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Selective social learning in infancy: looking for mechanisms

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Abstract

Although there is mounting evidence that selective social learning begins in infancy, the psychological mechanisms underlying this ability are currently a controversial issue. The purpose of this study is to investigate whether theory of mind abilities and statistical learning skills are related to infants' selective social learning. Seventy-seven 18-month-olds were first exposed to a reliable or an unreliable speaker and then completed a word learning task, two theory of mind tasks, and a statistical learning task. If domain-general abilities are linked to selective social learning, then infants who demonstrate superior performance on the statistical learning task should perform better on the selective learning task, that is, should be less likely to learn words from an unreliable speaker. Alternatively, if domain-specific abilities are involved, then superior performance on theory of mind tasks should be related to selective learning performance. Findings revealed that, as expected, infants were more likely to learn a novel word from a reliable speaker. Importantly, infants who passed a theory of mind task assessing knowledge attribution were significantly less likely to learn a novel word from an unreliable speaker compared to infants who failed this task. No such effect was observed for the other tasks. These results suggest that infants who possess superior social-cognitive abilities are more apt to reject an unreliable speaker as informant. A video abstract of this article can be viewed at: https://youtu.be/zuuCniHYzqo

RESEARCH HIGHLIGHTS

- Infants were more likely to learn a new word from a reliable speaker compared to an unreliable speaker.
- Infants who passed a theory of mind task measuring knowledge attribution were less likely to learn a new word from an unreliable speaker in comparison to infants who failed this task.
- No relation was found between statistical learning skills and selective social learning.
- The findings of the present paper provide evidence that social-cognitive abilities, such as theory of mind, are related to selective social learning in infancy.

1 | INTRODUCTION

Young children acquire new information mainly by interacting with and observing others (Box, 1984). This is known as social learning. Social learning is crucial for children, but it can also be risky as not all informants have accurate knowledge or good intentions (Poulin-Dubois & Brosseau-Liard, 2016). Because children frequently rely on information provided by other individuals, they need to be able to select informants who are accurate (Koenig & Sabbagh, 2013). The last decade has revealed that children engage in selective social learning, where they can differentiate unreliable and reliable sources of information, and thus select whom to trust and learn from (Koenig & Harris, 2005; Koenig & Sabbagh, 2013; Mills, 2013; Nurmsoo, Robinson, & Butterfill, 2010). In a landmark study, Koenig, Clément, and Harris (2004) presented 3- and 4-year-olds with an informant who labelled familiar objects accurately and an informant who labelled the same objects inaccurately (e.g., a ball was labeled a shoe). Results revealed that 3- and 4-year-olds preferred to learn a new word from the reliable speaker compared to the unreliable one.

While the bulk of the research on selective learning from testimony has been conducted with preschool-age children, there is now mounting evidence that it begins very early in development (see Poulin-Dubois & Brosseau-Liard, 2016, for a review). In a pioneering study, Chow, Poulin-Dubois, and Lewis (2008) presented 14-month-olds with an informant who looked inside a box containing a toy while expressing a positive emotion (reliable emoter) or an informant who demonstrated the same positive emotion towards an empty container (unreliable emoter). Results revealed that infants were able to detect the unreliable emoter, as shown by their increased latency to inspect the content of the box over trials. More importantly, they were less likely than the infants in the reliable emoter condition to subsequently follow the person's eye gaze in another context. Similarly, research has shown that infants are less likely to imitate the novel actions of an informant who displays unreliable emotional cues (Poulin-Dubois, Brooker, & Polonia, 2011). In line with this research, 18-month-olds have been found to differentiate congruent and incongruent emotional reactions to events such as losing an object, and are more willing to help and be guided by the emotional expressions of a reliable informant who previously displayed congruent emotional reactions (Chiarella & Poulin-Dubois, 2013, 2017). In addition to emotional cues, infants have also been shown to rely on the conventionality (Zmyj, Buttelmann, Carpenter, & Daum, 2010) as well as the confidence (Birch, Akmal, & Frampton, 2010; Brosseau-Liard & Poulin-Dubois, 2014) conveyed by the informant. Furthermore, studies have revealed that infants, like older children, use accuracy to determine whom to learn from, which is an epistemic, or knowledge-related cue (Brooker & Poulin-Dubois, 2013; Koenig & Woodward, 2010; Mills, 2013). For example, 18-month-old infants are more likely to learn a new word or a new action from a reliable speaker compared to an unreliable one (Brooker & Poulin-Dubois, 2013).

Although the evidence is well established that children prefer to learn from reliable sources of information, the psychological mechanisms underlying this ability are unclear and have recently been the topic of hot debate, particularly in interpreting infants' behaviours (Heyes, 2017; Poulin-Dubois, 2017; Sobel & Kushnir, 2013). According to one view, infants possess domain-specific, higher-order, cognitive abilities that allow them to selectively learn from others, whereas an alternative "leaner" interpretation posits that infants rely on more domain-general, lower-order, cognitive functions. In a recent provocative paper, Heyes (2017) has argued that given that selective learning occurs in animals which do not possess higher cognitive functions, such as theory of mind, cognitive sophisticated abilities are unnecessary to account for infants' selective behaviours. Instead, simple domain-general mechanisms, such as associative learning, might be sufficient (Heyes, 2017). It is only in adults and older children that social learning strategies can be explained by domain-specific processes, such as metacognition, learned through experience in social interactions (Heyes, 2016).

In terms of domain-specific abilities, theory of mind has been proposed to account for how young children selectively learn from others. Theory of mind is defined as the ability to understand that others possess mental states, such as beliefs, knowledge, intentions, and desires (Wellman, 2014). A relation between these two abilities has been put forward as children can make inferences based on others' mental states when deciding who is informative and who is deceptive. Thus, children who have a greater understanding of individuals' mental state of knowledge should be better able to selectively learn from others, since they can infer that the variability in accuracy reflects individual variation in knowledge (Brosseau-Liard, Penney, & Poulin-Dubois, 2015). In fact, such a link has been documented in numerous studies that have focused on preschool and school-age children (Brosseau-Liard et al., 2015; DiYanni & Kelemen, 2008; DiYanni, Nini, Rheel, & Livelli, 2012; Fusaro & Harris, 2008; Lucas, Lewis, Pala, Wong, & Berridge, 2013; Mills & Elashi, 2014). For example, in a recent study, 3- and 4-year-olds with superior theory of mind abilities performed better on a selective word learning task when the two informants differed on epistemic cues, such as verbal accuracy (Brosseau-Liard et al., 2015). Conversely, there was no such association with another selective learning task when the two informants differed on non-epistemic cues, such as physical strength. According to Brosseau-Liard and colleagues (2015), theory of mind should not be related to performance on a selective learning task involving physical strength, as it is not a knowledge-related attribute. Thus, 3- and 4-year-olds' theory of mind abilities did not lead them to selectively learn from informants by considering all of their attributes, but it was specific to informants who displayed knowledge-related cues. Although there is evidence of a relation between theory of mind and selective learning, the results are mixed. For example, in a study by Pasquini, Corriveau, Koenig, and Harris (2007), it was revealed that 3- and 4-year-olds who performed poorly on a false belief task were still able to perform well on a selective learning task. As such, the relation between theory of mind and selective learning is controversial and needs further research. In addition, this link has never been explored in infancy.

With regard to domain-general abilities, statistical learning has been proposed as a mechanism underlying selective social learning. Statistical learning is a rapid and robust ability by which infants use statistical cues to identify regularities in their environment (Aslin & Newport, 2012; Denison & Xu, 2014; Ruffman, Taumoepeau, & Perkins, 2012; Saffran, Aslin, & Newport, 1996). For instance, in a violation of expectation paradigm, 6- to 8-month-old infants looked significantly longer at a violation of random sampling (Xu & Garcia, 2008). It has also been demonstrated that 12- to 14-month-old infants are able to detect that an object has a higher probability of being found in one of two cups presented to them (Denison & Xu, 2010). More importantly, research suggests that there are individual differences in statistical learning in both infancy and childhood (Arciuli & Simpson, 2011; Ellis, Robledo, & Deák, 2014; Kaufman et al., 2010; Kidd, 2012; Kidd & Arciuli, 2016; Shafto, Conway, Field, & Houston, 2012). For instance, a recent study demonstrated that individual differences in statistical learning are associated with 6- to 8-year-olds' comprehension of syntax (Kidd & Arciuli, 2016). According to Sobel and Kushnir (2013), these individual differences in statistical learning abilities may be related to infants' selective social learning (Sobel & Kushnir, 2013). Just as statistical learning involves detecting patterns of regularity, selective social learning involves detecting patterns of reliability by keeping track of the informant's prior accuracy in deciding whether to learn from them (Sobel & Kushnir, 2013). Therefore, infants may be relying on statistical cues when tracking the accuracy of the informant and inferring conclusions based on their history (Sobel & Kushnir, 2013; Tummeltshammer, Wu, Sobel, & Kirkham, 2014).

Taken together, the nature of the psychological mechanisms underlying early selective social learning is currently a controversial issue with little empirical evidence available to settle the debate. Although theory of mind and statistical learning have both been proposed as potential correlates, no study has ever pitted these abilities against one another when investigating individual differences in selective learning. Therefore, the main purpose of the present study was to provide a better understanding of the nature of selective social learning by investigating whether theory of mind and statistical learning skills play a role in this ability. Infants observed a speaker label familiar objects either accurately or inaccurately and were then provided the opportunity to learn a new word from this speaker. In line with prior research, we hypothesized that infants would be more likely to learn a new word from a reliable speaker than an unreliable one. Two theory of mind tasks and a statistical learning task were also administered to investigate whether these abilities are related to infants' performance on the selective word learning task. If domain-general abilities are associated with selective social learning, then infants who performed better on the statistical learning task should be less likely to learn a new word from an unreliable speaker. Those with larger vocabularies might also be less likely to learn from an unreliable speaker if general abilities, such as verbal IQ, account for such selectivity. In contrast, if domain-specific abilities are associated with selective social learning, then superior performance on the theory of mind tasks should be associated with less willingness to learn from an unreliable speaker. No such links would be expected with performance in the reliable condition, as infants have been shown to learn new words even without any information about the competence of the speaker.

2 | METHOD

2.1 | Participants

The final sample consisted of 77 18-month-old infants (M_{age} = 18.54 months, *SD* = .50; range = 17.4–20; 39 males, 38 females). Infants were excluded from the sample if they did not meet a number of task-specific criteria (see details below). Participants were recruited from birth lists provided by a governmental health agency. All infants had no auditory or visual impairments, and were exposed to English or French.

2.2 | Measures and materials

2.2.1 | MacArthur-Bates Communicative Development Inventories: Short Form (MCDI-I)

The American-English and the French-Canadian adaptation of the MCDI-I were used to assess infants' total productive and receptive vocabulary (Fenson et al., 2000; Trudeau, Frank, & Poulin-Dubois, 1999). This vocabulary checklist, used for children aged 8–18 months, was completed by the child's primary caregiver. The MCDI-I consists of 89 vocabulary items and includes nouns, verbs, and adjectives that infants would have learned in this age range.

2.2.2 | Word comprehension checklist

Parents were asked to indicate, on a 20-word checklist, which words their infant understood (Brooker & Poulin-Dubois, 2013). The checklist consisted of typical words infants of this age would understand. This report was used for the selective social learning task in order to select words that a given child was familiar with.

2.2.3 | Selective social learning

There were two phases in the task measuring selective social learning, where infants were presented with labels for both familiar and novel objects (Brooker & Poulin-Dubois, 2013).

Reliability phase

Participants were randomly assigned to either a reliable (*n* = 33) or an unreliable (*n* = 44) condition. Four small plastic objects were labeled either correctly or incorrectly, depending on the condition. The four items were chosen from a set of words including *ball*, *banana*, *bird*, *dog*, *spoon*, *chair*, and *shoe*. The specific words tested depended on the child's knowledge of these words as reported on the word comprehension checklist. Children were required to know three out of the four chosen objects in order to be included in this task (Brooker & Poulin-Dubois, 2013). In phase 1, the child was allowed 15 s to explore each object. In phase 2, the experimenter manipulated each object, one at a time, and labeled it three times either correctly (reliable speaker) or incorrectly (unreliable speaker). The objects were always given the same incorrect labels. For example, in the unreliable condition, infants watched as the experimenter pointed to a shoe and said, "That's a *bottle*. See, it's a *bottle*. Look at the *bottle*", if their parents had indicated that they understood the word *shoe* and thus could recognize that it had been mislabeled (Brooker & Poulin-Dubois, 2013). Once the experimenter was finished labelling the object, the child was allowed to play with the toy again for 15 s.

Word learning phase

This task assessed infants' willingness to learn from the experimenter based on her accuracy during the reliability phase (adapted from Baldwin, 1993). This task included three phases: a warm-up phase, a training phase, and a test phase. In the warm-up phase, the experimenter presented the infant with a tray holding a pair of familiar objects (two objects not previously used in the reliability phase) and requested one. This phase was included for the purpose of making sure the infant understood the demands of the task (Brooker & Poulin-Dubois, 2013). In the training phase, the experimenter modeled the function of a pair of novel toys. For instance, a wooden nut and bolt was spun and a type of rattle was shaken. Both objects were then given to the child to explore for 15 s. The experimenter then retrieved one of the novel objects from the child and provided a novel label for it by saying, "It's a *Dax*". The same novel object was labeled four times with the same label. In the test phase, the experimenter presented the child with one of two pairs of objects on a tray: two familiar objects or two novel objects. The same object pairs were used across all trials. The experimenter requested one of the two objects from the infant by saying, "Where is X? Give me the X". The novel object that was requested was always the one that the experimenter had provided a novel label for in the training phase. Four familiar trials were alternated with four novel trials, for a total of eight trials. The novel object chosen, the location of the objects on the tray (left or right), and the type of trial (familiar or novel) that was presented first, was counterbalanced across participants. During the test phase, the object that the infant selected and gave to the experimenter was coded. If both toys were given simultaneously, the trial was repeated. This task yielded two scores measuring the proportion of trials (out of four) where infants offered the correct object; one for novel words and one for familiar words. A Pearson product-moment correlation was computed to assess inter-rater reliability and revealed perfect agreement among raters ($r(38) = 1.00$).

2.2.4 | False belief theory of mind task

An interactive false belief task was used to examine infants' theory of mind abilities by assessing their understanding that others may have different beliefs (Buttelmann, Carpenter, & Tomasello, 2009). In this task, one experimenter (E1) announced that she was going to get a toy. While E1 was away, the other experimenter (E2) showed the infant how to lock and unlock a set of 30 × 30 × 30 cm green and orange boxes with wooden pins, which were positioned at the furthest end of a table. E1 returned to the room with a toy caterpillar and told the infant that she was putting her toy in one of the boxes, while placing the toy inside as the child watched. E1 then said that she forgot her keys outside and left the room again. Following this, E2 invited the infant to play a trick on E1 by switching the location of the toy to the other box. When E1 returned, she tried to open the box in which she had placed her toy, and displayed disappointment and confusion as she realized that she was not able to open it. At this point, E2 pushed the boxes closer to the infant in order to allow the infant to touch and open one of the boxes. The infant was then prompted to help E1 find the toy in the correct box. This task assessed infants' ability to understand that E1 may hold a different belief of where the hidden toy was located. The trial was coded as pass or fail, where a pass was given to the child for choosing the box where the toy was currently located, demonstrating understanding of the experimenter's false belief. A Cohen's kappa coefficient was computed as $\kappa = 1.00$, which is indicative of a perfect degree of consistency across independent raters.

2.2.5 | Knowledge theory of mind task

A second theory of mind task was used to assess knowledge inference (Moll & Tomasello, 2007). This task measured infants' understanding that others may have knowledge that differs from their own and can make inferences based on this assumption. In a familiarization trial, two experimenters and the infant played with three familiar objects (i.e., a ball, a teddy bear, and a car) for 50 s. In a pre-test trial, E1 requested each of these toys, one at a time, in order to make sure that the infant was comfortable sharing with the experimenter. In order to pass the pre-test, infants were required to give the experimenter one of the first two objects requested. E1 then stated, "I'm going over there", while the infant watched her walk to the other end of the room and sit on a chair. E2 retrieved a novel toy (i.e., a plastic gardening tool) and brought it to E1 to play with for 30 s, as the infant watched. E2 then retrieved the toy from E1 and brought it back to the table for the infant to play with for 30 s. This process was repeated for a second novel toy (i.e., a modified bird-cage mirror). After playing with the second toy, E2 placed it on the tray next to the first novel object as E1 announced that she was leaving the room. E2 then introduced a third novel object to the infant and added it to the tray (i.e., a small modified abacus). The third novel object served as the target object. When E1 returned to the room, she had a look of surprise on her face and exclaimed "Oh, look! Look there! Look at that there! Can you give it to me please?", while pointing towards the tray with her arm. This task was coded on a pass or fail basis, where a pass reflected the child giving the target object to E1. This task reflected infants' ability to understand that E1 was acting surprised toward a new toy that was not there before she had left the room, and was therefore not knowledgeable about this toy. The target toy, the order in which the toys were introduced, as well as the placement order on the tray were counterbalanced. A Cohen's kappa was computed as $\kappa = .88$, indicating excellent inter-rater agreement.

2.2.6 | Statistical learning task

This task assessed infants' ability to make statistical inferences, while detecting patterns in others' behaviour. In this task, adapted from Kushnir, Xu, and Wellman (2010), the child was first introduced to two types of small objects (i.e., mini frogs and ducks or cows and pigs) and had 2 minutes to explore them with the experimenter. The infant, experimenter, and a confederate then engaged in a turn-taking game with some objects (i.e., a toy car, a cup, and a ball) in order to allow the child to become comfortable with sharing. After the game, the confederate left the room. The experimenter then showed the infant a clear box containing two of the animals they had been exposed to and labeled the two types of animals inside. The box always had a ratio of 7:31 animals, where one animal served as the minority and the other animal served as the majority. For instance, if the box contained 7 ducks and 31 frogs, the minority animal was the duck and the majority animal was the frog. In the next phase, the confederate sampled five of the same type of object from the box (i.e., 5 ducks or 5 frogs), while labelling the toy (e.g., "Wow frogs! Ribbit, ribbit!"). This served as the target object, while the remaining animals were considered the alternative objects. The confederate then left the room and the experimenter removed the box and put two bowls containing each toy in front of the infant. The confederate re-entered the room and exclaimed, "Oh goody! Just what I wanted! Can you give me one?" where the infant was then required to give a toy animal to the confederate. Each infant participated in this task twice, with the confederate sampling the majority animal on one trial and the minority animal on the other trial. For this reason, two sets of animals were used (i.e., cows and pigs in the other trial). On a minority trial (i.e., 7 ducks and 31 frogs), pulling out all ducks violated random sampling. Therefore, the child should use statistical reasoning to infer that the experimenter has a preference for this toy. On a majority trial (i.e., 31 cows and 7 pigs), pulling out all cows would not violate random sampling. This task was coded on a pass or fail basis. In order to replicate Kushnir and colleagues (2010), an infant passed when he or she gave the target toy on the minority trial. Since on the majority trial the confederate's selection was due to random sampling, it was expected that infants would randomly select the object to offer the confederate, and therefore passed this trial regardless of their selection. The minority and majority animal, the trial order, and the placement of the bowls (left or right) were counterbalanced. A Cohen's kappa was computed as κ = 1.00, which is indicative of perfect inter-rater agreement.

2.3 | Procedure

A warm-up phase was first conducted, during which infants familiarized themselves with the environment and the experimenters. During this time, the caregiver filled out the MCDI-I and the word comprehension checklist in order to establish the words that would be used on the selective social learning task. The testing session began with the selective social learning task, where each child was randomly assigned to either the unreliable or the reliable condition. The infant then participated in the theory of mind tasks (false belief and knowledge) and the statistical learning task, where the order of these tasks was counterbalanced. The selective learning task was always administered first because this task served as the basis for the study and it was crucial to avoid a fatigue effect with this key task. In total, there were three experimenters. The experimenter who conducted the selective learning task did not carry out the other tasks to avoid carryover effects from the word learning manipulation. Parents received $20 as financial compensation, and infants received a certificate of merit as well as a small gift.

3 | RESULTS

Participants excluded from the selective learning task were also excluded from all additional analyses in the present study. This decision was justified by the fact that performance on the selective learning task was required to test all hypotheses. Accordingly, in addition to the final sample of 77 infants, an additional 32 infants were tested but were excluded due to fussiness (n = 17), parental interference (n = 4), experimenter error (n = 2), not having enough words in their vocabulary to participate in the selective learning task (n = 6), a side preference on the word learning task (n = 1), or giving all ambiguous responses (touching and offering both toys or none) on the word learning task (n = 2).

Comparisons were made between the two conditions to ensure that both groups were equivalent on a number of factors. There were no significant differences between the two conditions with regard to age, $t(75) = -.47$, $p = .64$, or gender, $\chi^2(1) = .11$, $p = .74$. No significant differences were also observed in infants' receptive vocabulary across the reliable (M = 55.09, SD = 23.85) and unreliable conditions (M = 48.73, SD = 18.53), $t(75) = -1.32$, $p = .19$, Cohen's $d = .31$, or in infants' expressive vocabulary across the reliable (M = 19.27, SD = 18.11) and unreliable conditions (M = 17.93, SD = 16.33), $t(75) = -.34$, $p = .74$, Cohen's $d = .08$. Furthermore, infants did not differ with regard to the number of familiar words they knew in the reliability phase of the selective social learning task across the reliable (M = 3.85, SD = .36) and unreliable (M = 3.86, SD = .35) conditions, $t(75) = .19$, $p = .85$, Cohen's $d = -.03$.

3.1 | Selective social learning task

Infants' behaviours and looking time in seconds were coded during the reliability phase to ensure that infants in each group were equally attentive when the experimenter was labelling the objects and to the toy that they were given to engage with during the training phase. Six participants were excluded from the analyses on looking time, as their eyes were not in clear view to be coded. Results indicated that infants' proportion of looking time to the experimenter as she was labelling the toys during phase 2 of the reliability task was equivalent across conditions (unreliable: M = .94, SD = .11; reliable: M = .96, SD = .07), $t(69) = -.68$, $p = .50$, Cohen's $d = -.21$. These results suggest that infants were equally attentive when the experimenter was labelling the familiar objects accurately or inaccurately. Furthermore, a condition (reliable/unreliable) by looking area (experimenter/toy/parent) mixed ANOVA was computed with infants' proportion of looking time during phase 3 of the reliability task (once the infant was given the toy) as the dependent variable. No main effect of condition, $F(1, 69) = .10$, $p = .75$, $\eta_p^2 = .001$, nor significant interaction, $F(2, 68) = 1.78$, $p = .18$, $\eta_p^2 = .05$, was found. However, a significant main effect of looking area was revealed, $F(2, 68) = 215.63$, $p < .001$, $\eta_p^2 = .67$, indicating that infants' proportion of looking time at the toy (M = .46, SD = .15) was significantly greater than their looking time at the experimenter (M = .29, SD = .13) or at their parent (M = .07, SD = .07). Thus, infants were also equally likely to engage with the toy, irrespective of whether the experimenter's label was accurate or not. During the word learning task, the proportion of time spent looking at the experimenter as she labeled the novel object was coded. Results revealed that infants in the unreliable condition (M = .69, SD = .20) and reliable condition (M = .76, SD = .18) looked equally long at the experimenter during the labelling, $t(69) = -1.49$, $p = .14$, Cohen's $d = -.37$. In addition, there was no significant difference in the proportion of trials (out of four) that infants disengaged from their toy to attend to the experimenter's toy during the labelling phase between the reliable (M = .81, SD = .24) and unreliable (M = .84, SD = .24) conditions, $t(75) = .49$, $p = .63$, Cohen's $d = -.13$. These findings suggest that infants across both conditions were equally attentive as the experimenter labelled the novel object.

In order to determine whether infants in the unreliable condition were less likely to learn a new word in comparison to infants in the reliable condition, a condition (reliable/unreliable) by trial type (novel/familiar) mixed ANOVA was conducted. The dependent variable was the proportion of trials where infants offered the target object. A significant main effect of trial type was found, wherein infants

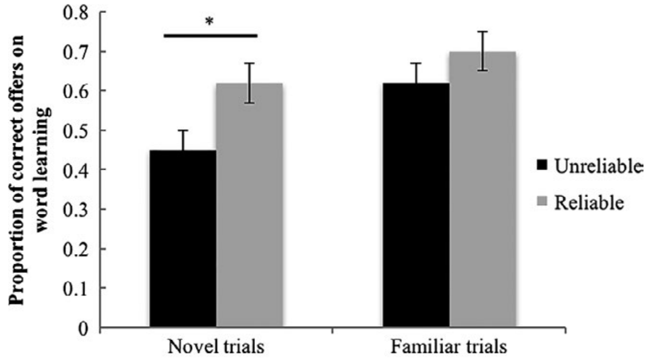

FIGURE 1 Proportion of correct trials on the word learning task as a function of condition

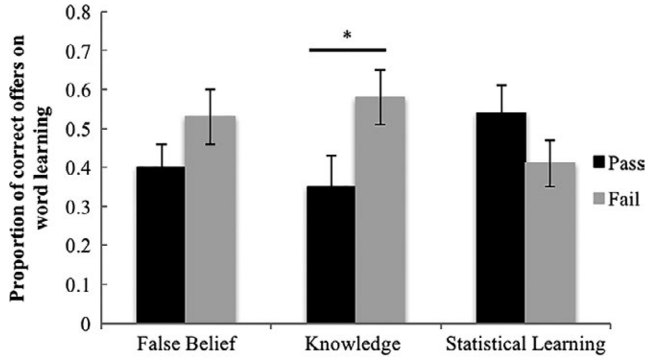

FIGURE 2 Mean proportion of correct responses in the unreliable condition as a function of performance on the theory of mind and statistical learning tasks

performed significantly better on the familiar trials (M = .66, SD = .32) than on the novel trials (M = .54, SD = .31), $F(1, 75) = 6.33$, $p = .01$, $\eta_p^2 = .08$. In addition, a significant main effect of condition was observed, revealing that infants in the reliable condition (M = .66, SD = .34) outperformed infants in the unreliable condition across trial types (M = .54, SD = .30), $F(1, 75) = 5.69$, $p = .02$, $\eta_p^2 = .07$. However, no significant interaction was found between condition and trial type, $F(1, 75) = .86$, $p = .36$, $\eta_p^2 = .01$. Nevertheless, in support of our hypothesis, planned comparisons revealed that there was a significant difference in word learning on the novel trials between infants in the unreliable and reliable conditions, $F(1, 75) = 5.89$, $p = .02$, $\eta_p^2 = .07$. In contrast, on the familiar trials, no significant difference was found between the unreliable and reliable conditions, $F(1, 75) = 1.23$, $p = .27$, $\eta_p^2 = .02$ (see Figure 1).

Furthermore, using one-sample t tests, the proportion of correct offers on the novel and familiar trials were compared to chance (.50). On the familiar trials, infants in both the reliable (M = .70, SD = .29), $t(32) = 3.88$, $p < .001$, Cohen's d = .68, and unreliable conditions (M = .62, SD = .33), $t(43) = 2.38$, $p = .02$, Cohen's d = .36, performed significantly above chance. In contrast, on the novel trials, infants in the reliable condition performed above chance (M = .62, SD = .27), $t(32) = 2.62$, $p = .01$, Cohen's d = .46, whereas infants in the unreliable condition performed at chance on the novel word trials (M = .45, SD = .33), $t(43) = -.96$, $p = .34$, Cohen's d = −.15.

3.2 | Correlates of selective social learning

In order to investigate whether domain-specific or domain-general abilities are related to selective social learning, a condition (reliable/unreliable) by score (pass/fail) ANOVA was conducted for each of the three tasks assessing the potential correlates of selective learning: false belief, knowledge, and statistical learning. The dependent variable for each ANOVA was the proportion of novel word trials where infants offered the target object on the word learning task. Pearson correlations were also computed between the MCDI scores and performance on the word learning task in order to determine whether infants' vocabulary size was related to their ability to selectively learn new words from others.

3.2.1 | False belief task

One additional participant was excluded on the false belief task due to inattentiveness. Descriptive statistics indicated that on this task, 51% of the 76 infants touched the correct box. A binomial test revealed that infants did not perform significantly above chance (.50) (p = .91). A condition (reliable/unreliable) by false belief task score (pass/fail) ANOVA with infants' performance on the novel trials of the word learning task as the dependent variable revealed a non-significant interaction, $F(1, 72) = .84$, $p = .36$, $\eta_p^2 = .01$. Planned comparisons indicated that for infants in the unreliable condition, performance on the novel trials of the word learning task did not significantly differ as a function of whether the infant passed (n = 22, M = .40, SD = .28) or failed (n = 21, M = .53, SD = .35) the false belief task, $F(1, 72) = 2.17$, $p = .15$, $\eta_p^2 = .03$, although results were in the expected direction (see Figure 2). Similar results were obtained in the reliable condition. No significant difference was found in the proportion of correct choices on the novel trials between infants who passed (n = 17, M = .62, SD = .25) or failed (n = 16, M = .63, SD = .29) the false belief task, $F(1, 72) = .01$, $p = .94$, $\eta_p^2 = .00$.

3.2.2 | Knowledge task

Sixteen additional participants were excluded on the knowledge task due to failure of the pre-test (n = 8), fussiness (n = 5), and experimenter error (n = 3). Descriptive statistics indicated that on this task, 46% of the 61 infants touched the target object. Using a binomial test, it was found that infants performed at a level above chance (.33) (p = .04). A condition (reliable/unreliable) by knowledge task score (pass/fail) ANOVA with infants' performance on the novel trials of the word learning task as the dependent variable yielded a statistically significant interaction, $F(1, 57) = 4.36$, $p = .04$, $\eta_p^2 = .07$. Planned comparisons revealed that for infants in the unreliable condition, there was a significant difference in the proportion of correct responses on the novel trials of the word learning task between infants who passed (n = 13, M = .35, SD = .32) and failed the knowledge task (n = 20, M = .58, SD = .29), $F(1, 57) = 4.87$, $p = .03$, $\eta_p^2 = .08$ (see Figure 2). This suggests that infants who passed the knowledge task were significantly

TABLE 1 Infants' responses on the statistical learning task

Response	Minority trial (sampling violation) *n*	Majority trial (no sampling violation) *n*
Target toy	35	20
Alternative toy	18	28
Both (target and alternative)	19	24
Total	72	72

Note. Response was coded by infants' first touch.

less likely to learn a novel word from an unreliable speaker. As expected, this was not the case in the reliable condition, where infants who passed (n = 15, M = .68, SD = .26) and failed (n = 13, M = .60, SD = .30) the knowledge task performed equally on the selective social learning task, $F(1, 57) = .63$, $p = .43$, $\eta_p^2 = .01$.

3.2.3 | Statistical learning task

Five additional participants were excluded on the statistical learning task due to fussiness (n = 4), and parental interference (n = 1). Descriptive statistics indicated that on this task, 49% of the 72 infants passed by touching the target object on the minority trial. As expected, the results of this task demonstrated that infants were significantly more likely to touch the target object on the minority trial, and were more likely to touch the alternative or both objects on the majority trial, $\chi^2 = 6.85$, $p = .03$ (see Table 1). A condition (reliable/unreliable) by statistical learning task score (pass/fail) ANOVA with infants' performance on the novel trials of the word learning task as the dependent variable yielded a non-significant interaction, $F(1, 68) = .001$, $p = .98$, $\eta_p^2 = .00$. Planned comparisons revealed that there was no statistically significant difference between infants who passed (n = 18, M = .54, SD = .28) or failed (n = 23, M = .41, SD = .35) the statistical learning task in terms of their performance on the novel trials of the word learning task in the unreliable condition, $F(1, 68) = 1.73$, $p = .19$, $\eta_p^2 = .03$ (see Figure 2). Similarly, in the reliable condition, infants who passed the statistical learning task (n = 17, M = .69, SD = .29) were as likely to offer the correct object on the novel word trials as infants who failed the statistical learning task (n = 14, M = .57, SD = .23), $F(1, 68) = 1.22$, $p = .27$, $\eta_p^2 = .02$.

3.2.4 | MCDI

No statistically significant correlation was found between infants' receptive vocabulary measured through the MCDI and their performance on the word learning task in the unreliable, $r(42) = .12$, $p = .43$, or reliable condition, $r(31) = .17$, $p = .33$. The correlation was also not significant when examining the relation between infants' expressive vocabulary measured through the MCDI and their performance on the word learning task in the unreliable, $r(42) = .17$, $p = .26$, or reliable condition, $r(31) = .17$, $p = .35$.

4 | DISCUSSION

The goal of the present study was to examine the contribution of domain-general and domain-specific correlates to selective social learning in infancy. Specifically, it was designed to contribute to the current debate regarding a rich versus lean interpretation of selective social learning (Heyes, 2017; Poulin-Dubois, 2017; Sobel & Kushnir, 2013). One side of the debate posits that higher-order, domain-specific functions, such as theory of mind, are fundamental to young children's ability to selectively learn from others. It is argued that children who show a greater understanding of others' behaviour should be more selective in their learning (Brosseau-Liard et al., 2015; Poulin-Dubois & Brosseau-Liard, 2016). The other side of the debate posits that lower-order, domain-general abilities, such as associative or statistical learning, influence selective social learning. According to Heyes (2017), the selective learning observed in infancy does not require any cognitive sophisticated skills, as a wide range of animals display this ability as well. In addition, Sobel and Kushnir (2013) suggested that infants' selective learning might depend on their ability to detect statistical cues. The present study found preliminary support for a rich interpretation, as the only link observed is between performance on the selective social learning and a theory of mind task.

The present contribution to the debate was to investigate the relation between infants' performance on theory of mind and statistical learning tasks and their ability to learn from an unreliable or reliable informant. Specifically, 18-month-olds participated in a word learning task following exposure to a competent or an incompetent speaker. We hypothesized that infants would be less likely to learn a new word from an unreliable speaker compared to a reliable speaker. Furthermore, it was hypothesized that if domain-general functions are related to selective social learning, then infants who passed the statistical learning task should be less likely to learn a new word from an unreliable speaker in comparison to infants who failed. On the other hand, if domain-specific functions are related to selective social learning, then infants who pass the theory of mind tasks should be less likely to learn a new word from an unreliable speaker in comparison to infants who failed. We hypothesized that there would be no relation between these correlates and selective learning in the reliable condition, as infants have been shown to learn novel words from individuals who do not display any information about their competence.

The results of the selective learning task were as expected and replicated previous research with a statistically significant difference in performance on the word learning task between infants in the unreliable and reliable conditions. Specifically, infants who observed a speaker label familiar objects inaccurately exhibited a lower proportion of correct responses on the novel trials in comparison to infants who observed a speaker label familiar objects accurately. As expected, infants in both conditions performed at a level significantly above chance on the familiar word trials. Furthermore, it was found that the differences in word learning across both conditions were not due to a lack of attention to the unreliable speaker during the labelling phase of the task. Taken together, these findings suggest that 18-month-olds are able to detect when an individual is unreliable, and have the ability to learn selectively from someone who provides more accurate information. These results are consistent with previous studies demonstrating selective social learning in the verbal domain with infants and toddlers (Brooker & Poulin-Dubois, 2013; Koenig & Woodward, 2010; Krogh-Jespersen & Echols, 2012). For instance, Brooker and Poulin-Dubois (2013) demonstrated that 18-month-olds were less likely to learn a new word from an unreliable speaker compared to a reliable speaker. Moreover, the present study adds to a growing body of literature demonstrating that young children are precocious selective learners who can use a speaker's reliability to guide their learning (see reviews by Mills, 2013; Poulin-Dubois & Brosseau-Liard, 2016).

In terms of the results regarding the psychological correlates, the findings of the present study support the hypothesis that domain-specific abilities are linked to selective learning in infancy, rather than domain-general abilities. It was found that infants who passed the knowledge task were significantly less likely to learn a novel word from an unreliable speaker compared to infants who failed the knowledge task. Importantly, in support of our hypothesis, no such relation was found for infants in the reliable condition. These results suggest that infants with superior theory of mind abilities may have been better at inferring that the unreliable speaker was ignorant or not knowledgeable. This finding is consistent with many studies demonstrating a relation between theory of mind abilities and selective learning in preschool-age and school-age children (Brosseau-Liard et al., 2015; DiYanni & Kelemen, 2008; DiYanni et al., 2012; Fusaro & Harris, 2008; Lucas et al., 2013; Mills & Elashi, 2014). However, this is the first study to demonstrate that this link is also apparent in infancy. It is important to point out that such a link does not provide support for a mentalistic view of theory of mind in infancy, that is, the knowledge that infants possess about people's behaviours might be rather shallow as opposed to deep. There is a current debate regarding the nature of theory of mind in infancy, with one view proposing continuity between implicit and explicit forms of theory of mind whereas another view suggests two separate systems developing in parallel (Low, Apperly, Butterfill, & Rakoczy, 2016). Regardless of the depth of infants' computations in the knowledge inference task, the present study provides evidence that the precursors of theory of mind are related to selective learning in human infants.

The present study included two different theory of mind tasks. While both tasks measured infants' understanding of others' mental states, one task assessed infants' ability to understand that others may have different beliefs, whereas the other task assessed infants' ability to attribute knowledge states to others. The inclusion of two theory of mind tasks was important as both of these tasks are epistemic in nature and can both potentially help infants in detecting inaccuracy when choosing whom to learn from (Sabbagh & Baldwin, 2001). Furthermore, it was of particular interest to contrast performance on the false belief and knowledge tasks to their relation to selective learning abilities. Although performance on the knowledge task was significantly related to selective learning, performance on the false belief task was not, but the results were in the expected direction. This null result is consistent with findings from Pasquini and colleagues (2007), where no significant relation was found between false belief abilities and selective learning. However, the researchers argued that the absence of this relation might be explained by the fact that performance on the false belief task was at chance level. Similarly, the null findings that we observed with false belief might be due to the infants' poor performance on this task.

When looking at the difference in the pattern of results across both theory of mind tasks, the findings revealed that the effect size for the knowledge task was three times greater than the effect size of the false belief task when examining its influence on infants' word learning. Therefore, the ability to infer knowledge states, as opposed to false beliefs, is a better predictor of selective social learning. Passing the knowledge task suggests that the infant has the ability to infer knowledge, as research indicates that infants not only understand what individuals are doing and seeing, but also what individuals know (Moll & Tomasello, 2007). Infants infer what other individuals know by understanding what they have had previous experience with (i.e., not having experience with the third object; Moll & Tomasello, 2007). With regard to the word labelling phase, infants may expect a speaker to share their knowledge of the labels for these common objects, so when they observe the speaker use inaccurate labels, they detect a lack of "agreement" and are less likely to subsequently learn from this speaker. In summary, these results suggest that infants who display a greater understanding of the knowledge states of others are more selective in their word learning, as they are better able to form attributions regarding whether this individual is knowledgeable and thus the best source to learn from (Brosseau-Liard et al., 2015; Poulin-Dubois & Brosseau-Liard, 2016).

Aside from infants' understanding of knowledge states being the ability most clearly related to their selective learning abilities, another potential reason why the false belief task did not reach statistical significance may be due to the fact that the original results were not replicated. Specifically, 51% of infants in the present study passed the false belief task, whereas 72% of infants passed in the study conducted by Buttelmann and colleagues (2009). Consistent with the present findings, a recent study also reported a low performance of 36.6% on the same false belief task with 18-month-old infants (Poulin-Dubois & Yott, in press). Additional research has also shown that even preschoolers fail this false belief task when control conditions are added to the design (Allen, 2015). However, it is important to note that slight methodological changes were made to the false belief task of the current study. Specifically, Buttelmann and colleagues (2009) administered the false belief task on the floor, whereas we administered the task on a table with infants sitting in a high chair. In fact, two recent studies have replicated Buttelmann and colleagues' (2009) pattern of results when the task was administered on the floor (Powell, Hobbs, Bardis, & Carey, 2017; Preiwasser, Rafetseder, Gargitter, & Perner, 2017). Given that the main goal of the present study was to contrast infants who passed and failed this task, the observed distribution of scores in the false belief task is ideal for our analyses since it provided us with similar sample sizes across subgroups. Still, future research should attempt to replicate the present null findings using other false belief tasks, such as those measured through an anticipatory looking or the violation of expectation paradigms.

Importantly, the present study did not find support for the hypothesis that domain-general abilities are linked to selective social learning in infancy, as no relation was found between infants' performance on the statistical learning task and their performance on the selective learning task. Specifically, infants who passed the statistical learning task demonstrated a similar performance on the word learning task to infants who failed this task. Although the link between statistical learning and selective learning has been suggested in the literature (Sobel & Kushnir, 2013), this is the first study to empirically investigate this relation. What is noteworthy is that the non-significant link between statistical learning and selective learning found in the present study cannot be accounted for by non-replication of the statistical learning task. In fact, 18-month-olds' performance on the statistical learning task in the present study is consistent with the performance of 19- to 24-month-olds' performance of this task in the original study conducted by Kushnir and colleagues (2010). The pattern of responses demonstrated that infants touched the target object significantly more on the minority trial compared to the majority trial. Since the experimenter's selection was likely not due to random sampling on the minority trial, it was expected that infants should recognize the experimenter's preference, and thus, offer the toy that the experimenter picked out. In contrast, infants touched the alternative object significantly more on the majority trial compared to the minority trial. According to Kushnir and colleagues (2010), infants may be able to recognize that the experimenter's selection on the majority trial was likely due to random sampling. As a result, infants may prefer the alternative toy, which is more novel to them (Kushnir et al., 2010). Although this task involves inferring the experimenter's preference, the pattern of results demonstrates that infants are using statistical and probabilistic cues when deciding which object to give to the experimenter. If the choice of object was based solely on the inference of a preference, then infants would be more likely to touch the target object on the majority trial as well. However, future studies should attempt to replicate these findings with other statistical learning tasks in order to provide further evidence that this ability is not associated with infants' selective social learning. Another domain-general correlate that was included in the present study was infants' vocabulary size, as a proxy for infants' verbal intelligence. The results revealed no significant association between infants' verbal skills and their selective learning behaviours. Thus, infants' tendency to learn less from the unreliable speaker was not due to the size of their vocabulary, suggesting that the effect between infants' knowledge attribution and selective social learning is robust and does not require advanced verbal skills.

In conclusion, this is the first study to investigate the correlates of selective social learning in infancy while examining theory of mind and statistical learning simultaneously. It is also the first to demonstrate that infants' ability to select competent informants is associated with the ability to infer people's knowledge state. Thus, our findings provide preliminary support for the rich interpretation of early selective social learning, in that domain-specific, socio-cognitive functions are linked with this ability in infancy. Future research should investigate the correlates of selective social learning in younger as well as older infants. This would allow researchers to explore a possible developmental trend in the correlates underlying this ability; that is, examining the continuity of these correlates across development.

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