceived mental states including beliefs, knowledge, intentions, and emotions. The CSUS was measured from “definitely untrue” to “definitely true” on a 4-point scale.

Children’s Social Preference Scale (CSPS). The Children’s Social Preference Scale (CSPS) is a parent-report measure of children’s shyness and social disinterest (See Appendix I; Coplan et al., 2004). Parents or legal guardians responded to 11-items about conflicted shyness and social disinterest. The CSPS asked “How much is your child like that?” and measured responses from “not at all” to “a lot” on a 5-point scale.

Results

Analyses were performed in SPSS (Version 28.0.0; IBM Corp., 2021), JASP (Version 0.17.1; JASP Team, 2023), and R (Version 4.2.3; R Core Team, 2023). Initial analyses were conducted to test for order and model effects by utilizing paired samples *t*-tests. The analyses for partner order or model effects (e.g., actor 1, actor 2) did not include the metronome, as the metronome was a natural pairing and therefore could not be counterbalanced. Analysis for partner one and partner two (regardless of counterbalancing) indicated no significant order effects for sticker sharing ($t(86) = -.817$, $p = .24$, $d = -.13$, 95% CI [-.74 .19]), mentalizing ($t(86) = -1.186$, $p = .24$, $d = -.13$, 95% CI [-.16, .04]), or social ascriptions ($t(86) = -1.275$, $p = .21$, $d = -.14$, 95% CI [-.25, .05]). Analysis for preference of specific models (actor 1 or actor 2; red robot or grey robot) indicated no significant preference to allocate stickers to a certain robot model ($t(45) = -.451$, $p = .65$, $d = -.07$, 95% CI [-.83, .53]) or human model ($t(39) = -1.623$, $p = .11$, $d = -.26$, 95% CI [-1.01, .11]), nor a preference for social ascriptions based on robot model ($t(46) = .550$, $p = .59$, $d = .08$, 95% CI [-.19, .33]) or human model ($t(39) = -1.688$, $p = .1$, $d = -.27$, 95% CI [-.22, .02]). For the mentalizing variable, there was a significant preference for the red robot ($t(46) = 2.570$, $p = .01$, $d = .38$, 95% CI [.04, .33]) such that the red robot ($M = 1.59$, $SD = .77$) was ascribed a greater number of mental states than the grey robot ($M = 1.40$, $SD = .72$), but no significant difference was found between the human models ($t(39) = -1.341$, $p = .19$, $d = -.21$, 95% CI [-.19, .04]). There was no ideal way to statistically control for the robot model effects (i.e., making “model” a random effect) since the metronome was a natural pairing. Therefore, in order to investigate mentalizing of the robots, follow-up data collection will directly compare synchronous and asynchronous robots of the same color (i.e., two red robots, two grey robots).

The manipulation check (i.e., “Which partner heard a different sound from you?”) was not an independent variable for the study design but was considered in exploratory models for each of the outcome variables. Since the manipulation check was added after data collection had begun, some participants did not have data for the manipulation check ($n = 12$). Regardless of age or agent condition, 59.9% of participants correctly identified the asynchronous partner. A Chi-Square analysis was conducted to examine if age was associated with accuracy in the manipulation check. The result was non-significant ($p = .66$), but 52.4% of 5-year-olds, 57.1%, of 6-year-olds, 56.5% of 7-year-olds, and 70.4% of 8-year-olds were correct at identifying the asynchronous partner. Additionally, a Chi-Square test indicated no significant difference between agent and accurately identifying the asynchronous partner (see Table 2; $p = .25$)

Table 2

Number and Percent of Participants Correct or Incorrect by Agent on Manipulation Check

	Correct		Incorrect	
Agent	*n*	%	*n*	%
Human	23	63.9%	13	36.1%
Robot	27	62.8%	16	37.2%
Metronome	5	38.5%	8	61.5%

Note. Percentages are calculated within agent condition.

Sharing Preferences with Synchronous or Asynchronous Partners

To analyze the preference for allocating stickers between synchronous partners, a distribution difference score was computed by subtracting the number of stickers the synchronous partner received by the number of stickers the asynchronous partner received (Distribution Difference = SYNC stickers – ASYNC stickers). Thus, a preference for the synchronous partner would be indicated by a positive value and a preference for the asynchronous partner would be indicated by a negative value[2]. If there was no preference for synchronous or asynchronous entities, it would be expected that the distribution difference average to be zero. An analysis of variance (ANOVA) was used to assess the factors of agent and age on the distribution difference. Age was a significant main effect ($F(3, 92) = 2.89$, $p = .04$, $\omega^2 = .047$). Post hoc comparisons using least significant difference (LSD) indicated that 7-year-olds significantly differed from 6-year-olds ($p = .02$, 95% CI [.56, 3.39]) and was approaching

[2] Two 8-year-old participants (*n*=1 robot and *n*=1 metronome condition) ripped a sticker in half to equally distribute between the partners (3.5 stickers given to each partner).

significance[3] from 5-year-olds (*p* = .08, 95% CI [.15, 3.02]), such that 7-year-olds (*M* = .78, *SD* = 2.90) preferred to allocate to the synchronous partner whereas 6-year-olds (*M* = -.68, *SD* = 1.89) and 5-year-olds (*M* = -.39, *SD* = 3.16) preferred to allocate to the asynchronous partner. Eight-year-olds did not differ from any other age group (*M* = -.17, *SD* = 1.23). Agent did not have a significant effect on the distribution difference ($F(2, 92) = 2.64$, $p = .08$, $\omega^2 = .028$). Planned contrasts on agent indicated a significant difference between the human and metronome (*p* = .04, 95% CI [.08, 2.74]), but no difference between the robot and human (*p* = .09, 95% CI [-.14, 1.84]) or robot and metronome (*p* = .39, 95% CI [-.74, 1.85]). As shown in Figure 3, the preference in the human condition was to allocate to the synchronous partner (*M* = .45, *SD* = 1.75), while the preference in the metronome condition was to allocate to the asynchronous partner (*M* = -.82, *SD* = 3.28). The interaction between age and agent was not significant ($F(6, 92) = 1.92$, $p = .09$, $\omega^2 = .047$).

To analyze whether (1) being correct about which partner was synchronous and asynchronous (manipulation check) or (2) anthropomorphism subscales influenced the sticker sharing, an exploratory regression was conducted with predictors of agent, age, manipulation check, anthropomorphism of animals, and anthropomorphism of technology and nature. A subset of the data was examined because the manipulation check item was added to the procedure after data collection had begun resulting in some missing data (*n* = 12) on this question. The overall model was non-significant ($F(5, 86) = .87$, $p = .5$, $R^2 =. 05$), and the manipulation check (*p* = .95), anthropomorphism of animals (*p* = .19), and anthropomorphism of technology and nature (*p* = .62) did not significantly predict the sticker distribution difference.

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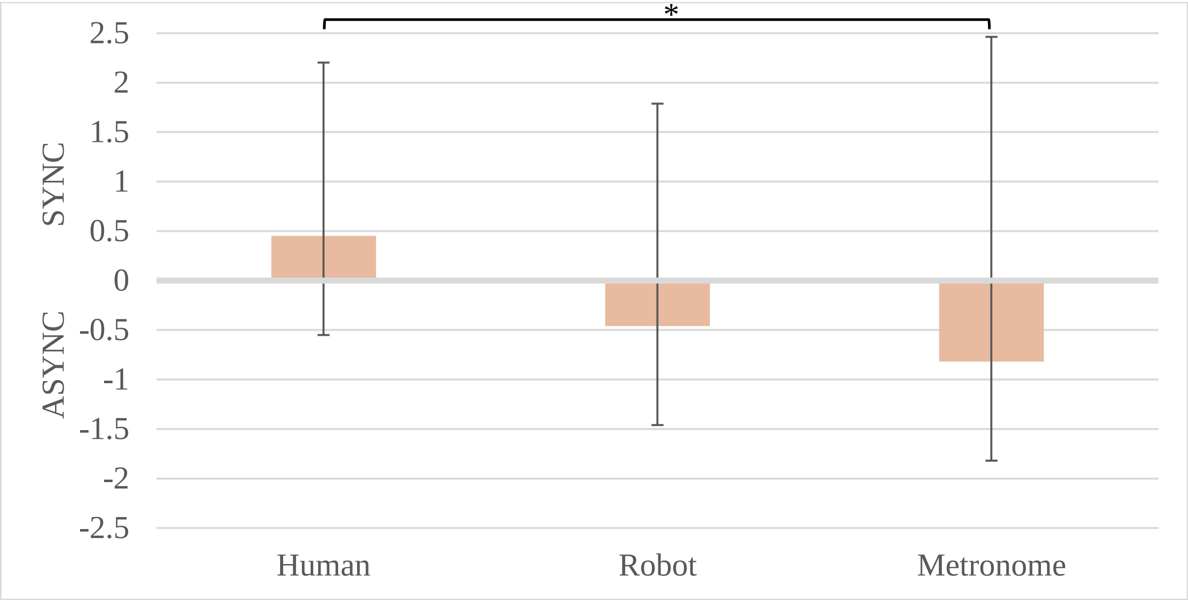
[3] The 5-year-olds comparison to 7-year-olds at *p*=.08 was indicated as approaching significance because of smaller sample of 5-year-olds in present analyses (*n*=23 5-year-olds of 30 planned), and therefore might reach significance with the full sample.

Figure 3

Mean Distribution Difference by Agent



Note. Error bars represent standard deviation.
* $p < .05$

Finally, a one-sample *t*-test was used to assess if the distribution difference differed from zero by conducting the analysis on each agent condition. If there was not a preference for the synchronous or asynchronous partner the sticker distribution difference would equal zero. Thus, the analysis would reveal if the preference by agent differed from no preference. Results indicated no significant difference in the human ($t(39) = 1.62$, $p = .11$, $d = .26$), robot ($t(46) = -0.83$, $p = .41$, $d = -.12$), or metronome conditions ($t(16) = -1.03$, $p = .32$, $d = -.25$). The effect size, as indicated by the Cohen's *d*, is a small effect for each of the agents and specifies the direction of the effect. It is plausible the sample size is not big enough in each agent condition, as the experimental design is not well suited for this analysis, but with a larger sample these distribution differences could differ significantly from zero.

Mental and Social Attributions to Synchronous and Asynchronous Partners

To analyze mentalizing and social ascriptions, linear mixed effects models were fit using the LMER package (Version 3.1-3; Kunzetsova et al., 2017) on R (Version 4.2.3; R Core Team, 2023). Mixed effects models were the decided analysis approach for this data as synchrony has a notably small effect size in previous literature (Mogan et al., 2017), thus the mixed effect modeling method would allow for more power and the ability to account for variability that may be influencing the data. Models were fit by using the maximum likelihood approach, rather than using the restricted maximum likelihood method. With the current study, model comparisons were crucial to understanding interactions in the data and examining which fixed effects best explained the current data. The only random effect considered in these models was participant number. With minimal random effects to test and an intention to test model comparisons, maximum likelihood estimation was the preferred approach. Model comparisons were conducted to examine fixed effects as interactions or main effects, as well as comparisons made for exploratory models to include the manipulation check and anthropomorphism measures. Akaike information criterion (AIC) was the primary assessment of model fit, however, models that were comparable in AIC or ambiguous were further inspected using the Flexplot package (Fife, 2022) to obtain a Bayes information criterion (BIC) and Bayes Factor. Synchrony conditions were coded with a one-unit difference (ASYNC = -.5, SYNC =.5) such that the coefficients could be considered as the average score regardless of synchrony. Agent conditions were contrast coded with the human as the referent (Metronome = -.5, Human = 0, Robot = .5).

Mentalizing

Items from the Mental Other Scale indicated sufficient reliability (α = .82) and were averaged into a metalizing score for each test phase (see Table 3). When examining the hypothesized effects of synchrony, agent, and age on mentalizing in the mixed effects model (see Appendix J for list of model comparisons), an interaction between synchrony and agent was the best fit model for the mental other variable (AIC = 410.92) where the interaction was significant (β = -.24, *SE* = .12, *p* = .05, 95% CI [-.46, .00]). However, when including the exploratory variables, the best fit model (see Table 4) was an interaction between synchrony and agent with age and the manipulation check as main effects (AIC = 362.50) and revealed significant effects for the interaction between synchrony and agent (β = -.31, *SE* = .14, *p* = .03, 95% CI [-.58, -.04]) and the manipulation check (β = .41, *SE* = .18, *p* = .02, 95% CI [.05, .76]), whereas age was not a significant effect (β = -.07, *SE* = .08, *p* = .39, 95% CI [-.22, .09]). Post hoc comparisons were conducted on the estimated marginal means using the EMMEANS package (Lenth, 2023) and Tukey adjustments. Pairwise comparisons of the estimated marginal means for the interaction between synchrony and agent (see Figure 4) revealed that the synchronous and asynchronous human were significantly different from the synchronous and asynchronous robot and metronome (all *p*s <.00). These pairwise comparisons also revealed that the asynchronous robot (*M*= 1.54, *SE*= .11) significantly differed from the asynchronous metronome (*M*= .89, *SE*= .19, *p* = .05). No other significant pairwise comparisons were found. Pairwise comparison on the manipulation check found that the difference between being correct or incorrect about the asynchronous partner was nearing significance (*p* = .06), such that those correct about the asynchronous partner (*M*= 1.74, *SE*= .10) attributed a greater number of internal states than those that were incorrect (*M*= 1.47, *SE*= .11).

Table 3

Raw Means and Standard Deviations for Mental Other by Agent and Synchrony

	SYNC Partner		ASYNC Partner	
Agent	*M*	*SD*	*M*	*SD*
Human	2.42	.55	2.37	.65
Robot	1.44	.78	1.55	.73
Metronome	.91	1.03	.80	.94

Note. The means listed are the raw means, and not the estimated marginal means which were used in pairwise comparisons.

Table 4

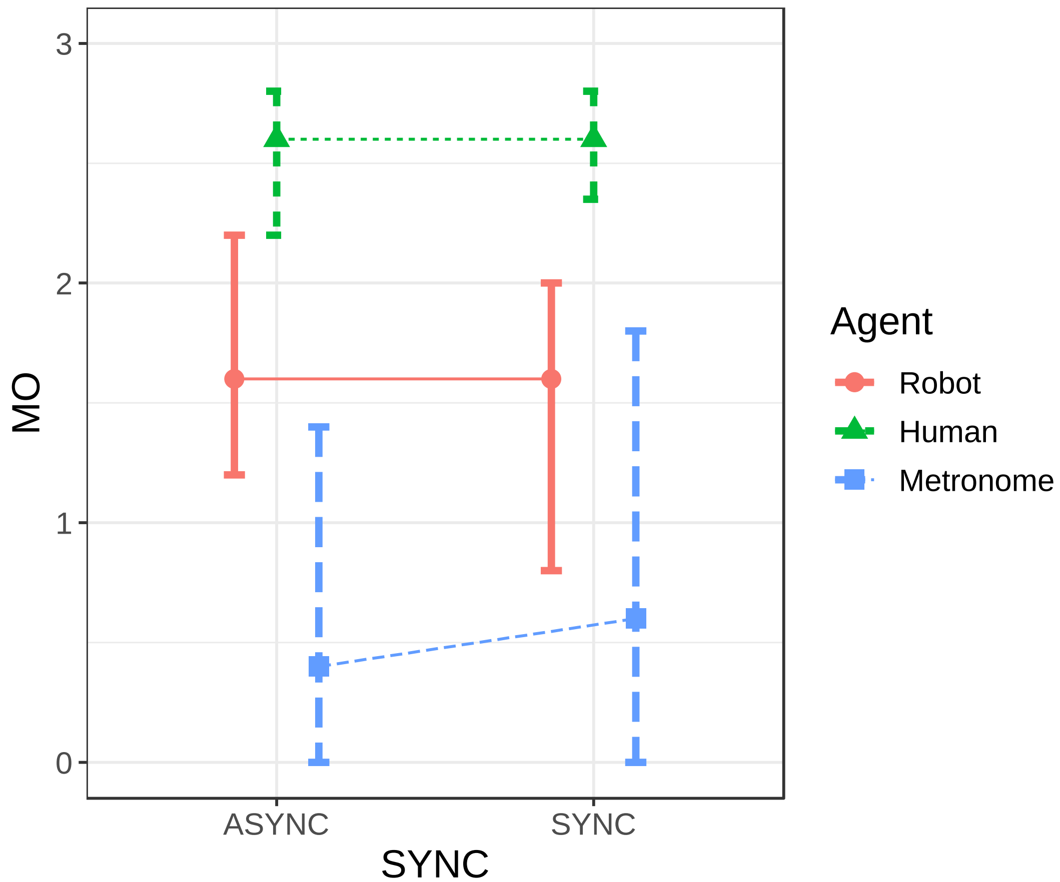
Summary of Random and Fixed Effects for Selected Mental Other Model

Random Effects	Variance	*SD*
Participant ID	.63	.79
Residual	.11	.33

Fixed Effects	Estimate	*SE*	*df*	*t*	95% CI	*p*
Intercept	1.98	.52	92	3.84	0.96, 3.00	< .00
SYNC	.04	.05	92	.68	-0.07, 0.14	.50
Agent	-.09	.25	92	-.37	-0.58, 0.39	.71
Age	-.06	.08	92	-.86	-0.22, 0.086	.39
Manipulation Check	.41	.18	92	2.28	0.05, 0.76	.02
SYNC * Agent	-.31	.14	92	-2.27	-0.58, -0.04	.03

Figure 4

Mental Other by Synchrony and Agent



Note. The synchronous and asynchronous human was significantly greater than the synchronous and asynchronous robot and metronome (*p*s < .00), and the asynchronous robot was significantly different from the asynchronous metronome (*p* = .05). Error bars represent standard error.

Social Attributions

Items from the Social Other Scale indicated sufficient reliability (α = .89) and were averaged into a sociality score for each test phase (see Table 5). When examining the hypothesized effects of synchrony, agent, and age on social attributions in the mixed effects model, the best fit model (see Table 6) was agent and age as main effects (AIC = 478.10) where agent (β = .71, *SE* = .22, *p* < .001, 95% CI [.27, 1.16]) and age (β = -.18, *SE* = .07, *p* = .02, 95%

CI [-.32, -.03]) were a significant fixed effect. Exploratory variables of manipulation check and the IDAQ subscales were not significant effects, although removing the subset of the data that did not include the manipulation check question (n = 12) improved the model fit (see Appendix K for list of model comparisons). Since the exploratory variables did not play a significant effect, the model that best fit the full data set was the selected model. General linear hypotheses were conducted to examine pairwise comparisons using the MULTCOMP package (Hothorn et al., 2008) since the selected model was additive. Pairwise comparisons of the estimated marginal means for age indicated that 7-year-olds (M= 1.33, SE= .17) differed significantly from both 5-year-olds (M= 1.93, SE= .18, p = .05) and 6-year-olds (M= 1.98, SE= .17, p = .02). Eight-year-olds did not differ from any other age group (M = 1.54, SE= .16). As shown on Figure 5, pairwise comparisons for agent indicated that the robot (M= 2.04, SE= .12) and metronome (M= 1.27, SE= .20, p <.00) significantly differed, whereas the human (M= 1.78, SE= .13) did not differ significantly from the robot (p = .3) or the metronome (p = .08).

Table 5

Raw Means and Standard Deviations for Social Other by Agent and Synchrony

	SYNC Partner		ASYNC Partner	
Agent	*M*	*SD*	*M*	*SD*
Human	1.76	.82	1.73	.92
Robot	1.97	.98	2.10	.86
Metronome	1.29	1.09	1.24	1.05

Note. The means listed are the raw means, and not the estimated marginal means which were used in pairwise comparisons.

Table 6

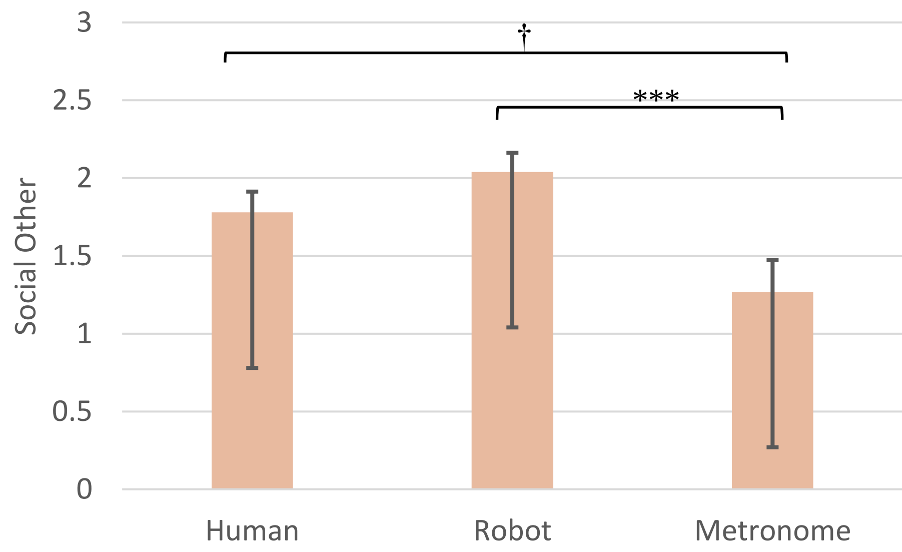
Summary of Random and Fixed Effects for Selected Social Other Model

Random Effects	Variance	SD
Participant ID	.58	.76
Residual	.22	.47

Fixed Effects	Estimate	*SE*	*df*	*t*	95% CI	*p*
Intercept	2.87	.49	103.99	5.823	1.90, 3.85	< .00
Age	-.18	.07	103.99	-2.434	-0.32, -0.03	.02
Agent	.71	.22	104	3.178	0.27, 1.16	< .00

Figure 5

Social Other by Agent



Note. Means reported are estimated marginal means. Error bars represent standard error.
*** $p \leq .00$ † p=.08

Differences in Mentalizing and Social Attributions by Sharing Preferences

Sharing preferences were categorized by whether each participant chose to give more stickers to the synchronous or asynchronous partner. Repeated measures ANOVAs were conducted to examine whether choosing to share with the synchronous or asynchronous partner (between-subjects factor) illustrated differences between the mentalizing and social attributions made to the two partners (repeated factor).

For mentalizing, a repeated measures ANOVA indicated there was no significant difference between sharing preference and the mean mental states attributed to the synchronous and asynchronous partner ($F(1, 100) = .011$, $p = .92$, $\omega^2 = .000$), such that those who decided to share synchronously or asynchronously were not more (or less) likely to mentalize the partner they decided to share with. Next, to test whether overall mentalizing tendencies differed between children who chose to share more with the synchronous partner and those who shared more with the asynchronous partner, mental other scores were combined to create a total mentalizing score by summing the mental other means for the synchronous and asynchronous partners. An independent samples *t*-test was conducted on the total mentalizing score and grouped by the sharing preference. Overall, there was no difference in mentalizing by sharing preference ($t(100) = .78$, $p = .44$, $d = .16$, 95% CI [-.46, .95]), such that choosing to share synchronously or asynchronously did not result in different tendencies to mentalize. However, when examining this outcome by each agent there was a significant difference for mentalizing by sharing preference for the metronome ($t(13.92) = 2.34$, $p = .03$, $d = 1.01$, 95% CI [.14, 3.27]). Those who shared more stickers with the asynchronous metronome ($n= 11$, $M = 2.53$, $SD = 2.16$) were more likely to attribute mental states to the synchronous and asynchronous metronomes than those who shared more stickers with the synchronous metronome ($n= 5$, $M = .64$, $SD = .82$). Table 7 illustrates means and standard deviations for all groups, although no differences were found for the robot ($t(44) = .94$, $p = .35$, $d = .28$, 95% CI [-.45, 1.24]) or human ($t(38) = .1.60$, $p = .12$, $d = .51$, 95% CI [-.15, 1.29]).

Table 7

Mental Other Scale by Sharing Preference and Agent

	Shared SYNC				Shared ASYNC			
	SYNC Partner		ASYNC Partner		SYNC Partner		ASYNC Partner	
Agent	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Human	2.32	.63	2.21	.78	2.53	.43	2.57	.36
Robot	1.29	.78	1.43	.85	1.50	.75	1.61	.65
Metronome	**.28**	.39	**.36**	.43	**1.27**	1.09	**1.07**	1.05

Note. Metronome condition significantly differed in mental states attributed to both SYNC and ASYNC partners based on sharing preference (p =.03).

Finally, a repeated measures ANOVA examined the mean social other score for the synchronous and asynchronous partners by sharing preference. A significant interaction was found between the social other scores and sharing preference ($F(1,100) = 6.27$, $p = .01$, $\omega^2 = .006$). Pairwise comparisons indicated that those who shared to the asynchronous partner were more likely to attribute sociality to the asynchronous partner ($M = 1.96$, $SD = .83$) than to the synchronous partner ($M = 1.78$, $SD = .89$, $p = .05$), but no differences were found for those who shared to the synchronous partner ($p = .12$). Examining this effect by agent condition indicated the effect was primarily in the human ($F(1, 38) = 3.40$, $p = .07$, $\omega^2 = .003$) and robot ($F(1, 44) = 3.12$, $p = .08$, $\omega^2 = .011$) conditions, but not the metronome condition ($F(1,14) = .75$, $p = .4$, $\omega^2 =$

.000). Table 8 illustrates the descriptive statistics for all groups. Pairwise comparisons indicated that those who shared synchronously with the human (n = 22) were more generous with social ascriptions to the synchronous human (M = 1.78, SD = .99) than the asynchronous human (M = 1.65, SD = 1.04, p = .096). Conversely, those who shared to the asynchronous robot (n = 27) were more generous with social ascriptions to the asynchronous robot (M = 2.26, SD = .60) than the synchronous robot (M = 1.95, SD = .92, p = .08). No other differences were found for the social other by sharing preference (all ps >.4).

Table 8

Social Other Scale by Sharing Preference and Agent

	Shared SYNC				Shared ASYNC			
	SYNC Partner		ASYNC Partner		SYNC Partner		ASYNC Partner	
Agent	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Human	**1.78[a]**	.99	**1.65[a]**	1.04	1.74	.58	1.82	.78
Robot	1.97	1.11	1.82	1.10	**1.95[b]**	.92	**2.26[b]**	.60
Metronome	1.23	.89	1.05	.94	1.43	1.18	1.43	1.10

Note. Differences between social attributions to SYNC and ASYNC partner are significant, [a]p=.096 and [b]p=.08.

Discussion

This study examined whether behavioral synchrony, or the notion that "moving in time equals moving in mind" (Baimel et al., 2018), applies similarly to humans, social robots, and mechanical devices. Synchronization of actions between people yields a myriad of positive benefits for human others, such as increase perspective taking, empathy, and prosocial behaviors (e.g., Kirschner & Tomasello, 2010; Tunçgenç & Cohen, 2018; Rabinowitch & Knafo-Noam, 2015; Wiltermuth & Heath, 2009). However, there are limits in our understanding of how broadly synchrony effects are applied with a child sample. Moreover, as personified technologies such as social robots are integrated into social settings, it is crucial to explore how children perceive such technologies. The current work sought to address these questions by examining children's sharing preferences, mentalizing, and social attributions to synchronous and asynchronous partners – whether those partners were humans, robots, or metronomes.

We predicted that preferential sharing will be greater for synchrony, such that synchronous partners will receive more stickers. Children's preference to allocate stickers was influenced by synchrony, but not entirely dovetailing with the predictions hypothesized for the study. Children shared more stickers with the *synchronous* human partner, whereas children preferred to share more stickers with the *asynchronous* metronome. The robot fell in-between the human and metronome (although did not differ significantly from either) and leaned towards a preference to share more stickers with the *asynchronous* robot. We also predicted that children's mentalizing would vary based on synchrony, such that synchronous partners will be attributed a higher degree of mental states. Contrary to this prediction, the results indicated that synchrony did not affect children's attributions of mental states, and that children attributed the highest level of mental states to humans, followed by robots, and the lowest level of mental states to the metronome. Finally, we predicted that social attributions will vary based on synchrony, such that synchronous partners will receive a higher degree of social attributions. The results indicated that children attributed the highest level of sociality to the robots, followed by the humans, and lastly the metronome, but synchrony did not directly affect social attributions to any agent. However, synchrony did play a role when considering mentalizing and social attributions in concert with sharing preferences. That is, children who preferred to share stickers with the asynchronous metronome were more likely view the synchronous and asynchronous metronome as have more mental states. And children who shared more stickers with the synchronous human and the asynchronous robot were more likely to view that specific partner as a social other.

One interpretation of the findings from this study is synchrony effects can apply to many types of agents, but children prefer synchronous human others and asynchronous non-human others. Likewise, the pattern for a preference for synchronous humans and asynchronous non-human agents was evident in children's social attributions. Children who shared with the synchronous human had ascribed greater sociality to the synchronous human than the asynchronous human. Children who chose to share more to the asynchronous robot had ascribed greater sociality to the asynchronous robot than the synchronous robot. However, those children who diverged from the more common sharing pattern (i.e., shared more with the asynchronous human or synchronous robot) did not differ in their social attributions to the synchronous and asynchronous partners. Thus, there appears to be an alignment between children's ascriptions of sociality and their sharing preferences – and the direction of the synchrony effect (preferring synchronous or asynchronous others) depends in part upon whether they are synchronizing with a human or robot. Perhaps unsurprisingly, the metronome did not follow these patterns, likely because children did not consider the metronome as a social other. Yet, given the small effect sizes for social attributions by sharing preferences, it is hard to determine whether these results emerged because the human and robot were viewed as social agents or if there was not enough power to detect a difference within the metronome condition.

One explanation for why children showed a preference to share with the asynchronous non-human others is an effectance motivation. In their three-factor model of anthropomorphism, Epley et al. (2007) suggest people may anthropomorphize non-human entities because they are uncertain how to understand the agent – a tendency referred to as effectance motivation. They argue that, “This uncertainty may arise because the agent is novel and unknown, because the agent appears unpredictable, because the agent violates one’s expectations, or because the causal mechanisms underlying an observed behavior are unknown or unobservable” (Epley et al., 2007, p. 872). Even though participants were made aware partners may have heard a different sound during the clapping game, the asynchronous non-human others could have surprised children by moving to a different sound than they were hearing. By observing a non-human agent move asynchronously, children could have found the agent to be more novel or violating expectations that the agent cannot act intentionally, thus resulting in a preference for the asynchronous other. The results from the mental other by sharing preference may support this argument to some extent. Children who chose to share more stickers with the asynchronous metronome were more likely to mentalize metronomes than those who shared to the synchronous metronome. Thus, consistent with Epley and colleagues (2017) proposition for adults, some children may be more sensitive to effectance motivation.

If asynchrony elicited a response to ascribe intentionality vis-à-vis effectance motivation as suggested by the three-factor theory of anthropomorphism (Epley et al., 2007), it may be that asynchrony is a cue for agency in non-human entities. In line with previous research with slightly older children (Kahn et al., 2012), children’s attributions of mental states to the entities followed a stair-step pattern, with attributions to humans at near-ceiling levels, attributions to the metronome at near-floor levels, and attributions to the robot in the middle. At first glance, it would appear that the mentalizing measure was not sensitive to synchrony effects as no differences were found in mentalizing the synchronous or asynchronous partner. Previous studies examining behavioral synchrony discovered adults were more likely to attribute mental states to synchronous partners, although these differences were subtle (Baimel et al., 2018). Yet, when considered in combination with sharing preferences, children who shared more stickers with the asynchronous metronome were more likely to attribute mental states to both metronomes. This result had a large effect, and it could be that some children are treating asynchrony as a cue for agency. Effectance motivation may not have been evident with the robot as children may already have a baseline attribution of mental states for the robots (e.g., Kahn et al., 2012; Thellman et al., 2022) that is not sensitive to synchrony. Moreover, in a previous study examining synchronizing with a robot, an adult sample demonstrated no differences anthropomorphizing the robot based on synchronous movement, nor differences in a dictator game leading the authors to conclude lack of support for effectance motivation when presented with asynchronous non-human agents (Heijnen et al., 2019).

The pattern of preferring the synchronous human and asynchronous human could also be a facet of children favoring those viewed as similar to themselves. Rabinowitch and Knafo-Noam (2015) reported that children who synchronized with each other found their partner to be more similar to themselves. Children's tendency to ascribe more sociality to the agent they later allocated more stickers may be more indicative of how agency is being ascribed. Moreover, children's perceived similarity with synchronous others may apply to humans and non-human others in different ways. Recall that children gave more stickers to the partner – either the *synchronous* human or the *asynchronous* robot – they previously attributed greater sociality to. Because sociality included questions about friendship and likeability, it is possible that children's tendency to affiliate with the synchronous human or asynchronous robot manifested in a preference to share with that partner. Importantly, synchrony differentially cued sociality and sharing depending upon the agent with the synchronous movement with human partners and asynchronous movement with robot partners yielding greater sociality and sharing. The in-progress blind coding of the clapping games will reveal if children were attending more to one of the partners and, in turn, help interpret whether the non-human asynchronous agents may be violating children's expectations or viewed as novel in line with the effectance motivation explanation.

Another salient finding from the current study is the emergence of age differences in sticker allocation and social attributions. In the sticker sharing task, 7-year-olds shared more stickers with the synchronous partner, 5- and 6-year-olds allocated more stickers to the asynchronous partner, and 8-year-olds did not show a preference when allocating stickers to either of the partners. When attributing sociality to the partners, 7-year-olds were more restrained, whereas 6-year-olds were more generous with their social attributions. Similar to 6-year-olds, 5-year-olds were also high on ascribing sociality, but did not quite differ from 7-year-olds. Again, 8-year-olds did not differ significantly from the other age group, but were descriptively between the 7-year-olds and 5- and 6-year-olds attributions.

Why might these age differences have emerged? One possibility is that there are developmental differences associated with the tasks. The sticker sharing task used in the study was modeled on the sticker allocation task with children 4-5 years and 8-9 years (Nijssen et al., 2021). Their study examined children's sharing with robots that differed in anthropomorphic appearance and affective states (present or absent) and did not result in any age differences between the younger (4-5 years) and older (8-9 years) age groups. By contrast, the current study demonstrated age differences between the 5- to 6-year-olds (who preferred to share with the asynchronous partner) and 7-year-olds (who preferred to share with the synchronous partner).

Similar to Nijssen and colleagues (2021), there were no differences in sticker sharing between the younger children (5-6 years) and the 8-year-olds. Given that sticker sharing tasks have been successfully employed with preschool-age children (Chernyak & Sobel, 2016) and that age differences in sharing preferences are not typically found (Nijssen et al., 2021), it follows that the age differences in the current study are not likely a result of the sharing task. As for the difference in ascribing sociality, 5- and 6-year-olds may be more willing to broadly ascribe sociality and older children may be more restrictive. To this point, notions of friendship tend to shift from a focus on similar interests and physical appearance in younger children (4-5 years) to more internal characteristics and expectations around social support among older children (6-7 years; Furman & Bierman, 1983).

Rather, the age-related differences could reflect differing susceptibility of synchrony effects or, more simply, differing levels of engagement in the clapping game. Children as young as 2.5-year-olds can successfully synchronize, even if with poor accuracy (Kirschner & Tomasello, 2009), and 8-year-olds are receptive to synchrony effects (Rabinowitch & Knafo-Noam, 2015). Thus, one possible explanation for these age-related differences evidenced in the current study is 5- and 6-year-olds were more engaged with the asynchronous partner during the clapping game because the partner was doing something different than what the child was hearing (and doing). This dissonance in what was observed visually and heard auditorily (and performed physically) could have bolstered the attention given to the partner and consequently affected social ascriptions and sharing preferences. Although our current data cannot address this possibility, the aforementioned in-progress blind coding will provide evidence to address this possiblity. That is, this data will provide evidence to indicate whether 5- and 6-year-olds were more attentive to the asynchronous partners than 7- and 8-year-olds. By contrast, 7-year-olds showed a preference for the synchronous partner suggesting they may have been sensitive to the effects of synchrony and less likely to find the asynchronous partner as violating an expectation. Nonetheless, it is unclear why 8-year-olds did not show a difference from either of the otger age groups.

In consideration of the current findings, previous research on behavioral synchrony has examined different outcomes for adults than children, with some overlap and conflicting findings. Baimel et al. (2018) found synchronous action with other humans yielded more mental states attributed to partners than asynchronous action for adults yet did not detect differences in social cohesion. Whereas in the literature about children's synchronous action with others, social bonding and social commitment have been observed outcomes (Kirschner & Tomasello, 2010; Tunçgenç & Cohen, 2016). One explanation to reconcile the differences between adults and children could be children are using synchrony differently than adults. While adults may use synchrony as a mentalizing cue, children may be using synchrony as a social cue. Children have demonstrated a greater affinity for those they are synchronizing with in previous work. The idea implying synchrony is a social concept for children for the current results aligns with previous research, such that the current study observed that as children attributed more sociality to the preferred entity (synchronous human, asynchronous robot), they were more likely to share with that entity. However, those who did not share to the synchronous human or asynchronous robot did not demonstrate this pattern. Taken together, synchrony seems to provide a social cue for children, while providing a mental state cue to adults.

The results of this study revealed two noteworthy conundrums, both involving children's mentalizing. First, the red robot was attributed a greater number of mental states than the grey robot. If there was a preference based on color, it would be expected that preferential sharing and the social other scale (e.g., likability) would be influenced by the effect of color more than the mental other measure. In other words, if children did prefer the red robot to the grey robot, it would be probable to see that more stickers were allocated to the red robot or the red robot received more ascriptions of friendship and likeability. Nevertheless, the mental other scale included items such as smartness and consciousness, items unrelated to a general preference. To examine this, as data collection continues, new robot conditions will examine how children preferentially share, mentalize, and make social attributions when the synchronous and asynchronous robots are both red and both grey (thereby eliminating potential robot model effects). This new data will allow for the examination of possible synchrony effects that may have been muddled by the robot color.

The second conundrum involved the manipulation check which indicated a significant effect for the mental other scale. Recall that the mental other questions were asked for each partner (randomly ordered along with the social other questions) directly after each clapping game test phase. The manipulation check was administered at the very end of the procedure to assess whether participants correctly recalled which model was the synchronous and asynchronous partner. Generally, participants were not very accurate in correctly identifying which partner clapped synchronously or asynchronously with 59.9% of participants correctly responding to the manipulation check. It may be that the manipulation check question challenged children's memory at the end of the procedure. To this point, while observing participants during the session, some would verbally express the current partner was hearing a different sound during the clapping game and proceed to answer the manipulation check incorrectly. Another possible explanation (that is not mutually exclusive) is that those who correctly answered the manipulation check were paying more attention and were more engaged during the session and as a result attributed more mental states. Nonetheless, it is puzzling why the manipulation check would show an effect on the mental other measure but no other variables, and the finding is particularly confusing since the mental other would have been completed for the first partner before seeing the second partner.

All things considered, does behavioral synchrony extend to social robots? Without the full sample size, it is difficult to draw strong conclusions. Still, the results from the sticker sharing task indicated a preference for synchronous humans and asynchronous non-human others, with a stronger inclination for children to share with the asynchronous metronome and the robot falling in-between the human and the metronome (but still favoring the asynchronous robot). The proclivity children demonstrated in preferring synchronous humans and asynchronous non-human others was augmented by the findings that those who decided to share with the synchronous human had previously ascribed more sociality to the synchronous human (than the asynchronous human) and those who decided to share with asynchronous robot ascribed more sociality to the asynchronous robot (than the synchronous robot). Notably, there were no such associations for the metronome; that is, children did not demonstrate any differences in social ascriptions based on their sharing preferences in the metronome condition. Considering both children's sharing preferences and its relation to their social ascription for humans and robots, it may be that the prosocial outcomes of synchrony may be limited to those that children view as a "social other" (humans, social robots) and not to mechanical devices (metronome). Interestingly, children's social ascriptions and sharing preferences favored the asynchronous robot which might suggest that asynchrony is a cue for agency or more simply that children attended more (and thus preferred) the asynchronous robot. Altogether, these finding suggest that synchrony elicits positive social benefits for humans and these benefits may extend to non-human social others, representing an exciting area for fruitful research.

Limitations and Future Directions

One of the salient limitations of the current study is the use of recorded videos to facilitate synchronous or asynchronous movement, reducing the ecological validity. Previous work has suggested that robots on screens result in diminished learning, ability to perform tasks, and attitudes (Belpaeme et al., 2018; Li, 2015). Yet, it is more common to use videos, images, or other non-present forms than it is to use a physically present robot when studying mental state attributions to robots (Thellman et al., 2022). Future research on behavioral synchrony should consider continuing to explore how children differentiate human and non-human agents which are physically present. As social robots are being incorporated into everyday settings, understanding the mechanisms and circumstances in which children will prefer synchronous or asynchronous agents can bolster interactions with technology. For example, programming social robots to facilitate movement-based learning would lead to compelling new research for behavioral synchrony by examining the effects of synchrony on learning outcomes.

Furthermore, previous work has suggested interpersonal synchrony must occur between those synchronizing, and precision in synchronizing influences the intensity of synchrony effects (Hove & Rise, 2009). Interpersonal synchrony could have been hindered using video, or children could have become disengaged with the video resulting in imprecision or inattention. The findings from the in-progress blind coding of the synchrony tasks should help clarify the concern of interpersonal synchrony. Despite the constraints of the robot condition, it is possible any of the agent types physically present in the room could modify the outcomes demonstrated by the current study.

The use of video stimuli in the current study was chosen for several pragmatic reasons. The Nao robot is considered unreliable to function properly for research studies requiring precision in tasks. It would be particularly difficult for the Nao to match the beats per minute of clapping during the test phases, and a crucial aspect of the synchrony manipulation was to have a beat of 150 bpm since children are more proficient at matching faster rhythms. In fact, the as described in the method, the programmed clapping rate had to be adjusted in creation of the video stimuli to match the 150 bpm and 100 bpm required for the synchronous and asynchronous conditions, respectively. Considering the large sample size needed for this study, the unreliability of the Nao robot, and the constraints in programming the robot's clapping rate, it was not practical to have Nao physically present for the experiment. One consideration for future directions could be using robots with programs and abilities that are more reliable and better suited for synchronizing movements.

Additionally, the natural pairing of the metronomes entailed barriers to the study. The metronome was a singular model, whereas the human and robot conditions involved two unique models. The metronome was only distinguishable by the height of the weight, and the synchronous and asynchronous metronome could not be counterbalanced due to these restraints. Thus, the metronome may be unbalanced in comparison to the human and robot conditions. Moreover, the natural pairing of the metronome complicated the approach of the analyses. When the model effect of the red robot receiving more mentalizing than the grey robot was confronted in preliminary analyses, the metronome natural pairing limited how the data could be further examined without removing the metronome data from analysis. The continued data collection will hopefully alleviate some of these constraints in the robot condition, but nonetheless, the natural pairing reduces limits interpretation of the differences between the agents.

Considering research on behavioral synchrony more broadly, it is important to recognize that synchronous movement manifest in a broad range of contexts. For example, many cultural practices or rituals require performing acts in a rhythm with others. Future work could examine the differences of the influences of synchrony based on the context – from movement-based learning to rituals, crowds forming a wave to religious services. These questions, provocative enough with human partners, could also incorporate the use of technology to facilitate synchrony. Not only would such research provide important insights into basic research questions (e.g., featural or behavioral cues of synchrony), but also theoretical and philosophical implications addressing, for example, whether a robot can perform a religious act or is capable of transmitting ritualistic behavior or if robots can only prompt synchrony effects in dance or educational settings. These questions are intriguing and ripe for future investigations.

Conclusion

Taken together, the current study examined the influence of behavioral synchrony on children's sharing, mentalizing, and social attributions to other people, social robots, and a mechanical device. The results from the study suggest children preferred synchronous humans and asynchronous non-human others, particularly mechanical metronomes. Humans were attributed the most mental states, and mentalizing did not differ by synchronicity of the partners. The robot was ascribed the most sociality, differing from the metronome which was attributed the least sociality. Those who shared more to the asynchronous robot ascribed more sociality to the asynchronous robot than the synchronous robot. Conversely, those who shared more to the synchronous human attributed more sociality to the synchronous human than the asynchronous human. Although this pattern did not emerge in the metronome condition, it mimics the preference for the synchronous human and the leaning preference for the asynchronous robot. In addition, 7-year-olds were more likely to share with the synchronous partner whereas 5- and 6-year-olds were more likely to share to the asynchronous partner. A similar parallel was illustrated in ascribing sociality; 7-year-olds attributed the least sociality in general, while 6-year-olds were generous and attributed the most sociality, followed closely by 5-year-olds which were approaching significance from 7-year-olds.

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Appendix A

Individual Differences in Anthropomorphism Questionnaire – Child Form (IDAQ-CF)

Researcher Instructions to Participant

"I am going to ask you some questions and we are going to use these cards to answer. The thumbs-up card is for "Yes" and the thumbs-down card is for "No."

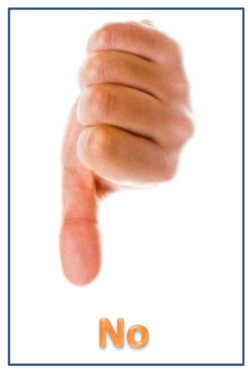
When you answer "yes" I will also ask you "how much?" and you can use these numbers to answer the questions.

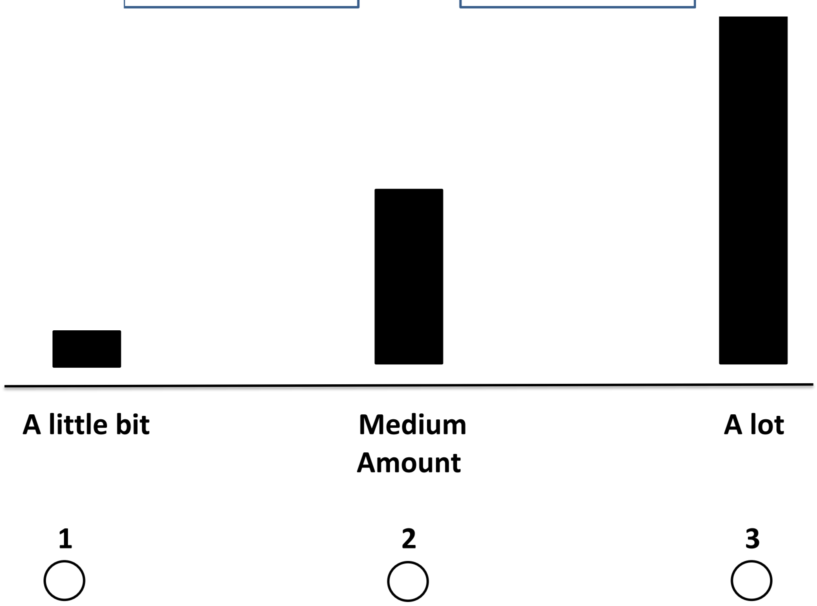
- The number 1 means "a little bit"
- The number 2 means "a medium amount"
- And the number 3 means "a lot."

To answer you can point or say your answer.

There are no right or wrong answers. I just want to know what you think. Let's practice with a couple questions."

Answer Cards





Training Questions Ordered		No	Yes - A little	Yes - Medium	Yes - A lot
T1	Do you like candy? (YES/NO) If yes, How much do you like candy?	0	1	2	3
T2	Do you like broccoli? (YES/NO) If yes, How much do you like broccoli?	0	1	2	3
T3	Do you like carrots? (YES/NO) If yes, How much do you like carrots?	0	1	2	3

IDAQ-CF Questions Random Order			No	Yes - A little	Yes - Medium	Yes - A lot
Technological	1	Does a [**robot]** know it's a robot? (YES/NO) If yes, How much does a robot know it's a robot?	0	1	2	3
	2	Does a [**TV]** have feelings, like happy & sad? (YES/NO) If yes, How much does a TV have feelings (happy & sad)?	0	1	2	3
	3	Does a [**car**] do things on purpose? (YES/NO) If yes, How much does a car do things on purpose?	0	1	2	3
	4	Does a [**computer**] think for itself? (YES/NO) If yes, How much does a computer think for itself?	0	1	2	3
Inanimate Nature	5	Does a [**mountain**] have feelings, like happy & sad? (YES/NO) If yes, How much does a mountain have feelings (happy & sad)?	0	1	2	3
	6	Does the [**ocean**] know it's an ocean? (YES/NO) If yes, How much does the **ocean** know it's an ocean?	0	1	2	3
	7	Does a [**tree**] think for itself? (YES/NO) If yes, How much does a tree think for itself?	0	1	2	3
	8	Does the [**wind**] do things on purpose? (YES/NO) If yes, How much does the wind do things on purpose?	0	1	2	3
Animate Nature	9	Does a [**cheetah**] have feelings, like happy & sad? (YES/NO) If yes, How much does a cheetah have feelings (happy & sad)?	0	1	2	3
	10	Does a [**turtle**] do things on purpose? (YES/NO) If yes, How much does a turtle do things on purpose?	0	1	2	3
	11	Does an [**insect or bug**] think for itself? (YES/NO) If yes, How much does an insect or bug think for itself?	0	1	2	3
	12	Does a [**lizard**] know it's a lizard? (YES/NO) If yes, How much does a lizard know what it is?	0	1	2	3

Appendix B

Blind Coding

1. Did they clap?
   - Yes
   - Yes, delayed start (# of claps: ___)
   - Yes, ended early (# of claps: ___)
   - Did not clap at all
2. Was the clap synchronous with the sound?
   - Synchronous
   - Asynchronous, slower than the sound
   - Asynchronous, faster than the sound
3. What motion did they do when clapping?
   - Two handed clap
   - Table tapping
   - Backhands clap
   - Finger claps
   - Unable to code (note: _____)
4. Where did the participant look:

   At the screen?
     - Yes
     - No

   Away from the screen?
     - Yes
     - No

   Eyes closed?
     - Yes
     - No

Appendix C

Mental Other Scale

1. How much does this **[person/robot/sound machine]** think for itself?

   (1) Not at all (2) A little bit (3) A medium amount (4) A lot

2. How much does this **[person/robot/sound machine]** have feelings, like happy and sad?

   (1) Not at all (2) A little bit (3) A medium amount (4) A lot

3. How much does this **[person/robot/sound machine]** know that it is a **[person/robot/sound machine]**?

   (1) Not at all (2) A little bit (3) A medium amount (4) A lot

4. How much does this **[person/robot/sound machine]** do things on purpose?

   (1) Not at all (2) A little bit (3) A medium amount (4) A lot

5. How smart do you think this **[person/robot/sound machine]** is?

   (1) Not at all (2) A little bit (3) A medium amount (4) A lot

Appendix D

Social Other Scale

1. How much do you like this **[person/robot/sound machine]**?

   (1) Not at all (2) A little bit (3) A medium amount (4) A lot

2. Would you like to be friends with the **[person/robot/sound machine]**?

   (1) Not at all (2) A little bit (3) A medium amount (4) A lot

3. If this **[person/robot/sound machine]** seemed sad, would you feel you should comfort them/it?

   (1) Not at all (2) A little bit (3) A medium amount (4) A lot

4. If you were lonely, would you want to spend time with this **[person/robot/sound machine]**?

   (1) Not at all (2) A little bit (3) A medium amount (4) A lot

5. How much did you enjoy playing the clapping game with this **[person/robot/sound machine]**?

   (1) Not at all (2) A little bit (3) A medium amount (4) A lot

Appendix E

Manipulation Check

Which partner do you think heard a *different* sound than you?

- ☐ Red Robot
- ☐ Grey Robot
- ☐ Actor 1
- ☐ Actor 2
- ☐ Low Weight Metronome
- ☐ High Weight Metronome

Appendix F

Demographics

Participant Demographics

Today's Date: ________________________

Child's Date of Birth: _________________________
Month / Day / Year

Age of Child: _______ years, ________months

Child's Gender: ☐ Male ☐ Female ☐ Another gender:______________

1. What are your child's ethnic origins? Ethnicity refers to the origins of the respondent's ancestors and should not be confused with citizenship, nationality, or place of birth. (Check any/all that apply)
   - ☐ African
   - ☐ Asian
   - ☐ Caribbean
   - ☐ East Indian
   - ☐ European
   - ☐ Latin/Central/South American
   - ☐ Middle Eastern
   - ☐ Native American
   - ☐ Pacific Islander
   - ☐ Another ethnicity: __________________

2. Has your child been **diagnosed** with any form of developmental delay, learning or reading deficiency or disability, or cognitive or social impairment? (such as dyslexia, an autistic spectrum disorder, Down's syndrome, nonverbal learning disability, specific language impairment etc.)
   - ☐ No.
   - ☐ Yes. Please specify what diagnosis your child received:

     ____

     ____

3. Do you **suspect** that your child may have a form of developmental delay, learning or reading deficiency or disability, or cognitive or social impairment (such as dyslexia, an autistic spectrum disorder, Down's syndrome, nonverbal learning disability, specific language impairment etc.)?
   - ☐ No.
   - ☐ Yes. Please specify what diagnosis your child received:

     ____

     ____

Information About the Child's Family

1. How many ***siblings*** does the participating child have? ____________

   If applicable, please list the dates of birth and gender/sex of siblings (from oldest to youngest):

Date of Birth (M/D/Y)	**Gender/Sex**	**Date of Birth (M/D/Y)**	**Gender/Sex**
(1) ______________	______________	(4)_____________	________________
(2) ______________	______________	(5)_____________	________________
(3) ______________	______________	(6)_____________	________________

2. Range of **family** income from **all sources**:

   ☐ 0 – 19,999
   ☐ 20,000 – 39,999
   ☐ 40,000 – 69,999
   ☐ 70,000 – 99,999
   ☐ 100,000-139,999
   ☐ 140,000 – 179,999
   ☐ 140,000 – 179,999
   ☐ 180,000 – 219,000
   ☐ 220,000 or greater

3. What religion, if any, does your family practice/affiliate with?

   ☐ Christian
   ☐ Jewish
   ☐ Buddhist
   ☐ Hindu
   ☐ Muslim/Islam
   ☐ Nonreligious/Agnostic/Atheist
   ☐ Another religion: _____________

4. If applicable, how strongly do you hold your religious beliefs (i.e. not how often you follow your religious practices, but how strongly do you believe in them)? **[circle a <u>number</u>]**

   [Not Very Strongly] **1 2 3 4 5 6 7** [Very Strongly]

5. Based on what you know about politics, are you [circle the number that best represents your political attitudes] **[circle a <u>number</u>]**

   [Liberal] **1 2 3 4 5 6 7 8 9 [**Conservative]

6. Based on what you know about politics, are you most likely to vote [circle the number that best represents your political attitudes] **[circle a <u>number</u>]**

   [Democrat] **1 2 3 4 5 6 7 8 9 [**Republican]

1. How many ***parents/legal guardians*** are involved in the participating child's life? ___________

Information about ***Parent/Legal Guardian A*** (person completing this form)

2. **Relationship to child:**
   - ☐ Biological parent
   - ☐ Adoptive parent
   - ☐ Step parent
   - ☐ Legal guardian

3. **Sex:**
   - ☐ Female
   - ☐ Male
   - ☐ Other: _____________

4. **Approximate percent of child's waking hours spent with you: ______%**

5. **Current age:**
   - ☐ 17 or less
   - ☐ 18 – 25
   - ☐ 26 – 30
   - ☐ 31 – 35
   - ☐ 36 – 40
   - ☐ 41 – 45
   - ☐ 46 – 50
   - ☐ 51 – 55
   - ☐ 56 – 60
   - ☐ 61 – 65
   - ☐ 66 +

6. **Current education level:**
   - ☐ Does not apply/Unknown
   - ☐ Primary School
   - ☐ Some High School
   - ☐ High School Diploma
   - ☐ Some College/University
   - ☐ Assoc./Trade Degree
   - ☐ Bachelor's Degree
   - ☐ Master's Degree
   - ☐ Professional Degree
   - ☐ Doctoral Degree
   - ☐ Other, please specify: __________________

7. **Current Occupational status:** *if on leave, please also check status when *not* on leave.
   - ☐ Employed full-time
   - ☐ Employed part-time
   - ☐ Temporary leave*
   - ☐ Stay-at-home
   - ☐ Student
   - ☐ Unemployed

If applicable, please provide information about other parents/legal guardians.

Information about ***Parent/Legal Guardian B***

8. **Relationship to child:**
   - ☐ Biological parent
   - ☐ Adoptive parent
   - ☐ Step parent
   - ☐ Legal guardian

9. **Sex:**
   - ☐ Female
   - ☐ Male
   - ☐ Other: _____________

10. **Approximate percent of child's waking hours spent with Parent/Legal Guardian B: ______%**

11. **Current age:**
    - ☐ 17 or less
    - ☐ 18 – 25
    - ☐ 26 – 30
    - ☐ 31 – 35
    - ☐ 36 – 40
    - ☐ 41 – 45
    - ☐ 46 – 50
    - ☐ 51 – 55
    - ☐ 56 – 60
    - ☐ 61 – 65
    - ☐ 66 +

12. **Current education level:**
    - ☐ Does not apply/Unknown
    - ☐ Primary School
    - ☐ Some High School
    - ☐ High School Diploma
    - ☐ Some College/University
    - ☐ Assoc./Trade Degree
    - ☐ Bachelor's Degree
    - ☐ Master's Degree
    - ☐ Professional Degree
    - ☐ Doctoral Degree
    - ☐ Other, please specify: __________________

13. **Current occupational status:** *if on leave, please also check status when *not* on leave.
    - ☐ Employed full-time
    - ☐ Employed part-time
    - ☐ Temporary leave*
    - ☐ Stay-at-home
    - ☐ Student
    - ☐ Unemployed

If applicable, please continue with information about other parents/legal guardians.

Information about ***Parent/Legal Guardian C***

14. **Relationship to child:**
- ☐ Biological parent
- ☐ Adoptive parent
- ☐ Step parent
- ☐ Legal guardian

15. **Sex:**
- ☐ Female
- ☐ Male
- ☐ Other: ______________

16. **Approximate percent of child's waking hours spent with Parent/Legal Guardian C: ______%**

17. **Current age:**
- ☐ 17 or less
- ☐ 18 – 25
- ☐ 26 – 30
- ☐ 31 – 35
- ☐ 36 – 40
- ☐ 41 – 45
- ☐ 46 – 50
- ☐ 51 – 55
- ☐ 56 – 60
- ☐ 61 – 65
- ☐ 66 +

18. **Current education level:**
- ☐ Does not apply/Unknown
- ☐ Primary School
- ☐ Some High School
- ☐ High School Diploma
- ☐ Some College/University
- ☐ Assoc./Trade Degree
- ☐ Bachelor's Degree
- ☐ Master's Degree
- ☐ Professional Degree
- ☐ Doctoral Degree
- ☐ Other, please specify: ___________________

19. **Current Occupational status:** *if on leave, please also check status when *not* on leave.
- ☐ Employed full-time
- ☐ Employed part-time
- ☐ Temporary leave*
- ☐ Stay-at-home
- ☐ Student
- ☐ Unemployed

If applicable, please continue with information about other parents/legal guardians.

Information about ***Parent/Legal Guardian D***

20. **Relationship to child:**
- ☐ Biological parent
- ☐ Adoptive parent
- ☐ Step parent
- ☐ Legal guardian

21. **Sex:**
- ☐ Female
- ☐ Male
- ☐ Other: ______________

22. **Approximate percent of child's waking hours spent with Parent/Legal Guardian D: ______%**

23. **Current age:**
- ☐ 17 or less
- ☐ 18 – 25
- ☐ 26 – 30
- ☐ 31 – 35
- ☐ 36 – 40
- ☐ 41 – 45
- ☐ 46 – 50
- ☐ 51 – 55
- ☐ 56 – 60
- ☐ 61 – 65
- ☐ 66 +

24. **Current education level:**
- ☐ Does not apply/Unknown
- ☐ Primary School
- ☐ Some High School
- ☐ High School Diploma
- ☐ Some College/University
- ☐ Assoc./Trade Degree
- ☐ Bachelor's Degree
- ☐ Master's Degree
- ☐ Professional Degree
- ☐ Doctoral Degree
- ☐ Other, please specify: ___________________

25. **Current Occupational status:** *if on leave, please also check status when *not* on leave.
- ☐ Employed full-time
- ☐ Employed part-time
- ☐ Temporary leave
- ☐ Stay-at-home
- ☐ Student
- ☐ Unemployed

Appendix G

Robot Interest and Knowledge Questions (Parent Report)

1. Rate the participating child's ***interest*** in robots:

1 2 3 4 5

1 = No Interest 5 = Really Interested

2. Rate the participating child's ***knowledge*** about robots:

1 2 3 4 5

1 = No Knowledge 5 = Really Knowledgeable

Appendix H

Children's Social Understanding Scale (CSUS) Short Form (Parent Report)

My Child…	**Definitely Untrue**	**Somewhat Untrue**	**Somewhat True**	**Definitely True**	**Don't Know**
1. Talks about differences in what people like or want (e.g., "You like coffee but I like juice").	1	2	3	4	DK
2. Uses words that express uncertainty (e.g., "We might go to the park"; "Maybe my shoes are outside").	1	2	3	4	DK
3. Realizes that experts are more knowledgeable than others in their specialty (e.g., understands that doctors know more than others about treating illness).	1	2	3	4	DK
4. Has trouble figuring out whether you are being serious or just joking.	1	2	3	4	DK
5. Is good at playing "hide and seek" (e.g., is hard to find, does not make give-away noises).	1	2	3	4	DK
6. Talks about how her/his beliefs have changed over time (e.g., "I used to think that drinking from a cup is hard, now I think it's easy").	1	2	3	4	DK
7. Talks about people's mistaken beliefs (e.g., "He thought it was a dog but it was really a cat"; "I thought mommy was coming but it was really daddy").	1	2	3	4	DK
8. Understands that hurting others on purpose is worse than hurting others accidentally.	1	2	3	4	DK
9. When given an undesirable gift, pretends to like it so as not to hurt the other person's feelings.	1	2	3	4	DK

	My Child…	Definitely Untrue	Somewhat Untrue	Somewhat True	Definitely True	Don't Know
10.	When talking on the phone, behaves as if the listener can actually see her/him (e.g., assumes that the listener knows what s/he is wearing).	1	2	3	4	DK
11.	Understands that different people can have different feelings about the same thing (e.g., one child likes a dog but another child is scared of it).	1	2	3	4	DK
12.	Takes into account what others want (e.g., takes turns, shares toys, compromises with other children regarding which game to play).	1	2	3	4	DK
13.	Talks about the difference between the way things look and how they really are (e.g., "It looks like a snake but it's really a lizard").	1	2	3	4	DK
14.	Talks about conflicting emotions (e.g., "I am happy to go on vacation, but I am sad about leaving friends behind").	1	2	3	4	DK
15.	Is good at directing people's attention (e.g., points at things to get others to look at them).	1	2	3	4	DK
16.	Talks about the difference between intentions and outcomes (e.g., "He tried to open the door but it was locked").	1	2	3	4	DK
17.	Understands that telling lies can mislead other people.	1	2	3	4	DK
18.	Talks about the difference between what people want and what they actually get (e.g., "She wanted a puppy but she got a kitten").	1	2	3	4	DK

Appendix I

Children's Social Preference Scale (CSPS) (Parent Report)

	How much is your child like that? Not at All ←→ A Lot				
1. My child often seems content to play alone.	1	2	3	4	5
2. My child seems to want to play with other children, but is sometimes nervous to.	1	2	3	4	5
3. My child is just as happy to play quietly by his/herself than to play with a group of children.	1	2	3	4	5
4. My child is happiest when playing with other children.	1	2	3	4	5
5. My child will turn down social initiations from other children because he/she is 'shy'.	1	2	3	4	5
6. My child often approaches other children to initiate play.	1	2	3	4	5
7. My child 'hovers' near where other children are playing, without joining in.	1	2	3	4	5
8. My child rarely initiates play activities with other children.	1	2	3	4	5
9. If given the choice, my child prefers to play with other children rather than alone.	1	2	3	4	5
10. My child often watches other children play without approaching them.	1	2	3	4	5
11. Although he/she appears to desire to play with others, my child is sometimes anxious about interacting with other children.	1	2	3	4	5

Appendix J

Mental Other Mixed Effects Models

Table J1

Model Comparison for Interaction or Reduced Fixed Effects

Fixed Effects	AIC	BIC	Log Likelihood
SYNC * Age	413.30	433.33	-200.65
SYNC * Agent	410.92	430.94	-199.46
Agent * Age	413.36	433.39	-200.68
SYNC + Age	411.97	428.65	-200.98
SYNC + Agent	412.71	429.40	-201.36
Agent + Age	411.81	428.50	-200.91
SYNC * Agent + Age	411.89	435.25	-198.94

Table J2

Model Comparison

Model	AIC	BIC	Bayes Factor
SYNC * Agent	410.92	430.25	8.61
SYNC * Agent + Age	411.89	435.25	0.12

Table J3

*Model Summary SYNC * Agent*

Random Effects	Variance	*SD*
Participant ID	.75	.87
Residual	.10	.31

Fixed Effects	Estimate	*SE*	*df*	*t*	95% CI	*p*
Intercept	1.72	.094	103.99	18	1.53, 1.90	< .00
SYNC	.02	.05	104	.37	-0.08, 0.11	.71
Agent	.14	.24	103.99	.569	-0.34 0.61	.57
SYNC * Agent	-.24	.12	104	-1.97	-0.47 0.00	.05

Table J4

Exploratory Model Comparisons

Fixed Effects	AIC	BIC	Log Likelihood	Bayes Factor
SYNC * Agent + Age + Manipulation Check	362.51	388.23	-173.25	142.03
SYNC * Agent + Age + Manipulation Check + IDAQ Animal + IDAQ Technology and Nature	366.41	398.56	-173.21	.01

Table J5

*Selected Model Summary SYNC * Agent + Age + Manipulation Check*

Random Effects	Variance	*SD*
Participant ID	.63	.79
Residual	.11	.33

Fixed Effects	Estimate	*SE*	*df*	*t*	95% CI	*p*
Intercept	1.98	.52	92	3.84	0.96, 3.00	< .00
SYNC	.04	.05	92	.68	-0.07, 0.14	.50
Agent	-.09	.25	92	-.37	-0.58, 0.39	.71
Age	-.06	.08	92	-.86	-0.22, 0.086	.39
Manipulation Check	.41	.18	92	2.28	0.05, 0.76	.02
SYNC * Agent	-.31	.14	92	-2.27	-0.58, -0.04	.03

Appendix K

Social Other Mixed Effects Models

Table K1

Model Comparison for Interaction or Reduced Fixed Effects

Fixed Effects	AIC	BIC	Log Likelihood
SYNC * Age	489.39	509.41	-238.69
SYNC * Agent	484.20	504.22	-236.10
Agent * Age	480.08	500.11	-234.04
SYNC + Age	487.45	504.14	-238.72
SYNC + Agent	483.59	500.28	-236.79
Agent + Age	478.09	494.78	-234.04
Agent + Age + SYNC	479.82	499.85	-233.91

Table K2

Model Comparison

Model	AIC	BIC	Bayes Factor
Agent * Age	480.08	500.11	0.07
Agent + Age	478.09	494.78	14.38

Table K3

Selected Model Summary Agent + Age

Random Effects	Variance	SD				
Participant ID	.58	.76				
Residual	.22	.47				

Fixed Effects	Estimate	*SE*	*df*	*t*	95% CI	*p*
Intercept	2.87	.49	103.99	5.823	1.90, 3.85	< .00
Age	-.18	.07	103.99	-2.434	-0.32, -0.03	.02
Agent	.71	.22	104	3.178	0.27, 1.16	< .00

Table K4

Exploratory Model Comparisons

Fixed Effects	AIC	BIC	Log Likelihood
SYNC + Agent + Age + Manipulation Check	432.39	454.90	-209.16
SYNC + Agent + Age + Manipulation Check + IDAQ Animal + IDAQ Technology and Nature	435.66	464.40	-208.83

Table K5

Model Summary SYNC + Agent + Age + Manipulation Check

Random Effects	Variance	*SD*
Participant ID	.56	.75
Residual	.24	.50

Fixed Effects	Estimate	*SE*	*df*	*t*	95% CI	*p*
Intercept	2.65	.52	92	5.17	1.63, 3.66	< .00
SYNC	-.06	.07	92	-.79	-0.20, 0.086	.43
Agent	.63	.24	92	2.59	0.15, 1.12	.01
Age	-.16	.08	92	-2.11	-0.31, -0.01	.04
Manipulation Check	.21	.18	92	1.19	-0.14, 0.57	.24