Knowing who knows: Infants' metacognitive and causal learning abilities guide selective social learning

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ABSTRACT

Knowing who knows: Infants' metacognitive and causal learning abilities guide selective social learning

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Given the widespread interest in the development of children's selective social learning, there is mounting evidence suggesting that infants prefer to learn from competent informants (Poulin-Dubois & Brosseau-Liard, 2016). However, little research has been dedicated to understanding how this selectivity develops. The present study investigated whether causal learning and precursor metacognitive abilities govern discriminant learning in a classic word-learning paradigm. Infants were exposed to a speaker who accurately (reliable condition) or inaccurately (unreliable condition) labeled familiar objects, and were subsequently tested on their ability to learn a novel word from the informant. The predictive power of causal learning skills and precursor metacognition (as measured through decision confidence) on infants' word learning was examined across both reliable and unreliable conditions. Results suggest that infants are more inclined to accept an unreliable speaker's testimony on a word learning task when they also lack confidence in their own knowledge on a task measuring their metacognitive ability. Additionally, when uncertain, infants draw on causal learning abilities to better learn the association between a label and a novel toy. This study is the first to shed light on the role of causal learning and precursor metacognitive judgments in infants' abilities to engage in selective trust.

Key words: Selective trust, metacognition, decision confidence, causal learning

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Knowing who knows: Infants' metacognitive and causal learning abilities guide selective social learning

The social world provides us with a wealth of information that we can choose or choose not to accept. Children are no exception. In fact, children mainly learn from those around them, a phenomenon referred to as social learning. However, social information can be outdated and inappropriate. Thus, children must be able to filter among potential informants and keep track of those who can offer accurate information in order to successfully learn from those around them. A plethora of research has demonstrated that children actively engage in social learning strategies that enable them to differentiate between reliable and unreliable sources of information, and then display selective trust in one source over another (Koenig & Harris, 2005; Koenig & Sabbagh, 2013; Mills, 2013; Nurmsoo, Robinson & Butterfill, 2010). For example, children evaluate informants and have been shown to prefer adults over children, but not if an adult has previously been inaccurate (Jaswal & Neely, 2006). Additionally, providing trait labels (e.g., "very good" or "not very good") enable 4-year-olds to prefer accurate informants after only one trial (Fitneva & Dunfield, 2010). Although research in this area has mainly focused on children of preschool age, there is increasing empirical support for selective social learning occurring during the infancy period (Harris et al., 2018; Mills, 2013; Poulin-Dubois & Brosseau-Liard, 2016 for reviews). To date, a large body of evidence has revealed that infants are sensitive to several properties of a social model to guide their learning. For example, it has been shown that infants are attuned to informants' accuracy (e.g., Brooker & Poulin-Dubois, 2013), age (e.g., Ryalls, Gul, & Ryalls, 2000), and confidence (e.g., Brosseau-Liard & Poulin-Dubois, 2014) to help them decide from whom to learn.

Despite growing empirical support for children's selectivity in social learning, there is surprisingly little research dedicated to understanding how this selectivity develops (Heyes, 2016). There is considerable theoretical disagreement among researchers over the mechanisms underlying selective social learning in early childhood and infancy. Consistent with a rich account of early selective trust, researchers argue that social learning in young children is governed by domain-specific, higher-order, cognitive abilities (Harris & Koenig, 2006; Poulin-Dubois, 2017; Sabbagh, Koenig, & Kulmeier, 2017). In contrast, a lean perspective holds the view that young children rely on domain-general, lower-order, cognitive functions (Heyes, 2016). According to the latter account, the abilities that underlie selective social learning in infancy are unsophisticated and shared with non-human animals, namely associative processes.

Social learning in non-human animals

There is a large body of work demonstrating that social learning is prevalent in the animal kingdom. Animals from various species—such as fruit flies, birds, rodents, fish and primates—have been shown to use social learning strategies to acquire biological information simply from observing others (Heyes, 2012). Social learning provides animals with information about habitat, diet, predators, mating, as well as collective behavior (see Galef & Heyes, 2004 and Hoppitt & Laland, 2008 for reviews). These strategies also specify situations when it might be adaptive to copy others (Heyes, 2016). In fact, experimental studies have revealed functional parallels in social learning across human and non-human animals (Rendell et al., 2011 for a review). Like humans, sticklebacks—a fresh water fish species—have been shown to copy others when uncertain, and when asocial learning is risky (van Bergen, Coolen, & Laland, 2004). Interestingly, there is also evidence indicating that other stickleback and guppy species are sensitive to social cues such as age (Dugatkin & Godin, 1993), size (Duffy, Pike, & Laland, 2009), boldness (Godin & Dugatkin, 1996), and familiarity (Swaney, Kendal, Capon, Brown & Laland, 2001). Studies with rats also provide empirical support for the use of social learning strategies such as copying others who are more successful, and when environments are relatively stable—as opposed to environments that are unpredictable and susceptible to rapid change (Galef, 2009). Moreover, research with chimpanzees shows a preference to copy individuals of higher rank and prestige (Horner, Proctor, Bonnie, Whiten, & de Waal, 2010). Together, these studies show us that even animals have the capacity to engage in learning by observing others of its species. Specifically, it appears that animals use state-based (e.g., copy when uncertain, when asocial learning is risky, etc.) and model-based (e.g., dominance rank based, prestige-based) social learning strategies to acquire important information for their survival (Rendell et al., 2011).

Domain-general account of selective social learning

Some attention has been given to the psychological mechanisms mediating the selectivity of this behavior in non-human animals. The mechanisms proposed are domain-general processes based on principles of associative learning—those that are driven by the learned predictiveness of a stimulus. Broadly, the productiveness of a stimulus refers to the accuracy of predicting action-outcome relationships (Le Pelley, Vadillo & Luque, 2013). Research indicates that learning of action-outcome relationships occurs more readily when the stimulus is predictive (i.e., when the stimulus consistently elicits the same outcome), as opposed to when the stimulus is non-predictive (Le Pelley et al., 2013). This finding suggests that learned predictiveness modulates attention. That is, more attention is directed to predictive stimuli relative to non-predictive stimuli, which therefore increases the rate by which an association is learned (Le Pelley et al., 2013). The ability to learn about relationships and predict future behavior is also thought to be based on causal theories of learning (Sawa, 2009). Causal learning refers to the ability of inferring causal relations from patterns of observed events and their respective outcomes (Gopnik et al., 2004). Specifically, we form internal causal models by observing sequences external events that are temporally contingent (Sawa, 2009). For example, people often infer causality when they observe that flipping a switch is followed by a light that is turned on (Sawa, 2009).

It has been suggested that similar, basic mechanisms operate in human social learning—particularly early in life. Heyes (2016) suggests that evidence of early selective social learning is often interpreted in a way that implies that children's behavior is guided by conscious efforts to apply learning strategies (e.g., copy if uncertain, copy the majority, etc.). However, it is argued that children appear to discriminately learn from others, but that the selectivity of their learning may not be known to the children themselves (Heyes, 2016). In other words, children do not apply social learning strategies deliberately—instead, their learning may be driven by associative and causal learning processes. To illustrate, in a study by Brooker and Poulin-Dubois (2013), infants demonstrated a preference to learn a new word from a reliable informant (i.e., who previously labelled familiar objects correctly) relative to an unreliable informant (i.e., who previously labelled familiar objects incorrectly). From an associative perspective, infants were less likely to learn from an unreliable informant because the association between the label and the familiar object was not predictive. In other words, the unreliable informant provided a label that did not accurately predict the object that was presented. As a result, this led the infants to attend less and learn less from the speaker. In line with a lean interpretation of selective social learning, more sophisticated abilities (e.g., metacognition— the ability of reflecting on one's own mental states; Flavell, 1979) are proposed to come online in late childhood and play a larger role in adulthood due to social experience (Heyes, 2016).

Domain-specific account of selective social learning

Alternatively, other researchers maintain that individual differences in precursor domain-specific abilities may explain early selective social learning (Harris & Koenig, 2006; Poulin-Dubois, 2017). In particular, theory-of-mind, or the ability to make rational inferences about others' mental states (e.g., knowledge) has been proposed to account for this link. Evidence in preschoolers suggests that children are capable of attributing knowledge or ignorance based on the accuracy or inaccuracy of an informant's behavior. These mental state inferences are thought to guide children's decisions about whether to endorse one informant relative to another (Brosseau-Liard, Penney, & Poulin-Dubois, 2015; Harris & Koenig, 2006; Sobel & Kushnir, 2013). Therefore, it is proposed that children who demonstrate a stronger understanding of others' mental states would also be more successful selective social learners (Brosseau-Liard et al., 2015; Sobel & Kushnir, 2013). This link has been demonstrated in children of pre-school and school age (Brosseau-Liard et al., 2015; DiYanni & Kelemen, 2008; DiYanni, Nini, Rheel, Livelli, 2012; Fusaro & Harris, 2008; Lucas, Lewis, Pala, Wong, & Berridge, 2013; Elashi & Mills, 2014). However, other studies have yielded inconsistent results, in that young children's theory-of-mind abilities have no bearing on the selectivity of their learning (e.g., Pasquini, Corriveau, Koenig & Harris, 2007). As such, additional research is required to further elucidate the relation between these abilities.

Selective trust & Theory-of-Mind

To our knowledge, there are only two studies that sought to examine such link in infancy—that is, to investigate whether domain-specific (i.e., theory-of-mind) or domain-general (i.e., associative learning and statistical learning—the ability of detecting statistical regularities in the environment) abilities govern selective social learning in infants. Crivello, Phillips, and Poulin-Dubois (2017) reported that 18-month-old infants who were able to correctly make inferences about the knowledge state of others were less likely to accept an unreliable informant's testimony. More specifically, infants who correctly inferred the knowledge state of an experimenter, also demonstrated decreased willingness to learn a novel word from an informant who had previously displayed incompetence (Crivello et al., 2017). Interestingly, no association was observed with statistical learning abilities, suggesting that infants' abilities to extract statistical regularities from their environment was not associated with their selective word learning abilities. In a recent follow-up study, Crivello and Poulin-Dubois (2018) examined the extent to which knowledge inference and associative learning abilities guide 14-month-old infants' detection of emotionally incongruent expressions (i.e., display of happiness while looking at an empty container). Consistent with previous results, infants who demonstrated stronger abilities to make inferences about others' knowledge states were better able to detect the unreliability of an emoter. Again, no link with associative learning was revealed. Together, these studies provide preliminary evidence for a domain-specific account of selective social learning in infancy.

Metacognition as a possible mechanism

Theory-of-mind abilities are often linked to metacognition. In fact, many would argue that that the two abilities are synonymous, such that both concepts refer to knowledge of mental states (Flavell, 2000). Despite this obvious similarity, research streams and the operational definition of these constructs differ (Ebert, 2015). Research on theory-of-mind is focused on children's understanding of other's mental states and the influence on their behavior (Flavell, 2000). Whereas, research on metacognition is targeted at examining how metacognitive ability impacts learning and school performance (Flavell, 2000). Here, we refer to theory-of-mind abilities as an understanding of *other's* mental states, such as beliefs, intentions, as well as desires (Wellman, 2014), and refer to metacognition as the ability to reflect on *one's own* mental states—particularly, one's thinking and learning (Flavell, 1979; Guerten & Willems, 2016).

That said, metacognitive abilities have also been proposed to govern selective social learning (Heyes, 2016). Heyes (2016) argues that explicit metacognitive social learning strategies permit cumulative cultural change in humans—that is, the creation of social traditions and the transmission of wisdom across generations. Explicit metacognition represents abilities that are conscious in form, and precipitate a slow and serial approach to problems (Heyes, 2016). It is functionally dependent on working memory, given that individuals must reflect on both current and previous knowledge to guide future learning (Heyes, 2016). Importantly, an explicit understanding of one's own mental states requires the ability to verbally generate explanations about the mental processes guiding our behavior (Frith, 2011). By contrast, implicit metacognition approaches problems rapidly and in parallel, and are also less dependent on working memory ability (Heyes, 2016). An implicit understanding refers to a process of reflecting on mental states without providing verbal justifications (Frith, 2011).

Explicit metacognition enables successful learning, such that individuals adjust their learning strategies based on their state of knowledge within a given context. Specifically, it is argued that explicit metacognition enables humans to ask themselves “who knows” when deciding from whom to learn (Heyes, 2016). Humans apply social learning strategies in more sophisticated ways that reflects their possible metacognitive content, and direct their learning to better sources of information. For instance, the “copy the majority” social rule becomes “copy the majority when the majority is likely to know best” (Heyes, 2016). A body of work with adults demonstrates that learning strategies that specify when and from whom to learn can be metacognitive in nature. For example, adults are more likely to use social information to respond to ambiguous perceptual and foraging tasks when their explicit confidence judgments were lower (Morgan, Rendell, Ehn, Hoppitt, & Laland, 2012).

Moreover, extant research supports that explicit metacognitive ability is predictive of successful social learning strategies even in school-age children (e.g., Dunlosky & Rawson, 2012; Sodian & Frith, 2008). Despite their strong propensity to learn, young children under the age of four years have been shown to make inaccurate metacognitive judgments (e.g., Flavell, 1999; Sodian, Thoermer, Kristen, & Perst, 2012). However, researchers suggest that young children’s explicit metacognitive abilities are underestimated in these studies given that the measures rely heavily on verbal ability. When non-verbal measures are considered across various experimental modalities (i.e., behavioral, neural and pupil dilation), it appears that these abilities may emerge earlier than expected (Goupil & Kouider, 2016; Goupil, Romand-Monnier, Kouider, 2016; Paulus, Proust & Sodian, 2013). For example, it has been shown that similar electrophysiological signatures of error monitoring are elicited in adults and infants following an incorrect decision (Goupil et al., 2016). In addition, pupillometric analysis in preschoolers reveals evidence for implicit metacognitive memory monitoring (Paulus et al., 2013). Behavioral forms of metacognition are assessed using decision confidence monitoring and information-seeking paradigms. These paradigms involve observing infants’ behavior under conditions in which an infant—or even an animal (e.g., Hampton, 2009)—would be uncertain following an event that is difficult to remember. Indeed, there is evidence to suggest that a wide range of animals, including bird species, monitor their own knowledge states and engage in information-seeking when ignorant (e.g., Call & Carpenter, 2001; Beran & Smith, 2011; Rosati & Santos, 2016; Watanabe & Clayton, 2016).

In infancy, when nonverbal forms of metacognition are assessed, it appears that 20-month-old infants are capable of monitoring their uncertainty and non-verbally express their uncertainty to others (Goupil, Romand-Monnier, Kouider, 2016). Additionally, there is evidence to suggest that 18-month-old infants monitor the accuracy of their decisions (Goupil & Kouider, 2016). More specifically, infants display increased post-decision persistence for correct choices as compared to incorrect choices when identifying the location of a toy following a delay of several seconds (Goupil & Kouider, 2016).

Taken together, explicit metacognitive strategies that enable reflecting on one's knowledge may be important for us to selectively learn from others. While it was previously believed that these abilities emerge at the preschool age when children begin to talk about their mental states (Guerten & Willems, 2016), there is some evidence showing that primitive forms of these abilities are manifested in infancy. Specifically, when demands of verbal abilities are removed, it appears that even infants are able to engage in metacognitive monitoring to guide their future behavior (Goupil & Kouider, 2016). As such, it may be the case that infants use precursor metacognitive judgments to direct their social learning to reliable sources of information.

The present study

The main objective of the present research is to explore the mechanisms at the origins of selective social learning by examining whether causal learning and precursor metacognitive abilities can account for 18-month-old infants' ability to avoid learning from incompetent informants. Infants were presented with a speaker who either accurately or inaccurately labeled a familiar object. Following this event, infants' willingness to learn a novel word from the speaker was examined. Based on prior findings using the word-learning paradigm, it was expected that infants would be less likely to learn a novel word from an unreliable speaker relative to a reliable one (Brooker & Poulin-Dubois, 2013; Crivello et al., 2017; Luchkina, Sobel & Morgan, 2018; Koenig, Clément, & Harris, 2004).

Consistent with extant research on the mechanisms of early selective trust (Crivello et al., 2017; Crivello & Poulin-Dubois, 2018), it is hypothesized that selective social learning in infancy is governed by domain-specific abilities (i.e., metacognition). More specifically, infants with better awareness of their confidence—as measured through a decision confidence paradigm—will be less likely to display selective trust in an unreliable source. That is, infants who display decreased persistence times on incorrect trials, and longer persistence times on correct trials on the metacognition task will be less willing to learn a novel word from an unreliable speaker. Subsequently, performance on a causal learning task is not hypothesized to predict infants' selective word-learning. This prediction is based on previous studies that have not reported a link between domain-general skills (i.e., associative and statistical learning) and selective trust abilities. Finally, infants' performance on both the metacognition and on the causal learning task is not expected to predict word-learning from a reliable informant, given that infants have been shown to learn new words from a model without any information about their competence.

Method

Participants

Participants lived in a large metropolitan Canadian city and were recruited from a governmental health agency. A total of 92 infants, aged 18 months, were tested. Selection criteria required that children did not have auditory or visual impairments, or any birth complications. Importantly, inclusion criteria required that infants be exposed to English or French. Given that the word-learning task served as the basis for the study, the following exclusions are specific to the word-learning task. An additional 28 infants were excluded as a result of fussiness ($n = 10$), having a dominant language that was not English or French ($n = 12$), providing ambiguous responses such as offering both toys or none ($n = 4$), parental interference ($n = 1$), and experimenter error ($n = 1$). Thus, the overall sample consisted of 64 infants ($M_{age} = 18.20$ months, $SD = .99$, range = 16 – 20.30 months; 31 males, 33 females).

Procedure

MacArthur-Based Short Form Vocabulary Checklist: Level II (MCDI-II). American-English and French-Canadian adaptations of the MCDI were administered to assess infants' total productive vocabulary (Fenson et al., 2000; Trudeau, Frank & Poulin-Dubois, 1999). The MCDI-II, developed for children between the ages of 16 and 30 months, is comprised of 100 vocabulary items that include nouns, verbs, and adjectives. The child's primary caregiver completed the form.

Word Comprehension checklist. French and English versions of a 20-word checklist were administered to obtain a brief estimate of children's receptive vocabulary, and to select words for the word-learning task (Brooker & Poulin-Dubois, 2013). The form consisted of nouns that would be familiar to children of this age, and was used to select stimuli in the selective social learning task.

Selective word-learning task. In a procedure identical to that of Brooker and Poulin-Dubois (2013), and Crivello and colleagues (2016), infants were presented with labels for familiar and novel stimuli.

Reliability exposure phase. Through random assignment, participants were allocated to a reliable ($n = 33$) or unreliable ($n = 31$) condition. A total of four small plastic toys were selected based on the words endorsed by the child's caregiver on the 20-word checklist described above, and were either labelled correctly (reliable) or incorrectly (unreliable). Participants were required to be familiar with a minimum of three of the four words in order to be included for analysis (Brooker & Poulin-Dubois, 2013; Crivello et al., 2017). A total of 53 infants were familiar with all four words, and a total of 11 infants were familiar with three of the four words. First, children were given 15 seconds to explore each of the toys. Following this, the experimenter labeled each object with the same label three times. For example, while manipulating the object, the reliable experimenter pointed to the toy and said "That's a shoe. See, it's a shoe. Look at the shoe". The child was given the toy again to play with (15 s) immediately after it was labelled by the experimenter.

Word-Learning phase. The word-learning phase assessed children's willingness to learn from the informant given the accuracy with which she previously labelled familiar objects (reliability phase). This was comprised of three sub-phases: warm-up, training, and test phase. First, the experimenter presented the child with two familiar toys (different from those in the reliability phase) on a tray, and requested one from the child. The purpose of this trial was to ensure that the child understood the task (Brooker & Poulin-Dubois, 2013). In the training phase, the experimenter introduced two novel toys, and modeled how to play with each of the toys. For example, a rattle-type plastic toy was shaken, and a wooden toy that looked like a spinner-top was spun. Children were then given 15 s to explore both toys. Following this, the experimenter retrieved one of the toys from the child, and labelled it by saying "It's a Dax". The experimenter provided this label a total of four times. The test phase consisted of two trial types: familiar and novel trials, wherein a pair of familiar and novel toys were introduced, respectively. The familiar toys were different from those shown in previous trials, and the novel toys were the same as those described above. The same pair of novel toys was presented to the child across all novel trials. A total of 8 trials were administered—four familiar and four novel trials, alternating in order. On each of the trials, the experimenter requested one of the two objects (i.e., "Where is the X? Give me the X."). Importantly, on the novel trials, the experimenter only requested the novel toy she had previously labeled as the "Dax". If the child offered two toys simultaneously, then the trial was repeated. The type of trial (i.e., familiar vs. novel) was counterbalanced in order. The type of novel toy and the location of the toys on the tray were also counterbalanced. The number of correct responses on test trials were coded for a maximum score of 4 across trial type.

Causal Learning task. An adaptation of the blicket task was administered to obtain an index of infants' causal learning abilities (Sobel & Kirkham, 2006). A blicket detector was used—identical to that described by Sobel and Kirkham (2006)—which was made of wood (painted grey) and a red Lucite top. The box was developed so that it can be plugged into an electrical outlet with a switchbox attached. This allowed the experimenter to control the detector out of the child's view. The detector became immediately activated when an object was placed on the red top and was deactivated when the object was removed. When activated, the detector lit up and played a song (Für Elise). A total of nine blocks—different in shape and color—were used as stimuli for the imitation and test trials. The detector and the blocks rested on a tray throughout the administration.

First, the child played with the experimenter with a set of blocks (different from those used in the imitation and test trials) for three minutes. Following the familiarization phase, the child and caregiver sat on one side of a child-size table. The caregiver sat behind the child, and held the child upright in front of him or her. The experimenter sat on the opposite side of the table with the blicket detector on a tray. The imitation trial required that the experimenter place two blocks on opposite ends of the tray, and then place each block separately on the detector. Importantly, only one of the blocks activated the detector. This was demonstrated twice. The experimenter provided verbal cues when one block activated the detector, and when the other did not by saying "Wow" or "No", respectively. The experimenter then encouraged the child to activate the detector by sliding the tray over, and saying "It's your turn. Make it go." Importantly, the child was only given one opportunity to make a response before the experimenter slid the tray out of the child's reach.

A total of three experimental trials were administered. The location of the blocks on the tray for each trial was counterbalanced. On the first trial, two different blocks were successively placed on the tray (A and B). Block A activated the detector, whereas Block B did not. Then, both blocks were placed on the detector, and it was activated. This demonstration was administered twice. Following this, the experimenter slid the tray over to the child and said "It's your turn. Make it go." On the next trial, another pair of blocks was placed on the tray. Both blocks were placed on the detector twice, activating the machine. Then, one of the two blocks (Block B) was placed on the detector, and the machine did not activate. The experimenter then slid the tray over to the child, and said "It's your turn. Make it go."

Finally, a series of three different blocks were placed on the tray. Two blocks (A and B) were placed on either end of the tray, and the third (C) was placed in the middle. Blocks A and C were placed on the detector together twice, which activated the detector both times. Subsequently, only Block C was placed on the detector, and the machine activated. Block C was then removed, and the tray was slid over to the child while the experimenter said “It’s your turn. Make it go.” The proportion of correct test trials (out of 3) was calculated.

Metacognition task. Adapted from the task designed by Goupil & Kouider (2016), an interactive metacognitive task was used to measure infants’ ability to monitor decision confidence. Infants were exposed to two identical black boxes (15.5 x 25.5 x 30.5 cm) that were made from white Styrofoam. The front of each of the boxes had an opening (9.5 x 15.5 cm) covered in green spandex with a horizontal slit. The green covering was layered on top of a black piece of spandex with a vertical slit. The boxes were designed so that children were able to reach inside the boxes, but unable to see its contents. Inside each of the boxes was a small pocket that was created by cutting and removing a piece of Styrofoam. The stimuli used for the warm-up and familiarization trials were small plastic toys—two of which measured 7 cm by 4 cm and the other two measured 3.5 cm by 5 cm. The test stimuli consisted of four colorful (blue, orange, yellow and green) rectangular wooden blocks (3.5 x 5 cm). The stimuli were randomly selected for each trial. Finally, a small puppet theatre was used (80.5 x 34 cm) with two black curtains hanging from it.

First, the experimenter introduced each of the boxes by saying “Look [child’s name]! The nice box! I put my hand inside! You try!” The experimenter then pushed the box towards the child so that it was within his/her reach, encouraging the child to put his/her hand inside the box. A total of two warm-up trials were administered, wherein a toy was hidden in one of the two boxes and infants were asked to retrieve the toy. Before hiding the toy, the experimenter presented it to the child by centering it on the table and saying “Look [child’s name’]! A toy! I hide it in the box!” After the child watched the experimenter place the toy in the box, it was pushed forward so that the child can retrieve the toy.

Two familiarization trials were then administered. Similar to the warm-up trials, the familiarization trials followed an identical procedure as outlined above. However, the familiarization trials required both boxes to be pushed toward the child so that he/she was required to select the box that he/she thought the toy was hidden. As the experimenter pushed the boxes forward, she said, “Where is the toy? Can you show me?” The experimenter waited until the child pointed to one of the boxes—indicating that the child selected the box that he/she would like to search—and then moved the box forward. Correct responses were praised ("Yes, it is here. Look!"), whereas incorrect responses were corrected ("No, it is there. Look!"). If the child selected the incorrect box, he or she was given the opportunity to search the correct box for the toy.

A total of eight experimental trials were then administered. The procedure was identical to that of the familiarization trials, except that the experimental trials incurred a delay (6 or 9 seconds randomized in order), and both boxes were hidden from the child's view by a curtain. Importantly, the toy was now secretly hidden in a pocket inside the box, rendering the toy impossible for the child to find. Post-decision persistence time was measured by coding the amount of time the child searched the box.

Design

Prior to the testing session, infants were exposed to a warm-up phase in order to become accustomed to the environment and the experimenters. During this period, the caregiver was asked to complete the MCDI-II and the Word comprehension checklist to guide the selection of stimuli for the selective word-learning task. Infants were randomly assigned to either the reliable or unreliable condition, and the administration of the word-learning task followed. Counterbalanced in order, the subsequent two tasks (causal learning and metacognition tasks) were then administered. The word-learning task was always administered first given that performance on this task was critical for our main analysis, and thus made it important to circumvent any fatigue effect. Of note, the experimenter who administered the word-learning task did not administer either of the subsequent tasks in order to avoid possible carry-over effects due to the reliability exposure phase. As such, two experimenters were required. Parents were offered $20 to cover travel costs, and children were given a small toy and a certificate of merit.

Results

A series of comparative analyses were conducted across reliable and unreliable conditions of the selective word-learning task to ensure that the groups were equivalent in age, gender, and vocabulary knowledge. Analyses revealed no significant differences in age t (64) = .25, p = .80, d = .04, or gender, χ^2 = .06, p = .81. Moreover, analyses did not yield significant differences in the proportion of known words on the receptive vocabulary checklist, t (64) = .92, p = .36, d = .04 (Reliable: M = .63, SD = .25; Unreliable: M = .68, SD = .22) or on the index of expressive vocabulary, t (64) = -25, p = .81, d = .07 (Reliable: M = .15, SD = .13; Unreliable: M = .16, SD = .16). Finally, participants did not differ on the proportion of words they were familiar with on the 20-word checklist used for the reliability phase of the word-learning task, t (64) = -.14, p = .89 (Reliable: M = .94, SD = .02; Unreliable: M = .94, SD = .02).

Selective Word-Learning task.

To examine possible fatigue effects, a one-way analysis of variance was conducted across 8 trials, irrespective of condition and trial type, with correct choice as the dependent variable. The analysis revealed a significant decrease in the number of correct offers across trials, F (1, 452) = 13.23, p < .001, η^2 = .39. As follow up, two binary logistic regression models were conducted to assess whether correct responses on the task varied as a function of block (first four vs. last four trials) and trial type (familiar vs. novel trials) across unreliable and reliable conditions. Both predictors were entered into the models simultaneously. The model conducted for the unreliable condition yielded significant findings, χ^2 (2) = 9.10, p = .01, Nagelkerke R^2 = .055. Trial type significantly predicted correct offers of the target object irrespective of block (b = .77), such that infants were 2.2 times more likely to offer the target object across familiar trials relative to novel trials. Moreover, the model conducted for the reliable condition also yielded significance, χ^2 (2) = 6.01, p = .05, Nagelkerke R^2 =.035. Trial type did not emerge as a significant predictor. Instead, block of trials significantly predicted correct responses, irrespective of trial type (b = .59). Infants in the reliable condition were 1.8 times more likely to offer the target object in Block 1 relative to Block 2. Given these results, subsequent analyses for the selective word-learning task only included the first four trials—consisting a total of two novel and two familiar trials—to minimize statistical error in the data.

A mixed analysis of variance was conducted in order to examine differences in performance across both conditions on familiar and novel trials. The proportion of correct responses was entered as the dependent variable. A significant main effect of trial type emerged, wherein infants' performance on familiar trials (*M* = .71, *SD* = .38) was superior as compared to performance on novel trials (*M* = .56, *SD* = .33), *F* (1,62) = 4.80, *p* = .03, η^2 = .07. Additionally, a significant main effect of condition was observed, in that infants in the reliable condition correctly offered the target object more frequently irrespective of trial type (*M* = .72, *SD* = .33), relative to the unreliable condition (*M* = .56, *SD* = .33), *F* (1,62) = 7.46, *p* =.01, η^2 = .107). Moreover, a Condition x Trial type interaction emerged as a trend, *F* (1,62) = 3.44, *p* = .07, η^2 = .05. Consistent with our hypotheses, planned comparisons revealed that infants in the reliable condition presented with a larger proportion of correct offers on novel trials (*M* = .71, *SD* = .37) relative to infants in the unreliable condition (*M* = .42, *SD* = .38), *F* (1,62) = 7.93, *p* = .01, η^2 = .11). Also in line with our predictions, differences between reliable and unreliable conditions across familiar trials were not observed, *F* (1, 62) = .06, *p* = .81, η^2 = .001 (see Figure 1). Proportion of correct offers across familiar and novel trials were subsequently examined against chance responding (.50). On familiar trials, infants in both the reliable (*M* = .73, *SD* = .36), *t* (32) = .37, *p* = .001, and unreliable condition (*M* = .69, *SD* = .40), *t* (30) = 2.68, *p* = .01, performed above chance. On novel trials, infants in the reliable condition performed above chance (*M* = .71, *SD* = .35), *t* (32) = 3.35, *p* = .002, whereas infants in the unreliable condition did not differ from chance level (*M* = .42, *SD* = .32), *t* (30) = -1.41, *p* = .17. Of note, similar pattern of results were obtained when infants were familiar with all four words on the word comprehension checklist.

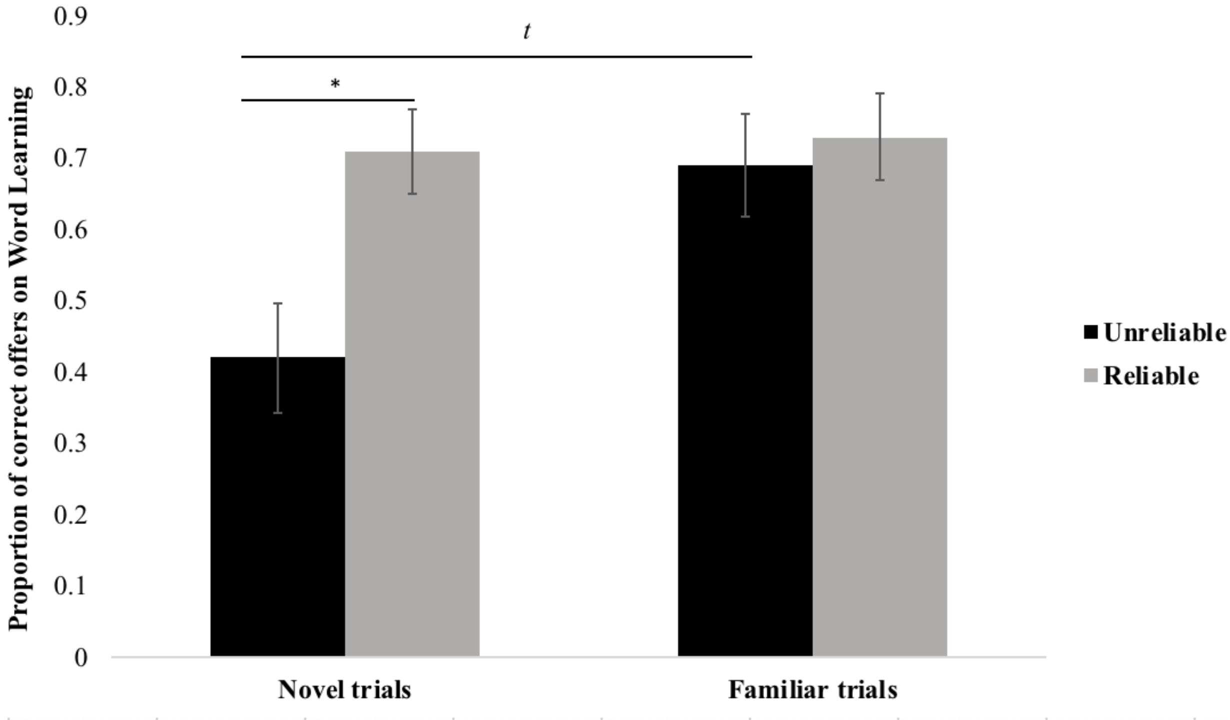

Figure 1. Performance on the selective word-learning task across unreliable and reliable conditions. Error bars represent standard error of the mean. * significantly different performance in unreliable and reliable groups on novel trials. ^{t} trend difference between novel and familiar trials in unreliable group.

Correlates of Selective Social Learning.

Children's performance on correlate tasks were first examined independently, regardless if they were included on the selective word-learning task. This was in order to evaluate children's performance relative to performance reported in the original studies.

Causal Learning task.

Performance on the Blicket task was examined relative to a chance criterion (.50) to reflect two possible response options across trials (i.e., Block A or B). Akin to Sobel and Kirkham (2006), only infants who passed the imitation trial were included in the analysis. Of the 92 participants who were tested, non-parametric analyses were conducted among a sample of 56 infants. A total of 36 participants were excluded—specifically, because failure of the imitation trial (n = 18), fussiness (n = 11) or technical difficulties (n = 7). Results revealed that performance on both the "screening-off trial" and the "indirect screening-off trial" did not yield differences from chance, such that 42% (p = .40) and 56% (p = .50) of infants placed the correct block on the detector, respectively. Similarly, performance on the backward blocking trial was at chance level (64%; p = .16). Consistent with the original study, chance responding was compared to the frequency with which infants placed block A on the detector given the ambiguity of the correct response. That is, children were required to select between Block A and a block whose causal efficacy was unknown.

Moreover, given that trials were presented in a fixed order, subsequent analyses were conducted in order to test for order effects. Results indicated that performance on the "screening-off trial" influenced performance on the "indirect screening off trial", χ^2 (1, N = 56) = 36.64, p = .002, and "backward blocking trial", χ^2 (1, N = 56) = 36.64, p = .002. Additionally, the impact of performance on the "indirect screening trial" on performance on the "backward blocking trial" emerged as a trend, χ^2 (1, N = 56) = 12.98, p = .07. Together, results suggest that performance on later trials was influenced by performance on trials that were previously administered.

Metacognition task.

Analysis for the metacognition task was conducted among a sample of 61 infants. A total of 31 participants were excluded—specifically, due to fussiness (n = 17), non-responsiveness across trials (n = 6), not having completed a sufficient number of trials (n = 5), side preference (n = 2) and experimenter error (n = 1).

A one-way analysis of variance was first conducted to examine possible fatigue effects across the 8 trials, irrespective of delay (i.e., 6 or 9 seconds). The dependent variable was infants' accuracy in identifying the box where the toy is hidden. Results indicated a significant decrease in accuracy across trials, F (1, 420) = 11.43, p = .001, η^2 = .31. A binary logistic regression was subsequently conducted to assess whether accuracy on the metacognition task varied across block (first four vs. last four trials) and memorization delay (6 vs. 9 seconds). The model yielded significant findings, χ^2 (2) = 8.80, p = .01, Nagelkerke R^2 = .03. Block of trials emerged as a significant predictor of accuracy (b = .60), whereas memorization delay did not (b = -.01). Results suggest that infants were 1.8 times more likely to respond correctly across trials in Block 1 relative to trials in Block 2, and were equally likely to accurately identify where the toy was hidden across trials with 6- and 9-second delays. Given these findings, subsequent analyses for this task included the first four trials in an effort to reduce the amount of statistical error in the data. Infants' performance was next examined against chance responding (.05), and demonstrated that accuracy was above chance, t (60) = 5.42, p < .001 (M = .62, SD = .18).

Following this, a paired-samples comparison was conducted to evaluate differences in persistence time—as measured in seconds—across correct and incorrect trials. Infants were not included in this analysis if they achieved perfect accuracy across all four trials. Of note, data screening revealed that persistence time data were not normally distributed and were thus log transformed. Results from paired-samples comparisons with log transformed values and original data were compared, and were found to yield similar findings. Thus, non-transformed data are reported in an effort to preserve the original metric and facilitate the interpretation of results. Descriptive statistics of non-transformed data indicated that, on average, infants correctly identified the location of the toy across 2.31 trials (SD = .73) and incorrectly identified the location of the toy across 1.60 trials (SD = .69). Consistent with our predictions and in line with those of the original experiment (Goupil et al., 2016), infants demonstrate increased persistence on correct trials (M = 2.87, SD = 1.21) relative to incorrect trials (M = 2.07, SD = 1.01), t (53) = 5.72, p = .001, d = .72. Moreover, a positive correlation emerged between persistence time on correct and incorrect trials, r (60) = .470, p = .002.

In addition to infants' accuracy and persistence time, two subsequent behaviors were analysed across both correct and incorrect trials, namely frequency to look inside the box selected and frequency to touch the other box. A sample of 27 infants demonstrated at least one of these behaviors across the four test trials. First, paired samples comparisons were conducted to examine differences in the frequency of each of these behaviors across correct and incorrect test trials. Results revealed that infants looked inside the selected box on correct trials more frequently (M= 1.00, SD = 1.77) relative to incorrect trials (M = .07, SD = .27), t (26) = 4.22, p < .001, d =. 73. In contrast, infants equally touched the other box on correct trials (M = .67, SD = 1.07) as compared to incorrect trials (M = .78, SD = .75), t (26) = -.49, p = .63, d = .12.

Cross-task relations among Word-Learning and Correlate tasks

Inclusion criteria required that infants completed all three tasks—that is, the word-learning, causal learning and metacognition tasks—in order to be included in regression analyses. For the causal learning task, infants were included for analysis irrespective of whether they passed (n = 37) or failed (n = 8) the imitation trial to maximize sample size. The final sample consisted of 41 infants (Unreliable: n = 21: Reliable: n = 20).

Zero-order correlations were conducted in order to examine the associations between performance on novel trials of the learning task and performance on the correlate tasks in the reliable and unreliable conditions independently. Bootstrapping procedures were followed given that they are recommended practice when data violate normality assumptions, and for analyses with small sample sizes (Dwivedi, Mallawaarachchi, Alvarado, 2017). This non-parametric procedure is used to empirically generate the distribution of the test statistic in order to yield more accurate estimates of the population parameters of interest and the respective confidence intervals (Dwivedi et al., 2017). The test of statistical significance is dependent on whether the 95% confidence interval spans zero.

Analyses yielded no significant correlations among the selective social learning task and correlate tasks in the reliable condition. A positive association was obtained between infants' scores on the causal learning task and performance on novel trials of the selective social learning task in the unreliable condition, r (20) = .52, p = .02, 95% CI [.109, .776]. Moreover, a negative relation emerged between persistence time on incorrect trials of the metacognition task and performance on novel trials in the unreliable condition, r (20) = -.43, p = .05, 95% CI [-.737, -.007]. In both instances confidence intervals did not span zero, suggesting that those who demonstrated superior performance on the causal learning task were also more willing to learn a new word from an unreliable speaker. Results also indicate that infants who displayed less persistence across incorrect trials of the metacognition task, were more willing to learn a novel word from an unreliable speaker.

Table 1. *Zero-Order correlations among Selective Word-Learning task and Correlate tasks in the unreliable condition*

Variables	1	2	3	4	5
1. Causal learning task	-	.14	-.12	.005	.52*
		p = .56	p = .60	p = .98	p = .02
2. MC PT correct trials		-	.42^{t}	.10	-.01
			p = .06	p = .67	p = .97
3. MC PT incorrect trials			-	.05	-.43*
				p = .82	p = .05
4. Accuracy on MC task				-	.13
					p = .59
5. SWL task (novel trials)					-

Note. Bootstrapping procedures were used to derive more accurate estimates of zero-order correlation coefficients; PT = Persistence time; MC = Metacognition task; SWL = Selective Word-Learning. * refers to significance at p < .05 level; ** refers to significance at <.001 level; ^{t} refers to statistical trend; n = 21.

Table 2. *Zero-Order correlations among Selective Word-Learning task and Correlate tasks in the reliable condition*

Variables	1	2	3	4	5
1. Causal learning task	-	.17	-.11	.09	.15
		p = .48	p = .64	p = .71	p = .53
2. MC PT correct trials		-	.51*	.28	.09
			p = .02	p = .24	p = .70
3. MC PT incorrect trials			-	-.11	-.18
				p = .66	p = .45
4. Accuracy on MC task				-	.65**
					p = .002
5. SWL task (novel trials)					-

Note. Bootstrapping procedures were used to derive more accurate estimates of zero-order correlation coefficients; PT = Persistence time; MC = Metacognition task; SWL = Selective Word-Learning. * refers to significance at p < .05 level; ** refers to significance at <.001 level; ^{t} refers to statistical trend; n = 20.

Regression models predicting performance on novel trials of Word-Learning task

A series of hierarchical regression models were conducted in order to derive estimates of the predictive power of each of the correlate tasks (i.e., causal learning and metacognitive ability) on performance on novel trials of the selective word-learning task across both reliable and unreliable conditions. Given that zero-order correlations among performance on novels trials of the word-learning task and post-decision persistence on correct trials of the metacognition task did not yield significance, infants' persistence on incorrect trials were only included in regression models. To examine the predictive power of metacognitive ability above and beyond that of causal learning, performance on the causal learning task was entered first, followed by persistence time on incorrect trials of the metacognitive task. Performance on novel trials (i.e., proportion of correct offers) was included as the criterion. Importantly, robust regression parameters were estimated using bootstrapping procedures described by (Dwivedi et al., 2017).

Model 1: Predicting performance on novel trials in the unreliable condition. In step 1, causal learning predicted scores, and accounted for approximately 27% of the variance on novel trials, $F\,(1, 19) = 6.99$, $p = .016$, $R^2 = .27$. When metacognitive ability was entered into the model, both predictors of interest significantly predicted scores on novel trials, $\Delta\, F\,(2, 18) = 6.23$, $p = .009$. $R^2 = .41$. The change in R^2 value indicated that an additional 14% of variance was explained by persistence time on incorrect trials of the metacognition task, $\Delta\, R^2 = .14$. Given these values, it can be interpreted that a significant portion of the variance in scores on novel trials was explained by the predictor variables, and that both predictor variables contribute significantly to the variance explained in the model. Values displayed in Table 2 correspond to the unstandardized regression coefficients, standard errors of the mean, beta weights, R^2 values, t values, and respective significance values. For the final regression model, the lower and upper limits of the 95% confidence interval for causal learning were .24 and 1.13, whereas upper and lower limits for metacognitive ability were -.22 and -.01. Because confidence intervals did not span zero, these results indicate that greater proportion of correct trials on the causal learning task is associated with a larger proportion of correct novel trials on the selective social learning task ($\beta = .47$, $t\,(20) = 2.59$, $p = .02$). Moreover, results suggest that a decrease in persistence time values on incorrect trials of the metacognition task is associated with a larger proportion of correct novel trials ($\beta = -.38$, $t\,(20) = -2.10$, $p = .04$).

Table 3. *Performance on novel trials of SWL task regressed on correlates in the unreliable condition*

Predictors	*B*	*SE*	*b*	*t*	*p*	R^2	Δ R^2
Step 1							.27
Causal learning task	.69	.26	.52	2.65	.01		
						.27	
Step 2							.14
Causal learning task	.63	.24	.47	2.60	.01		
Metacognition task	-.10	.05	-.38	-.06	.04		
						.41	

Note. *n* = 21.

Model 2: Predicting performance on novel trials in the reliable condition. Performance on novel trials of the selective word-learning task was not significantly predicted by the predictor variables of interest at Step 1 and 2, Δ F (2, 17) = .43, p = .66. The unstandardized regression coefficients, standard errors of the mean, beta weights, R^2 values, t values, and respective significance values are presented in Table 3. In other words, the predictor variables did not account for a meaningful portion of variance on novel trials of the selective word-learning task.

Table 4. *Performance on novel trials of SWL task regressed on correlates in the reliable condition*

Predictors	*B*	*SE*	*b*	*t*	*p*	R^2	ΔR^2
Step 1							.02
Causal learning task	.19	.25	.15	.64	.42		
						.02	
Step 2							.03
Causal learning task	.17	.26	.13	.55	.51		
Metacognition task	-.08	.14	-.16	-.69	.50		
						.05	

Note. n = 20.

Regression models comprised of Causal Learning and PTs on first trials of Metacognition task.

In light of findings suggesting that persistence behavior decreases over repeated trials as a function of response-reinforcer contingencies (Nevin, 2009), additional prediction models were conducted. Specifically, the extent to which persistence time on the *first* incorrect trial of the metacognition task accounted for variance in performance on novel selective word-learning trials across experimental groups. Akin to the models described above, performance on the causal learning task was entered prior to persistence time on the *first* incorrect trial of the metacognition task. Results revealed comparable results, in that performance on novel trials of the selective word-learning task was predicted by both predictor variables of interest exclusively in the unreliable condition. It was indicated that in Step 1, causal learning accounted for 27% of the variance on novel trials, F (1, 19) = 6.60, p = .02, R^2 = .27. In Step 2, when persistence time on the metacognition task was included, 42% of the variance was explained by both predictor variables of interest, F (2, 18) = 6.16, p = .01, R^2 = .42.

Discussion

The present study addressed two important questions in the field of early selective trust: (i) whether causal learning and precursors of metacognitive abilities—as measured through decision confidence—support selective social learning in 18-month-olds, and (ii) to what extent does each of these abilities predict such discriminant learning in infants. Although a large body of work has focused on preschoolers' tendencies to display selective trust in reliable sources of information relative to unreliable sources, there is mounting empirical support for the emergence of such abilities in infancy (Poulin-Dubois & Brosseau-Liard 2016). However, there is a considerable amount of disagreement surrounding the psychological underpinnings at the origins of selective social learning. According to one account, infants draw on domain-general cognitive abilities (e.g., statistical learning and causal learning) (Heyes, 2016), whereas another account posits that young children use higher-order, domain-specific cognitive mechanisms (e.g., theory-of-mind and metacognition) to resist learning from an unreliable speaker (Poulin-Dubois, 2016). To our knowledge, this is the first investigation of causal learning and precursor metacognitive abilities as potential mechanisms associated with selective social learning in infancy. This study presents preliminary evidence of predictive relations between both causal learning and metacognitive abilities with epistemic trust in infancy. Specifically, we find some support indicating that infants who displayed less decision confidence, and who had better causal learning skills, were also more willing to learn a novel word from an incompetent speaker on a word-learning task.

The classic selective word-learning paradigm was adapted to achieve our research objectives, wherein infants were exposed to an informant who offered accurate or inaccurate testimony—that is, an informant who correctly (reliable condition) or incorrectly (unreliable condition) labelled familiar objects. Infants' willingness to learn a novel word was examined following this reliability induction phase. Consistent with previous work (Brooker & Poulin-Dubois, 2013; Crivello et al., 2017; Luchkina et al., 2018; Koenig et al., 2004) and with our predictions, infants in the unreliable condition were less likely to learn a new word, relative to infants in the reliable condition. As expected, infants performed above chance across trial type in the reliable condition. In contrast, infants in the unreliable condition performed above chance on familiar trials, but performance did not differ from chance on novel trials. In the unreliable condition, above chance-level performance on familiar trials suggest that infants accurately offered the target object more often than would be expected to occur by chance alone, whereas chance-level performance on novel trials indicate that infants were likely performing at random. Taken together, these results indicate that infants were able to discriminate between sources of information, displaying selective trust in reliable sources relative to unreliable ones.

These findings contribute to a growing body of work demonstrating that infants are sensitive to epistemic cues that guide their future learning (see Harris et al., 2018; Mills, 2013; Poulin-Dubois & Brosseau-Liard, 2016 for reviews). That is, infants may take into consideration what they know about the speaker's knowledge when deciding from whom to learn. However, some researchers caution an interpretation that would suggest that this learning is rational, given that it may appear that children use epistemic cues to inform their learning but, in fact, may be unaware of the selectivity of their learning themselves (Heyes, 2016). Instead, it is proposed that this selectivity may be driven by simple causal learning processes (Heyes, 2016, 2017).

In an effort to address this debate—namely, whether general learning abilities are related to early selective social learning, and more sophisticated abilities come online later in development— two correlate tasks (i.e., causal learning and metacognition) were administered to examine the predictive power of different types to abilities on infants' selective word-learning. According to Heyes (2016), domain-general mechanisms, such as causal learning, may be important for early selective word-learning, given that infants may use causal learning abilities to map words onto their intended referents. As such, causal information may facilitate the acquisition of new words from a reliable speaker, but thwart learning from an unreliable speaker because the association between a label and the respective familiar object is broken (Heyes, 2016). A causal learning task was thus administered to obtain an index of 18-month-olds causal learning abilities. Akin to Sobel and Kirkham (2006), performance on three experimental trials was assessed relative to chance responding. In the present sample, 18- month-olds' performance on all the three experimental trials was not different from chance. Performance on the "screening indirect screening-off" and "backward blocking" trials are consistent with response patterns reported by Sobel and Kirkham (2006). However, our results indicate that infants performed at chance level on the "screening-off" trials, whereas Sobel and Kirkham (2006) reported above chance performance. Moreover, contrary to what was reported by the original authors, results of the present study suggest an order effect, such that infants appear to perform progressively better across the fixed series of trials. This pattern of results may be indicative of learning across trials.

Considering that comprehension of the task was dependent on verbal ability (i.e., “Make it go”), perhaps these apparent differences across studies may reflect variability in infants’ comprehension of task instructions. Moreover, the task required goal-directed imitation that involves understanding of an agent’s intentions and to act on this knowledge by imitating the goals of the actor (Sakkalou, Ellis-Davies, Fowler, Hilbrink & Gattis, 2013). Thus, infants’ gradual improvement in performance may simply indicate better grasp of task demands, as well as improvements in interpreting an agent’s intentions and producing goal-directed behavior.

Alternatively, other researchers suggest that selectivity in social learning is associated with individual differences in more sophisticated cognitive abilities (Poulin-Dubois, 2016; Sabbagh et al., 2017). Although less recognized in the selective social learning literature, metacognitive skills have been hypothesized to guide discriminate social learning, in that individuals reflect on their own knowledge states in order to adjust their social learning strategies (Heyes, 2016; Sobel & Kushnir, 2013). Whereas more explicit forms of metacognition emerge late in development, it has recently been shown that even infants are capable of using metacognitive judgments to guide their behavior (Goupil et al., 2016). That is, within the context of the present study, infants who were more confident in their own knowledge were hypothesized to learn less from an unreliable speaker. As such, a non-verbal form of metacognition was examined using a decision confidence monitoring paradigm, wherein infants were required to search for a toy in one of two boxes following a delay. Consistent with results reported by Goupil and colleagues (2016), infants searched the box longer after correctly identifying where the toy was hidden, as compared to trials where infants incorrectly identified the location of the toy. These findings suggest that more perseverance on correct trials indicate degrees of decision confidence, whereas less persistence on incorrect trials indicates a lack thereof. Results also revealed a positive relation among persistence time on correct and incorrect trials, suggesting that infants’ who persisted more on correct trials, also demonstrated increased persistence on incorrect trials. This result sheds light on the nascent nature of this behavior at this age, in that the metacognitive skills tapped by this specific task do not fully reflect infants’ internal monitoring of the accuracy of their own decisions. Moreover, the frequency with which infants looked inside the target box was analyzed as a subsequent measure of metacognitive ability. Indeed, infants more often looked inside the selected box on correct trials relative to incorrect trials, which may also represent an index of infants’ decision confidence. Together, the present results provide additional empirical support for infants' early metacognitive monitoring abilities. Given that metacognitive monitoring appear to be primitive in nature, future research should aim to examine these abilities in older samples of children.

Overall, some support for our hypothesis was obtained, in that precursor metacognitive skills appear to be linked with 18-month-olds selective word-learning abilities exclusively in the unreliable condition. However, the pattern of results across trial type was unexpected. Infants who displayed less decision confidence on incorrect trials of the metacognition task appeared to be more willing to learn from an unreliable speaker on a selective word-learning task. Interestingly, causal learning skills also appear to play a significant role so that infants' performance on both correlate tasks predicted performance on the word-learning task, but only in the unreliable condition, as anticipated. Moreover, infants who presented with better causal learning abilities were also more willing to accept an unreliable speaker's testimony. Visual inspection of the regression paths suggests a possible interaction of the two abilities. However, the extent of infants' willingness to learn from an unreliable speaker as a function of an interaction between causal learning and metacognitive abilities was not examined given the small sample sizes. Based on these findings, it appears that infants who were more inclined to learn from an unreliable speaker, also lacked confidence in their own knowledge in a confidence-monitoring task. It may be that under such circumstances of uncertainty, they may rely on more causal learning abilities to better learn the association between a novel label and the respective object. This would be in line with a domain-general account of early word-learning (Booth, 2009), and may reflect a variation of the *copy when uncertain* social learning rule (Rendell et al., 2011). Future research should aim to assess this directly in order to provide more insight into how selective social learning manifests in infancy.

Moreover, the predictive power of causal learning abilities was observed to be greater than that of precursor metacognition. We propose that this may be a reflection of the immature development of these higher-order cognitive functions. As such, it is anticipated that explicit metacognitive judgments play an increasingly important role in early selective social learning as this ability becomes more mature—particularly when children begin to verbalize their mental states. Similarly, no association between persistence on correct trials of the metacognitive task and infants' willingness to learn from an unreliable speaker was obtained. It appears that precursor metacognitive abilities only predicts infants' social learning when they are uncertain of their knowledge. We anticipate that confidence would govern successful selective learning as young children become better equipped to make more accurate estimates of what they do know. More specifically, as children acquire more experience in metacognitive monitoring and regulate their behavior accordingly, they would be better able to optimize their social learning from appropriate sources of information.

Indeed, it has been proposed that knowledge confidence involves serial efforts of evaluating i) the source of knowledge (e.g., "How does this fit with my own knowledge") and ii) developing justifications for knowing (e.g., "Do I judge this claim to be credible?") (Hofer, 2004). This, no doubt, represents a more sophisticated form of epistemological thinking that is likely not present in infancy. We, therefore, echo Heyes' (2016) hypothesis specifying that as children develop a stronger capacity for metacognition, they will then be able to more readily adjust social learning strategies that reflect metacognitive judgments. Finally, in contrast with predictions from a domain-general perspective of early selective social learning, causal learning abilities appear to be associated with a more indiscriminate—rather than discriminate—form of learning.

To date, extant research on this topic only includes two studies that investigated the link between domain-general and domain-specific mechanisms with selective social learning abilities in infancy (Crivello et al., 2017; Crivello & Poulin-Dubois, 2018). Both studies support a rich account for early selective social learning, such that infants' abilities to develop inferences about others' states of knowledge has been found to govern successful selective word-learning (Crivello et al., 2017), and successful detection of emotional reliability (Crivello & Poulin-Dubois, 2018). More specifically, 18-month-olds were less likely to acquire a new word from an unreliable speaker if they displayed better understanding of an informant's knowledge, but no such link with statistical learning abilities emerged (Crivello et al., 2017). Similarly, 14-month-olds demonstrated increased persistence to inspect an empty container following an unreliable display of emotion (i.e., emoter displaying happiness when the container did not contain a toy). Moreover, in-group variability in latency to inspect the empty container was associated with superior performance on an adaptation of a knowledge inference task (Crivello & Poulin-Dubois, 2018). Again, no link was reported between successful emotional unreliability detection and an associative learning task (Crivello & Poulin-Dubois, 2018).

How can we reconcile previous research with the present findings? Several explanations can be offered to account for what appears to be a discrepancy. First, infants' causal learning abilities were measured in an effort to investigate the predictive power of this ability on early selective word-learning. Contrary to what was previously reported (Crivello et al., 2017; Crivello & Poulin-Dubois, 2018), results suggest that particular domain-general mechanisms may facilitate word-learning in a selective trust paradigm. It should be noted that the mechanisms that drive infants' abilities to represent and acquire causal knowledge is currently a topic of debate in developmental psychology. Specifically, whether associative theories can account for predictive behavior in infancy (e.g., Rescorla & Wagner, 1972), or whether more sophisticated computational models of causality underlie infants' ability to predict future behavior (Lagnado & Sloman, 2004; Steyvers, Tenenbaum, Wagenmakers, & Blum, 2003). As such, this debate challenges the view that causal learning abilities represent "simple" mechanisms in infancy. Moreover, unlike statistical and associative learning mechanisms, causal learning abilities necessitate complex inferential capabilities that are based on principles of causality, temporal priority, spatial priority, and contingency (Bullock, Gelman, & Baillargeon, 1982). As such, the ability to develop causal inferences involving multiple potential causes and based on more complex probabilistic reasoning (i.e., principles of conditional independence; Sobel & Kirkham, 2006), may represent a more sophisticated form of domain-general abilities compared to those examined in previous research.

In addition, the causal learning task developed by Sobel and Kirkham (2006) may not reflect asocial learning—"i.e., direct interaction with the inanimate environment"— that characterizes many general learning mechanisms (e.g., associative learning; Heyes & Pearce, 2015). As previously mentioned, the causal learning task required infants to draw inferences about an agent's goal, and subsequently imitate goal-directed behavior. Thus, this task may rely on the ability to develop an understanding of an individual's intention in order successfully imitate their behavior. This would not only support the idea that the domain-general mechanism measured here may reflect a more complex ability, but indicates that the task may be confounded by domain-specific, mental state attribution skills.

Subsequently, we examined a domain-specific ability that was initially thought to only emerge during the preschool period (Flavell, 1999; Sodian et al., 2012). In particular, we investigated metacognition of one's own ignorance, first demonstrated at 18-months of age

(Goupil et al., 2016), whereas previous efforts to examine the correlates of selective trust in infancy investigated theory-of-mind abilities—those that have been shown to emerge as early as 7-months (Kovács, Téglás, & Endress, 2010). Although evidence of infant theory-of-mind rests on a similar debate surrounding its origins (see Heyes, 2014; Poulin-Dubois & Yott, 2017; Scott & Baillargeon, 2014; Ruffman, 2014), it appears that there may be more opportunity for the development of mental state attribution abilities (i.e., theory-of-mind knowledge) relative to an understanding of one's own knowledge (metacognition) (but see Meltzoff, 1999 for a different view). A recent longitudinal research provides support for the primacy of theory-of-mind over metacognition (Ebert, 2015). Thus, theory-of-mind abilities may be better predictors of early selective trust as compared to metacognition, given that infants may show more understanding of others' knowledge relative to their own. Moreover, the nature of the metacognitive task may also account for the current pattern of results. That is, the uncertainty monitoring paradigm may only reflect an implicit understanding of infants' own mental states—an understanding that we share with non-human animals (see De Waal, 2016 for a review). Indeed, a more explicit understanding of one's own knowledge and ignorance may better account for successful selective social learning (Heyes, 2016). However, a task that requires more effortful reflection of knowledge or ignorance, such as an information-seeking paradigm, may better elucidate the relation between metacognitive ability and early selective social learning.

Finally, the limitations of this study should be acknowledged. First, the between-subjects design may limit our interpretations, in that it does not permit infants to select from who they prefer to learn. A within-subjects approach to early word-learning would allow for a better understanding of the mechanisms supporting infants' decision to select from who to learn, and thus enable us to draw more powerful conclusions. It should be noted, however, that a within-subjects design would incur executive function demands that would likely increase the difficulty of the task given that these abilities have been shown to improve significantly during the preschool period (see Diamond, 2013 for a review). Infants would be required to track the reliability of two informants simultaneously and draw on inhibitory control abilities to attend to the competent speaker while ignoring the incompetent one. Ongoing research in our laboratory is using a within-subjects adaptation of the word-learning task with 18-month-olds. Preliminary findings suggest that although infants prefer to learn from a reliable speaker, the effect is less robust than when tested with a between-subjects design. Additionally, the present study does not include a control condition that would examine the specificity of the effect. It is possible that infants' tendency to resist learning from an unreliable speaker is merely a reflection of their general cognitive abilities, and not as a result of stronger metacognitive and causal learning skills. As a consequence, the impact of infants' productive vocabulary size on selective word-learning abilities was analyzed as proxy for general intelligence. Results did not reveal any significant associations between productive vocabulary and novel word-learning in both the reliable and unreliable conditions.

In conclusion, the present set of findings informs the heated debate between rich and lean approaches to early selective social learning. This is the first investigation to provide preliminary support that both implicit metacognitive abilities and causal learning skills may be related to 18-month-olds stronger propensity to learn from an unreliable speaker. Findings may reflect a variation of the copy when uncertain social learning rule, in that infants may draw on causal learning to learn a new word—irrespective of the speaker's competency—when unconfident in their own knowledge. Future research initiatives should examine the predictive power of more explicit forms of metacognitive awareness on early selective trust.

References

Beran, M. J., & Smith, J. D. (2011). Information seeking by rhesus monkeys (Macaca mulatta) and capuchin monkeys (Cebus apella). *Cognition, 120*, 90-105. doi:10.1016/j.cognition.2011.02.016

Booth, A. E. (2009). Causal supports for early word learning. *Child Development, 80*, 1243 1250.

Brooker, I., & Poulin Dubois, D. (2013). Is a bird an apple? The effect of speaker labeling accuracy on infants' word learning, imitation, and helping behaviors. *Infancy, 18*.E46–E68. doi: 10.1111/infa.12027

Brosseau Liard, P. E., & Poulin Dubois, D. (2014). Sensitivity to confidence cues increases during the second year of life. *Infancy, 19*, 461-475. doi: 10.1111/infa.12056

Brosseau Liard, P., Penney, D., & Poulin Dubois, D. (2015). Theory of mind selectively predicts preschoolers' knowledge-based selective word learning. *British Journal of Developmental Psychology, 33*, 464-475. doi: 10.1111/bjdp.12107

Bullock, M., Gelman, R., & Baillargeon, R. (1982). The development of causal reasoning. In W. J. Freidman (Ed.), *The Developmental Psychology of Time* (pp. 209–253). New York, NY: Academic Press.

Call, J., & Carpenter, M. (2001). Do apes and children know what they have seen? *Animal Cognition,3*, 207-220. doi: 10.1007/s100710100078

Crivello, C., & Poulin-Dubois (2018). Infants' ability to detect emotional incongruency: Deep or shallow? Manuscript submitted for publication.

Crivello, C., Phillips, S., & Poulin-Dubois, D. (2017). Selective social learning in infancy: Looking for mechanisms. *Developmental science, 21*, e1259. doi: 10.1111/desc.12592

De Waal, F. (2016). Time will tell. In *Are we smart enough to know how smart animals are?* (pp. 205-234). New York, NY: WW Norton & Company.

Diamond, A. (2013). Executive functions. *Annual review of psychology*, *64*, 135-168. doi: https://doi.org/10.1146/annurev-psych-113011-143750

DiYanni, C., & Kelemen, D. (2008). Using a bad tool with good intention: Young children's imitation of adults' questionable choices. *Journal of experimental child psychology, 101*, 241-261. doi: 10.1016/j.jecp.2008.05.002

DiYanni, C., Nini, D., Rheel, W., & Livelli, A. (2012). ‘I won't trust you if I think you're trying to deceive me': Relations between selective trust, theory of mind, and imitation in early childhood. *Journal of Cognition and Development, 13*, 354-371. doi: 10.1080/15248372.2011.590462

Duffy, G. A., Pike, T. W., & Laland, K. N. (2009). Size-dependent directed social learning in nine-spined sticklebacks. *Animal Behaviour, 78*, 371-375. doi:10.1016/j.anbehav.2009.05.015

Dugatkin, L. A., & Godin, J. G. J. (1993). Female mate copying in the guppy {Poecilia reticulata): agedependent effects. *Behavioral Ecology, 4*, 289-292. doi:10.1093/beheco/4.4.289

Dunlosky, J., & Rawson, K. A. (2012). Overconfidence produces underachievement: Inaccurate self evaluations undermine students’ learning and retention. *Learning and Instruction, 22*, 271-280. doi: 10.1016/j.learninstruc.2011.08.003

Dwivedi, A. K., Mallawaarachchi, I., & Alvarado, L. A. (2017). Analysis of small sample size studies using nonparametric bootstrap test with pooled resampling method. *Statistics in Medicine, 36*, 2187-2205. doi: 10.1002/sim.7263

Ebert, S. (2015). Longitudinal relations between theory of mind and metacognition and the impact of language. *Journal of Cognition and Development*, *16*, 559-586. doi: 10.1080/15248372.2014.926272

Elashi, F. B., & Mills, C. M. (2014). Do children trust based on group membership or prior accuracy? The role of novel group membership in children’s trust decisions. *Journal of Experimental Child Psychology, 128*, 88-104. doi: https://doi.org/10.1016/j.jecp.2014.07.003

Fenson, L., Pethick, S., Renda, C., Cox, J. L., Dale, P. S., & Reznick, J. S. (2000). Short-form versions of the MacArthur communicative development inventories. *Applied Psycholinguistics, 21*, 95- 116. doi:10.1017/S0142716400001053

Fitneva, S. A., & Dunfield, K. A. (2010). Selective information seeking after a single encounter. *Developmental psychology*, *46*, 1380. doi: http://dx.doi.org/10.1037/a0019818

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive developmental inquiry. *American Psychologist, 34*, 906- 911. doi:10.1037//0003 066x.34.10.906

Flavell, J. H. (1999). Cognitive development: Children's knowledge about the mind. *Annual Review of Psychology, 50*, 21-45. doi: 10.1146/annurev.psych.50.1.21

Flavell, J. H. (2000). Development of children's knowledge about the mental world. *International journal of behavioral development*, *24*, 15-23.

Frith, C. D. (2012). The role of metacognition in human social interactions. *Phil. Trans. R. Soc.B*, *367*, 2213-2223. doi: 10.1098/rstb.2012.0123

Fusaro, M., & Harris, P. L. (2008). Children assess informant reliability using bystanders' non verbal cues. *Developmental Science, 11*, 771-777. doi: 10.1111/j.1467 7687.2008.00728.x

Galef Jr, B.G., & Heyes, C.M. (2004). Special issue on social learning and imitation. *Learning and Behavior, 32*, 1-140.

Galef, B.G. (2009). Strategies for social learning: testing predictions from formal theory. *Advances in the Study of Behavior, 39*, 117-151. doi: 10.1016/S00653454(09)39004-X

Geurten, M., & Willems, S. (2016). Metacognition in early childhood: Fertile ground to understand memory development?. *Child Development Perspectives, 10*, 263-268. doi: 10.1111/cdep.12201

Godin, J. G., & Dugatkin, L. A. (1996). Female mating preference for bold males in the guppy, Poecilia reticulata. *Proceedings of the National Academy of Sciences, 93*, 10262-10267. doi:10.1073/pnas.93.19.10262

Gopnik, A., Glymour, C., Sobel, D. M., Schulz, L. E., Kushnir, T., & Danks, D. (2004). A theory of causal learning in children: Causal maps and Bayes nets. *Psychological Review, 111*, 3-32. doi: 10.1037/0033-295X.111.1.3

Goupil, L., & Kouider, S. (2016). Behavioral and neural indices of metacognitive sensitivity in preverbal infants. *Current Biology, 26*, 3038-3045. doi: 10.1016/j.cub.2016.09.004

Goupil, L., Romand-Monnier, M., & Kouider, S. (2016). Infants ask for help when they know they don't know. *Proceedings of the National Academy of Sciences, 113*, 3492-3496. doi: 10.1073/pnas.1515129113

Hampton, R. R. (2009). Multiple demonstrations of metacognition in nonhumans: Converging evidence or multiple mechanisms? *Comparative Cognition & Behavior Reviews, 4*, 17–28. doi:10.3819/ccbr.2009.40002

Harris, P. L., & Koenig, M. A. (2006). Trust in testimony: How children learn about science and religion. *Child development*, *77*, 505-524. doi: https://doi.org/10.1111/j.1467 8624.2006.00886.x

Harris, P. L., Koenig, M. A., Corriveau, K. H., & Jaswal, V. K. (2018). Cognitive foundations of learning from testimony. *Annual Review of Psychology, 69*, 251-273. doi: 10.1146/annurev-psych-122216-011710

Heyes, C. (2012). What's social about social learning? *Journal of Comparative Psychology, 126*, 193-202. doi: 10.1037/a0025180

Heyes, C. (2014). False belief in infancy: a fresh look. *Developmental Science, 17*, 647-659. doi: 10.1111/desc.12148.

Heyes, C. (2016a). Blackboxing: social learning strategies and cultural evolution. *Phil. Trans. R. Soc. Lond. B. Biol. Sci., 371*, 20150369. doi: 10.1098/rstb.2015.0369

Heyes, C. (2016b). Who knows? Metacognitive social learning strategies. *Trends in Cognitive Sciences, 20*, 204-213. doi: 10.1016/j.tics.2015.12.007

Heyes, C. (2017). When does social learning become cultural learning? *Developmental Science, 20.* doi: 10.1111/desc.12350

Heyes, C., & Pearce, J. M. (2015). Not-so-social learning strategies. *Proceedings of the Royal Society of London B: Biological Sciences*, *282*, 20141709. doi: 10.1098/rspb.2014.1709

Heyes, C. M., & Frith, C. D. (2014). The cultural evolution of mind reading. *Science, 344*, 1243091. doi: 10.1177/1745691613518076

Hofer, B. K. (2004). Epistemological understanding as a metacognitive process: Thinking aloud during online searching. *Educational Psychologist, 39*, 43-55. doi:10.1207/s15326985ep3901_5

Hoppitt, W., & Laland, K. N. (2008). Social processes influencing learning in animals: a review of the evidence. *Advances in the Study of Behavior, 38*, 105-165. doi: 10.1016/S00653454(08)00003X

Horner, V., Proctor, D., Bonnie, K. E., Whiten, A., & de Waal, F. B. (2010). Prestige affects cultural learning in chimpanzees. *PloS one, 5*, e10625. doi:10.1371/journal.pone.0010625

Jaswal, V. K., & Neely, L. A. (2006). Adults don't always know best: Preschoolers use past reliability over age when learning new words. *Psychological Science*. doi: 10.111/j.14679280.2006.01778.x

Koenig, M.A., Clément, F., & Harris, P. L. (2004). Trust in testimony: Children's use of true and false statements. *Psychological Science, 15*, 694-698. doi: 10.1111/j.0956 7976.2004.00742.x

Koenig, M. A., & Harris, P. L. (2005). Preschoolers mistrust ignorant and inaccurate speakers. *Child Development, 76*, 1261-1277. doi: 0009-3920/2005/7606-0010

Koenig, M. A., & Sabbagh, M. A. (2013). Selective social learning: New perspectives on learning from others. *Developmental Psychology, 49*, 399. doi: 10.1037/a0031619

Kovács, Á. M., Téglás, E., & Endress, A. D. (2010). The social sense: Susceptibility to others' beliefs in human infants and adults. *Science, 330*, 1830-1834. doi: 10.1126/science.1190792

Lagnado, D.A. & Sloman, S. (2004). The advantage of timely intervention. *Journal of Experimental Psychology: Learning, Memory and Cognition,* 30, 856-876. doi: 10.1037/0278-7393.30.4.856

Le Pelley, M. E., Vadillo, M., & Luque, D. (2013). Learned predictiveness influences rapid attentional capture: evidence from the dot probe task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 39*, 1888. doi: 10.1037/a0033700

Lucas, A. J., Lewis, C., Pala, F. C., Wong, K., & Berridge, D. (2013). Social-cognitive processes in preschoolers' selective trust: Three cultures compared. *Developmental Psychology, 49*, 579-590. doi: 10.1037/a0029864

Luchkina, E., Sobel, D. M., & Morgan, J. L. (2018). Eighteen month olds selectively generalize words from accurate speakers to novel contexts. *Developmental Science*, e12663. doi: 10.1111/desc.12663

Meltzoff, A. N. (1999). Origins of Theory of Mind, Cognition, and Communication. *Journal of Communication Disorders, 32, 4,* 251-269.

Mills, C. M. (2013). Knowing when to doubt: Developing a critical stance when learning from others. *Developmental Psychology, 49*, 404. doi: 10.1037/a0031619

Morgan, T. J. H., Rendell, L. E., Ehn, M., Hoppitt, W., & Laland, K. N. (2012). The evolutionary basis of human social learning. *Proceedings of the Royal Society of London B: Biological Sciences, 279*, 653-662. doi: 10.1098/rspb.2011.1172

Nevin, J. A. (2009). Stimuli, reinforcers, and the persistence of behavior. *The Behavior Analyst, 32*, 285-291. doi: 10.1007/BF03392191

Nurmsoo, E., Robinson, E. J., & Butterfill, S. A. (2010). Children's selective learning from others. *Review of Philosophy and Psychology, 1*, 551-561. doi: 10.1007/s13164-010 0043-y

Pasquini, E.S., Corriveau, K.H., Koenig, M., & Harris, P.L. (2007). Preschoolers monitor the relativeaccuracy of informants. *Developmental Psychology, 43*, 1216-1226. doi: 10.1037/0012-1649.43.5.1216

Paulus, M., Proust, J., & Sodian, B. (2013). Examining implicit metacognition in 3.5-year-old children: An eye-tracking and pupillometric study. *Frontiers in Psychology, 4*, 145. doi: 10.3389/fpsyg.2013.00145

Poulin-Dubois, D. (2017). Rattling the developmental psychologist's cage? *Developmental Science, 20*, e12414. doi: 10.1111/desc.12414

Poulin-Dubois, D., & Brosseau-Liard, P. (2016). The developmental origins of selective social learning. *Current Directions in Psychological Science, 25*, 60-64. doi: 10.1177/0963721415613962

Poulin Dubois, D., & Yott, J. (2017). Probing the depth of infants' theory of mind: Disunity in performance across paradigms. *Developmental Science*. doi: 10.1111/desc.12600

Rendell, L., Fogarty, L., Hoppitt, W. J., Morgan, T. J., Webster, M. M., & Laland, K. N. (2011). Cognitive culture: theoretical and empirical insights into social learning strategies. *Trends in Cognitive Sciences, 15*, 68-76. doi: 10.1016/j.tics.2010.12.002

Rescorla, R. A., & Wagner, A. R. (1972). A theory of Pavlovian conditioning: variations in the effectiveness of reinforcement and nonreinforcement. In A.H. Black & W.F. Prokasy (eds.), *Classical conditioning II: current research and theory* (pp. 64-99). New York: Appleton Century Crofts.

Rosati, A. G., & Santos, L. R. (2016). Spontaneous metacognition in rhesus monkeys. *Psychological Science, 27*, 1181-1191. doi: 10.1177/0956797616653737

Ruffman, T. (2014). To belief or not belief: Children's theory of mind. *Developmental Review, 34*, 265-293. doi: 10.1016/j.dr.2014.04.001

Ryalls, B. O., Gul, R. E., & Ryalls, K. R. (2000). Infant imitation of peer and adult models: Evidence for a peer model advantage. *Merrill-Palmer Quarterly, 46,*10. doi:10.1111/j.15327078.2010.00045.x

Sabbagh, M. A., Koenig, M. A., & Kuhlmeier, V. A. (2017). Conceptual constraints and mechanisms inchildren's selective learning. *Developmental Science, 20*, e12415. doi: 10.1111/desc.12415

Scott, R. M., & Baillargeon, R. (2014). How fresh a look? A reply to Heyes. *Developmental Science, 17*, 660-664. doi: 10.1111/desc.12173

Sobel, D. M., & Kirkham, N. Z. (2006). Blickets and babies: the development of causal reasoning in toddlers and infants. *Developmental Psychology, 42*, 1103-1115. doi: 10.1037/00121649.42.6.1103

Sobel, D. M., & Kushnir, T. (2013). Knowledge matters: How children evaluate the reliability of testimony as a process of rational inference. *Psychological Review*, *120*, 779. doi: http://dx.doi.org/10.1037/a0034191

Sakkalou, E., Ellis-Davies, K., Fowler, N. C., Hilbrink, E. E., & Gattis, M. (2013). Infants show stability of goal-directed imitation. *Journal of experimental child psychology*, *114*, 1-9. doi: 10.1016/j.jecp.2012.09.005

Sodian, B., & Frith, U. (2008). Metacognition, theory of mind, and self control: The relevance of high-level cognitive processes in development, neuroscience, and education. *Mind, Brain, and Education, 2*, 111-113. doi: 10.1111/j.1751-228X.2008.00040.x

Sodian, B., Thoermer, C., Kristen, S., & Perst, H. (2012). Metacognition in infants and young children. In *Foundations of metacognition.* (pp. 119-133). Oxford, UK: Oxford University Press

Steyvers, M., Tenenbaum, J. B., Wagenmakers, E. J., & Blum, B. (2003). Inferring causal networks from observations and interventions. *Cognitive science*, *27*, 453-489. doi: 10.1016/S0360213(03)00010-07

Sawa, K. (2009). Predictive behavior and causal learning in animals and humans 1. *Japanese Psychological Research*, *51*,3, 222-233. doi: 10.1111/j.1468-5884.2009.00396.x

Swaney, W., Kendal, J., Capon, H., Brown, C., & Laland, K. N. (2001). Familiarity facilitates social learning of foraging behaviour in the guppy. *Animal Behaviour, 62*, 591-598. doi: 10.1006/anbe.2001.1788

Trudeau, N., Frank, I., & Poulin-Dubois, D. (1999). Une adaptation en français québécois du MacArthur Communicative Development Inventory. *La revue d'orthophonie et d'audiologie, 23*, 61-73.

van Bergen, Y., Coolen, I., & Laland, K. N. (2004) Nine-spined sticklebacks exploit the most reliablesource when public and private information conflict. *Proc. R. Soc. Lond. B 271*, 957–962. doi: 10.1098/rspb.2004.2684

Watanabe, A., & Clayton, N. S. (2016). Hint-seeking behaviour of western scrub-jays in a metacognition task. *Animal cognition, 19*, 53-64. doi: 10.007/s10071-015-0912-y

Wellman, H.M. (2014). *Making minds: How theory of mind develops*. New York: Oxford University Press.

Appendix A

Sample Parental Consent Form

Parental Consent Form

This is to state that I agree to allow my child to participate in a research project being conducted by Dr. Diane Poulin-Dubois, in collaboration with graduate student Olivia Kuzyk of Concordia University.

A. PURPOSE

I have been informed that the purpose of the research is to examine how children learn selectively from others.

B. PROCEDURES

For the present study, you will be invited to complete a short questionnaire about your child's vocabulary. You will also be invited to complete a short questionnaire about your own child-rearing values. Then, your child will participate in a series of short games with three female researchers. In the first game, your child will observe an experimenter label familiar objects either incorrectly or correctly. Next, your child will have the opportunity to learn new words from this individual. Of interest is whether his/her prior learning experience with the experimenter will influence his/her ability to learn from her. Other tasks will involve searching for a toy, and playing with different shapes that activate a "magic box".

We will videotape your child's responses and all tapes will be treated in the strictest of confidentiality. That means that the researcher will not reveal your child's identity in any written or oral reports about the study. You and your child will be assigned a coded number, and that code will be used on all materials collected in this study. All materials and data will be stored in secure facilities in the Department of Psychology at Concordia University. Only members of the research team will have access to these facilities. Questionnaires and electronic datafiles will be identified by coded identification numbers, unique to each family. Information collected on paper (questionnaires) or videotapes (observed behaviours) will be entered into computer databases. Raw data will be kept for a minimum of 5 years. When it is time for disposal, papers will be shredded, heard-drives will be purged, and videotapes and computer disks will be magnetically erased.

As well, because we are only interested in comparing children's understanding as a function of age, no individual scores will be provided following participation. The whole session should last approximately 60 minutes. During all tasks, your child will be sitting in a child seat and you will be seated directly behind.

C. RISKS AND BENEFITS

Your child will be given a certificate of merit at the end of the session as a thank-you for his/her participation. Also, you will be offered $20 for your participation.

There is one condition which may result in the researchers being required to break the confidentiality of your child's participation. There are no procedures in this investigation that inquire about child maltreatment directly. However, by the laws of Québec and Canada, if the researchers discover information that indicates the possibility of child maltreatment, or that your child is at risk for imminent harm, they are required to disclose this information to the appropriate agencies. If this concern emerges, the lead researcher, Dr. Diane Poulin-Dubois, will discuss the reasons for this concern with you and will advise you of what steps will have to be taken.

D. CONDITIONS OF PARTICIPATION

- I understand that I am free to withdraw my consent and discontinue my participation at any time without negative consequences, and that the experimenter will gladly answer any questions that might arise during the course of the research.
- I understand that my participation in this study is confidential (i.e. the researchers will know, but will not disclose my identity).

- I understand that the data from this study may be published, though no individual scores will be reported.

I would be interested in participating in other studies with my child in the future (yes/no): ______

I HAVE CAREFULLY STUDIED THE ABOVE AND UNDERSTAND THIS AGREEMENT. I FREELY CONSENT AND VOUNTARILY AGREE TO HAVE MY CHILD PARTICIPATE IN THIS STUDY.

MY CHILD'S NAME (please print) ___________________________________

MY NAME (please print) ____

SIGNATURE ___________________________ DATE ___________________

WITNESSED BY ________________________ DATE ___________________

If at any time you have questions about your rights as a research participant, you are free to contact the Research Ethics and Compliance Officer of Concordia University, at (514) 848-2424 ext 7481 or by email at ethics@alcor.concordia.ca.

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Participant # _____________ Researcher: __________________

Appendix B

Sample Demographic Information Form

The Cognitive and Language Development Laboratory
Concordia University
Participant Information

Child's Name: _______________________________ _________________________________
First Last

Child's Date of Birth: ____________________ Child's Gender: ☐ M ☐ F
MM / DD / YY

<u>Basic Family Information</u>

Parent A's Full Name: ________________________ __________________________ ☐ **M** ☐ **F**
First **Last**

Parent B's Full Name: ________________________ __________________________ ☐ **M** ☐ **F**
First **Last**

Address (including **<u>postal code</u>**):

____

____

Phone numbers	**Where?** (e.g. home, Mom work, Dad cell)
1.	
2.	
3.	
4.	
5.	

E-mail: ____

Does your child have any siblings?

Name of Sibling	**Date of Birth** **MM / DD / YY**	**Gender**	**Can we contact you for future studies for this child?**
		M F	☐ **Yes** ☐ **No**
		M F	☐ **Yes** ☐ **No**
		M F	☐ **Yes** ☐ **No**

<u>Languages Spoken in the Home, School, or Childcare Setting</u>

Note. Total of all languages should add up to 100%.

What percent of the time does your child hear **English**? _________ **%**

What percent of the time does your child hear **French?** _________ **%**

What percent of the time does your child hear **another language**? _________ **%**
Please specify this language**:** ________________________

Has the child lived/vacationed in any country **where s/he would hear a language other than English or French**? ☐ **Yes** ☐ **No**
If yes, please detail (when, where, and for how long?) _________________________________

<u>Health History</u>

What was your child's birth weight? __ __ **lbs** __ __ **oz** OR __ __ __ __ **grams**

How many weeks was your pregnancy? ____________**weeks**

Were there any **complications** during the pregnancy? ☐ **Yes** ☐ **No**
If yes please detail ____

Has your child had any major **medical problems**?
If yes please detail____

Does your child have any **hearing or vision problems**?
If yes please detail____

Does your child **<u>currently</u>** have an ear infection? ☐ **Yes** ☐ **No**

Has your child had any ear infections **<u>in the past</u>**? ☐ **Yes** ☐ **No**
If yes at which ages____

Does your child have a **cold** today? ☐ **Yes** ☐ **No**

If yes, does he/she have pressure/pain in ears (if known)? ☐ **Yes** ☐ **No**

Is there any other relevant information we should know (health or language-related)?

Has another university contacted you to participate in one of their studies? ☐ **Yes** ☐ **No**
If yes, which university? _________________________________

Family and Child Background Information (optional)

Parent A's Marital Status:

- ☐ Married
- ☐ Separated
- ☐ Remarried
- ☐ Single
- ☐ Divorced
- ☐ Common Law
- ☐ Widow
- ☐ Other

Parent B's Marital Status

- ☐ Married
- ☐ Separated
- ☐ Remarried
- ☐ Single
- ☐ Divorced
- ☐ Common Law
- ☐ Widow
- ☐ Other

Parent A's Current Level of Education
Check any/all that apply:

- ☐ Primary School
- ☐ Some High School
- ☐ High School
- ☐ Some College/University
- ☐ College Certificate/Diploma
- ☐ Trade School Diploma
- ☐ Bachelor's Degree
- ☐ Master's Degree
- ☐ Doctoral Degree
- ☐ Professional Degree
- ☐ Not Applicable/Unknown
- ☐ Other (please specify): ____________________

Parent B's Current Level of Education
Check any/all that apply:

- ☐ Primary School
- ☐ Some High School
- ☐ High School
- ☐ Some College/University
- ☐ College Certificate/Diploma
- ☐ Trade School Diploma
- ☐ Bachelor's Degree
- ☐ Master's Degree
- ☐ Doctoral Degree
- ☐ Professional Degree
- ☐ Not Applicable/Unknown
- ☐ Other (please specify): ____________________

Parent A's Occupational Status (optional)
Check any/all that apply:

- ☐ Employed Full-Time
- ☐ Employed Part-Time
- ☐ Stay-at-Home-Parent
- ☐ Student
- ☐ Unemployed
- ☐ Not Applicable/Unknown
- ☐ On Temporary Leave (e.g., maternity, paternity, sick, etc.; **please also check status when *not* on leave**)
- ☐ Other (please specify): ____________________
- ☐ Occupation: ____________________

Parent B's Occupational Status (optional)
Check any/all that apply:

- ☐ Employed Full-Time
- ☐ Employed Part-Time
- ☐ Stay-at-Home-Parent
- ☐ Student
- ☐ Unemployed
- ☐ Not Applicable/Unknown
- ☐ On Temporary Leave (e.g., maternity, paternity, sick, etc.; **please also check status when *not* on leave**)
- ☐ Other (please specify): ____________________
- ☐ Occupation: ____________________

In which of the following ranges does your annual household income fall (per year/before taxes)?

- ☐ < $ 22 000
- ☐ Between $22,000 and $35 000
- ☐ Between $35 000 and $50 000
- ☐ Between $50 000 and $75 000
- ☐ Between $75 000 and $100 000
- ☐ Between $100 000 and $150 000
- ☐ > $150 000

What language(s) community do you (and your partner) identify with? Check any/all that apply:

- ☐ Anglophone
- ☐ Francophone
- ☐ Allophone
- ☐ Other (please specify): ____

What are your child's ethnic origins? Check any/all that apply:

- ☐ Aboriginal
- ☐ African
- ☐ Arab
- ☐ West Asian
- ☐ South Asian
- ☐ East and Southeast Asian
- ☐ Caribbean
- ☐ European
- ☐ Latin/Central/South American
- ☐ Pacific Islands
- ☐ Canadian
- ☐ Not Applicable/Unknown
- ☐ Other (please specify):

____

What culture(s) do you (and your partner) identify with? Check any/all that apply:

- ☐ Aboriginal
- ☐ African
- ☐ Arab
- ☐ West Asian
- ☐ South Asian
- ☐ East and Southeast Asian
- ☐ Caribbean
- ☐ European
- ☐ Latin/Central/South American
- ☐ Pacific Islands
- ☐ Canadian/American
- ☐ Not Applicable/Unknown
- ☐ Other (please specify):

____

Appendix C

Word Comprehension Checklist

Participant ID: ______

Word Checklist

Please indicate which words your child *understands* from the following list. If you use a different word for any of these objects, please write it down as well.

- O Shoe
- O Banana
- O Dog
- O Book
- O Spoon
- O Apple
- O Sock
- O Rabbit
- O Chair
- O Bird
- O Cup
- O Duck
- O Airplane
- O Cow
- O Boat
- O Truck
- O Car
- O Bottle
- O Cookie
- O Cat
- O Telephone
- O Ball
- O Flower

Appendix D

Task Stimuli

i) Selective Word Learning Task (Novel objects)

ii) Metacognition Task

iii) Causal Learning Task