

## SELECTIVE INFORMATION SEEKING IN 12-MONTH-OLDS

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### **RUNNING HEAD: Selective information seeking in 12-month-olds**

“I don’t know but I know who to ask”:

12-month-olds actively seek information from knowledgeable adults

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### **Author Contributions**

MB, GW and EP conceived and designed the study and wrote the manuscript. MB collected and analyzed the data.

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**Open Practices Statement**

The data that support the findings of this study are openly available at the Open Science Framework [[https://osf.io/dj9cn/?view\\_only=72b0e95b5ab144cc85ab07f8a04839f2](https://osf.io/dj9cn/?view_only=72b0e95b5ab144cc85ab07f8a04839f2)]; the study was not formally preregistered.

“I don’t know but I know who to ask”:

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### **Research highlights**

- 12-month-olds reliably assessed the informative potential of the available social partners and selectively queried the best source only when information was needed.
- Pre-verbal infants used social referencing to actively and selectively seek information from social partners as part of their interrogative communicative toolkit.
- Social referencing served as a communicative means to seek epistemic rather than emotionally laden information in the situation of referential uncertainty.
- Results indicate that infants actively participate in the cultural interpersonal process of knowledge transmission, using basic nonverbal communicative tools at their disposal.

### **Abstract**

Active social communication is an effective way for infants to learn about the world. Do pre-verbal and pre-pointing infants seek epistemic information from their social partners when motivated to obtain information they cannot discover independently? The present study investigated whether 12-month-olds ( $N = 30$ ) selectively seek information from knowledgeable adults in situations of referential uncertainty. In a live experiment, infants were introduced to two unfamiliar adults, an Informant (reliably labeling objects) and a Non-Informant (equally socially engaging, but ignorant about object labels). At test, infants were asked to make an impossible choice - locate a novel referent among two novel objects. When facing epistemic uncertainty – but not at other phases of the procedure - infants selectively referred to the Informant rather than

the Non-Informant. These results show that pre-verbal infants use social referencing to actively and selectively seek information from social partners as part of their interrogative communicative toolkit.

**Keywords:**

- information seeking
- social referencing
- referential uncertainty
- active social learning
- epistemic knowledge
- knowledge transmission

Infants are notoriously curious and active learners. To enable effective knowledge acquisition, they actively seek information in both independent and social learning contexts (Begus & Southgate, 2018; Oudeyer & Smith, 2016). Recent research has begun to investigate infants' ability to judge their social partners' suitability to provide relevant information and selectively seek it from the most suitable informant (Harris, Koenig, Corriveau, & Jaswal, 2018). Nevertheless, early developmental manifestations of active information seeking are poorly understood. Here we investigate the developmental origins of intentional communication soliciting information in social learning by asking whether and how pre-verbal and pre-pointing infants actively and selectively refer to others in situations of epistemic uncertainty.

Infants' selective attention and active exploration of their environment has been investigated both in non-social contexts, highlighting infants' independent discovery-oriented behaviors that optimize their learning outcomes (Gottlieb, Oudeyer, Lopes, & Baranes, 2013; Kidd & Hayden, 2015), and in social learning contexts. Beginning in their first year of life, infants are capable to quickly and accurately form situational epistemic profiles of their social partners based on a variety of cues (Poulin-Dubois & Brosseau-Liard, 2016), such as the social partner's competence (Begus & Southgate, 2012; Begus, Gliga, & Southgate, 2016), reliability (Crivello, Phillips, & Poulin-Dubois, 2017; Tummeltshammer, Wu, Sobel, & Kirkham, 2014), credibility (Birch, Akmal, & Frampton, 2010), and confidence (Brosseau-Liard & Poulin-Dubois, 2014). In sum, infants show vigilance towards and keen understanding of knowledge distribution among social partners. However, little is known about whether pre-verbal infants actively, spontaneously and strategically seek information in social contexts. Do infants possess the communicative means to query others for epistemic information even before being able to formulate questions verbally?

Active social communication is an effective way for infants to learn about the world. In addition to supporting their social and emotional needs, one early communicative signal – pointing - has been proposed to serve an interrogative, or information-seeking function (Harris & Lane, 2014; Southgate, Van Maanen, & Csibra, 2007), endorsing the idea that pointing holds a special place as a cognitive milestone (Tomasello, Carpenter, & Liszkowski, 2007) in that it enables infants to take an active interrogative stance which is not available to them earlier in development. Specifically, pointing has been demonstrated to be a unique communicative tool used selectively in the presence of an informative social partner emerging in the second year of life (Begus & Southgate, 2012, at 16 months; Kovács, Tauzin, Téglás, Gergely, & Csibra, 2014, at 12 months; Lucca & Wilbourn, 2018, at 18 months).

Several crucial insights about interrogative communication in infancy have been gained from this line of research: infants are capable of recognizing the informative potential of their social partners and, when motor development allows it, can use pointing gestures to interrogate them. However, to our knowledge, no studies of infants' interrogative pointing have shown whether requesting information is selective from a specific source, such as demonstrating that infants point to a knowledgeable person when competing sources of information are available. All previous studies employed a between-subject design in which an infant encountered a single experimenter, and they have focused on very specific aspects of information provision. For example, in the seminal interrogative pointing study (Begus & Southgate, 2012), one group of infants interacted with an informant providing correct object labels, and a second group with an informant providing false labels. In another study (Kovács et al., 2014, Experiment 1), infants either interacted with an adult who showed varied emotional response or expressed positive interest, or provided either a familiar or a novel label (Kovács et al., 2014, Experiment 2). The

general cognitive mechanism specifying if and how infants select an information source from a set of options remains unknown.

While pointing has been the primary focus of attention in this line of investigation, other pre-verbal behaviors emerge prior to pointing which could serve the same functional mechanisms or act as a cognitive prerequisite for interrogative communication (Begus & Southgate, 2018; Ronfard, Zambrana, Hermansen, & Kelemen, 2018). One of them is social referencing, defined as initiating a look at a social partner in order to obtain situational information which may help guide behavioral choices (Walden & Ogan, 1988). Social referencing has been primarily used to show how infants resolve situations of emotional uncertainty by assessing the affective response of their caregiver or another adult to aversive, unsettling or potentially dangerous events, such as approaching a perceptual drop off (Campos & Stenberg, 1981; Sorce, Emde, Campos, & Klinnert, 1985). Having been initially linked to indices of attachment and comfort seeking (Stenberg & Hagekull, 2007; Striano, Vaish, & Benigno, 2006), social referencing has been established as a behavior specifically eliciting social appraisal information - albeit only in emotional contexts. In utilizing this behavior, infants are sensitive to adults' manifested expertise and competence cues in selectively choosing who to refer to in order to resolve their emotionally-laden uncertainty (Schieler, Koenig, & Buttelmann, 2018; Stenberg, 2009, 2013).

While adults serve as a point of reference for infants in uncertain situations, similar to other sources of information (both passive non-social and active social), such initiation of a social referencing look at an adult can be interpreted as an active communicative act of asking them for information – a request for input, an “interrogative social referencing”, aimed at not only expecting but actively eliciting a response from a social partner from whom they wish to

obtain information. In this sense, social referencing, like pointing, may be a proto-interrogative requestive act of a specific kind which functions to “induce the manifestation of some knowledge from the willing adult” (Southgate et al., 2007, p .738).

Do pre-verbal infants also use social referencing to actively and selectively seek epistemic information? Recent research has gone beyond studying social referencing exclusively in emotional contexts, challenging the long-standing view that it evolved for socio-emotional engagement purposes only, that it is not fully social until the second year of an infant’s life, and that infants are not capable of intentional information seeking at this age (Baldwin & Moses, 1996). Several reports showed that infants also use social referencing in non-emotional uncertainty, such as when their expectations are violated (Dunn & Bremner, 2016; Walden, Kim, McCoy, & Karrass, 2007), when they are presented with referential ambiguity such as two novel objects and only one novel label (Hembacher, deMayo, Frank, 2017; Vaish, Demir, & Baldwin, 2011), and when they know they can obtain information from a social partner about the location of hidden objects (Goupil, Romand-Monnier, & Kouider, 2016). But none of the previous studies of social referencing demonstrated whether infants go beyond appreciation of informative potential of social partners, and are able to query the best available source when in need of specific information.

A small number of studies suggest that social referencing is an active communicative behavior allowing pre-verbal infants to resolve epistemic uncertainty in social learning contexts. For example, Vaish et al (2011) demonstrated that infants at 13 months sought disambiguating referential gaze from an adult in a labeling uncertainty situation. At 16 months, infants referred to their social partner while signaling their ignorance when they did not know the name of the novel item (Harris, Bartz, & Rowe, 2017). Goupil et al (2016) showed that 20-month-olds’



increased social referencing to their caregiver to solicit help locating a hidden object. Here, we propose that social referencing enables them to not only selectively seek epistemic information from an appropriate source, but to do so specifically when needed. We chose to study this process in 12-month-olds and in a word learning context. Infants at the end of their first year are active word-learners with a mean receptive vocabulary of around 80 words (Frank, Braginsky, Yurovsky, & Marchman, 2017) and we here capitalize on their active interest in learning new words (Mani & Ackermann, 2018).

We developed a novel experimental paradigm that invites 12-months-olds' active and spontaneous search for epistemic information from social partners, where social referencing is an available communicative tool to ask for help from either a knowledgeable (Informant) or an ignorant adult (Non-Informant). Building on the findings from interrogative pointing and social referencing research, we aimed at eliciting infants' spontaneous, rather than experimentally trained, social referencing looks in a dynamic social interaction. Infants met two new adults who contrasted in their ability to provide specific information (a label) while remaining equally engaging and sociable. We predicted that infants would show selectivity based on the established informative potential of their social partners, using social referencing with the intention to gain specific information when needed. Our goal was to understand infants' developing ability and cognitive prerequisites to interrogating informants in order to resolve a situation of epistemic uncertainty.

## **Method**

### **Participants**

The final sample consisted of 30 1-year-old infants (14 boys,  $M = 368$  days,  $SD = 17$ , range 340 to 404 days). With a power of 0.80 and alpha of 0.05, a sample size of 29 is sufficient

to produce a large effect size (G\*Power analysis software, Faul, Erdfelder, Lang, & Buchner, 2007). Twelve additional infants were tested but not included due to unwillingness to participate in the procedure ( $N = 9$ ) or substantial parental procedural interference ( $N = 3$ ).

### **Equipment**

Two video cameras captured the scene from two different angles. We used a head-mounted eye-tracker (Positive Science) to record infants' gaze direction (PSLiveCapture, v1.8.3). We used Yarbus (v2.2.9) for offline calibration and GazeTag (v0.94) for post gaze processing. Parents and experimenters could follow timing and instructions of the experimental procedure on a prompts screen displaying a Power Point presentation.

### **Stimuli**

Three familiar toys (ball, banana and book) and two novel objects were used during the familiarization trials, two familiar toys (duck and fish) during the warm-up training trials, and six pairs of novel objects during the test trials. All objects were brightly colored, and pairs were selected based on perceptual similarity (see Figure 1a).

### **Procedure**

A researcher not involved in the experimental procedure completed parental consent and training on the procedure, played with the infant and brought them to the testing room. There, the infant was first introduced to two unfamiliar experimenters, and then sat in a high chair at the short end of a rectangular table. The researcher mounted the eye-tracker on the infant's head, engaged the infant in warm-up play, and performed the calibration procedure with two familiar objects. The two experimenters (Informant and Non-Informant) sat at the long ends of the table across from each other, with sides counterbalanced across participants. The caregiver was

positioned across the table from the infant, facing the prompts screen, while the researcher remained behind the infant (Figure 1b).

### **Experimental procedure**

The procedure (Figure 1c) involved a familiarization phase, followed by a warm up training trial and a test phase.

#### **Familiarization**

There were four familiarization trials, each lasting 25 seconds, two with familiar objects and two with novel objects. A reinforcement trial, identical to familiarization trials with familiar objects, was presented later on, following the first test trial. This trial was introduced after piloting in order to ensure infants' sustained attention on the procedure for the remaining five test trials and it is not used for main statistical analyses (but see Supplementary Materials for these data).

On each familiarization trial the caregiver retrieved one of the 3 familiar objects (Trials 1 and 2, later labeled by the Informant as *ball*, *banana*, and *book*) or one of the 2 novel objects (Trials 3 and 4, labeled by the Informant as *dani* and *fifa*) from a tray below the table (Figure 1a) and placed it on the table out of the infant's reach. Upon placing the object, the caregiver asked "What is this?". Following the caregiver's question, both the Informant and the Non-Informant established joint attention with the infant, making direct eye-contact, smiling, and speaking in child-directed intonation. Either the Informant or the Non-Informant spoke first, counterbalanced across trials. The Non-Informant said: "I don't know!", whereas the Informant provided the label as she pointed to the object: "This is a [label]!". The caregiver then pushed the toy closer to the infant for a 20-second object exploration, during which the Informant and the Non-Informant continued with their respective utterances as described below. The Informant labeled the object

4-6 times, using utterances such as “Look, this is a ball!”, “Wow, a ball!”, “What a nice ball!”, “I like this ball!”, “Where is the ball?”, “A ball!”. The Non-Informant provided a positive, engaging social interaction, using 4-6 utterances such as “Look at this!”, “Oh Wow!”, “What is this?”; “Hmm...”; “This is nice!”, “I like this!” Both experimenters naturally took turns speaking to the infant, taking care to not interrupt each other.

### **Warm-up training**

The single warm-up training commenced a substantial change in the procedure and was designed specifically to introduce and ease infants to the change in the object presentation routine after the familiarization trials: here, infants were not provided an opportunity to explore presented toys immediately. This trial (and the subsequent test trials) consisted of the following episodes: object presentation, information seeking, information provision, object exploration, and object choice (Figure 1d).

During the warm-up training trial, two familiar objects, a *duck* and a *fish*, were placed by the caregiver out of the infant’s reach, with the caregiver asking: “Which one is the duck?”. After a period of 15 seconds, during which all adults remained silent and looked at the infant, the caregiver repeated the question. During this period the infant could seek information by looking at the experimenters. In the next, “information provision” episode, the Informant responded with the correct label (“This one is the duck!”), simultaneously pointing to the duck toy, while the Non-Informant expressed ignorance about the label (“Oh wow! Is it?” or “I don’t know!”), just as she did during the familiarization phase, with the order of who spoke first counterbalanced as during familiarization. Following the experimenters’ respective utterances, the caregiver placed both objects in front of the child for a 20-second exploration.

### **Test**

The test trials' procedure was identical to the warm-up training trial except that the infant now was presented with two novel objects and inducing high referential uncertainty ("Which one is the [pseudoword]?") (Figure 1d). The caregiver did not know the novel objects' labels. Following the infant's opportunity to seek information, the Informant (either speaking first or after the Non-Informant's utterance) pointed to and labeled one of the objects with the pseudoword in question, consistently labeling the same pre-selected object in each of the pairs. There were six test trials; the first test trial followed the warm-up training trial, and the remaining five test trials followed the reinforcement familiarization trial which was identical to the familiarization trials (Figure 1c).

### **Trial exclusion criteria**

For behavioral data analyses, 99% (N = 119) of familiarization, 73% (N = 22) of training, and 87% (N = 143) of test trials were included. Infants completed on average 5.4 test trials, with 4.8 valid trials retained for analyses. Trials were excluded due to infant fussiness or refusal to take part in the procedure (N = 10), experimenter error (N = 8), caregiver procedural interference (N = 4), and technical problems (N = 4). As expected by design, the warm-up training trials were excluded most often due to infant fussiness resulting from not having access to the toys immediately and due to caregiver mistakes following a change in the procedure. As a result, only 22 (out of 30) warm-up training trials were available for analyses.

For the head-mounted eye-tracking based data analyses of the length of visual fixations, we obtained a limited dataset comprised of 20 infants for familiarization, 10 for training, and 15 for test trials. This was due to low tolerance of wearing the equipment, as well as pulling the eye-tracker off in the middle of the experimental procedure, e.g., after the familiarization trials when they were facing silent periods during the warm-up training or test trials' "opportunity to seek

information” episodes. We therefore had a restricted sample available for analyses of the length of infants’ visual fixations and consider such analyses supplementary to the main behavioral social looks analyses. Nevertheless, these analyses were instrumental for comparison of the number of looks and the total looking durations as two distinct measures.

### **Coding**

We were interested in determining how much attention infants directed at each experimenter in all phases of the procedure, measured by first looks, total looks, and the duration of the looks. We distinguish these measures from a functional standpoint. For the familiarization trials, we used the video recordings to code the number of looks at each experimenter and the eye-tracker to code the length of visual fixations on each experimenter. We calculated a proportion of looks at the Informant and the Non-Informant out of the total looks infants made at the two experimenters during the familiarization phase, averaging across four trials. This measure indexes infants’ attention as they encoded the experimenters’ epistemic profiles. We also coded infants’ first looks at this phase. However, as infants’ initial attention was expected by design to be directed at whoever spoke first on each trial, the function of infants’ first looks is inevitably different from the function of the first looks during the warm up and test trials when infants were facing uncertainty and nobody was speaking for 15 seconds (Figure 1d).

For both the warm-up training and the test trials, we coded first looks, total number of looks averaged across six trials (from the video recordings), and length of infants’ visual fixations (from the eye-tracker) at each experimenter during the 15-second-long “opportunity to seek information” episode. Here, the hypothesized function of looks is to solicit information from the experimenters as opposed to attend to their information provision as during familiarization.

Of note, further, are the functional differences between the measures of duration of looks and the discrete social looks. It has been debated what looking time preferences mean (Aslin, 2007; Sim & Xu, 2019) and whether looking time and social looks index the same cognitive mechanisms (Dunn & Bremner, 2018; Haith, 1998; Walden et al., 2007). The exact measure of social looking as epistemic information seeking is a topic of ongoing investigation as both the number of social looks and the duration of social looks have been previously used as a primary outcome measure (e.g., Koenig & Echols, 2003; Vaish et al., 2011). Here we focused on the number of discrete social looks as an index of information seeking and the looking duration as an index of information encoding.

Two independently trained research assistants coded 100% of the behavioral data, achieving substantial agreement (Landis & Koch, 1977) for the first looks (Cohen's kappa  $\kappa = .78$ ,  $p < .001$ ) and excellent agreement for the total looks coding (Cronbach's alpha  $\alpha = .92$ ,  $p < .001$ ); all disagreements were resolved through discussion. The main coders were not blind to the identity of the experimenters. A subset (20%) of test trials was also coded by a coder blind both to the hypotheses and the identity of the experimenters, achieving excellent reliability both for first looks ( $\kappa = .90$ ,  $p < .001$ ) and for total looks ( $\alpha = .94$ ,  $p < .001$ ).

## Results

The results of infants' social looks at the Informant and the Non-Informant are presented separately for the familiarization, warm-up training and test trials, followed by the cross-phase comparisons and regression analyses. Exploratory analyses and additional figures are available in the Supplementary Materials. A Bayes Factor analysis was performed to determine the probability of the null or the alternative hypothesis being true (i.e., that there is no difference between looks at the Informant and the Non-Informant or that there is a difference) given the

data (Jeffreys, 1961). For all analyses, we used a default Bayes factor (Rouder et al., 2012) with a half normal distribution (assuming a maximum possible effect size of 0.707).

### **Familiarization**

Averaged across four trials, infants' looks at the Informant were at chance for first looks ( $M = .56$ ,  $SD = .24$ ,  $t(29) = 1.35$ ,  $p = .1$ , one-sample t-test;  $BF_{01} = 1.7$ ; Figure S1) and total looks ( $M = .51$ ,  $SD = .12$ ,  $t(29) = .64$ ,  $p = .53$ ,  $BF_{01} = 3.28$ ; Figure 2a), and there were no differences between length of visual fixations on the Informant ( $M = 284$ ,  $SD = 230$  ms) and the Non-Informant ( $M = 264$ ,  $SD = 385$  ms),  $t(19) = .23$ ,  $p = .82$ , paired t-test;  $BF_{01} = 3.2$ .

### **Warm-up training**

The proportion of looks at the Informant was at chance for first looks ( $M = .50$ ,  $SD = .51$ ,  $t(21) = 0$ ,  $p = 1$ ,  $BF_{01} = 4.48$ ), total looks ( $M = .42$ ,  $SD = .42$ ,  $t(21) = -.91$ ,  $p = .37$ ;  $BF_{01} = 4$ ) and length of visual fixations (Informant  $M = 303$ ,  $SD = 548$  ms, Non-Informant  $M = 171$ ,  $SD = 224$  ms;  $t(9) = .67$ ,  $p = .52$ ;  $BF_{01} = 2$ ), Figure S2.

### **Test**

Infants were significantly more likely, on average during six trials, to first reference the Informant rather than the Non-Informant,  $M = .69$ ,  $SD = .30$ ;  $t(29) = 3.34$ ,  $p = .002$ , 95% CI (.07, .30), Cohen's  $d = .63$ , one-sample t-test; 21 out of 30 infants looked at the Informant first, Wilcoxon Signed Ranks test  $z = -2.8$ ,  $p = .005$ . Bayes Factor Analysis yielded a  $BF_{10} = 23$ , strongly supporting the alternative hypothesis and thus corroborating the result obtained with the frequentist statistics. The proportion of total looks at the Informant was significantly higher than the proportion of total looks at the Non-Informant,  $M = .65$ ,  $SD = .24$ ;  $t(29) = 3.43$ ,  $p = .002$ , 95% CI (.12, .48), Cohen's  $d = .63$ ,  $BF_{10} = 28$ , with 22 out of 30 infants showing the effect, Wilcoxon Signed test  $z = -3.14$ ,  $p = .002$  (Figure 2a). Infants' visual fixations were significantly



longer for looks at the Informant ( $M = 253$ ,  $SD = 160$  ms) than at the Non-Informant ( $M = 134$ ,  $SD = 83$  ms),  $t(14) = 2.41$ ,  $p = .03$ , 95% CI (12.98, 224.49), Cohen's  $d = .62$ ;  $z = -2.05$ ,  $p = .04$ ;  $BF_{10} = 3.2$ .

### **Cross-phase comparisons**

To clarify whether infants preferentially looked at the Informant only when a situation of epistemic uncertainty warranted further information seeking (as during the test phase's opportunity to seek information episode), instead of preferentially looking in appreciation of the Informant's knowledge overall (as during the familiarization phase), we conducted the following cross-phase comparisons. We compared total looks and length of fixations between familiarization and test phases. The cross-phase comparison of first looks is reported in Supplementary Materials, Figure S1, due to the distinctions in functional meaning between first looks at different phases (familiarization: first look at whoever speaks first; test: first look at whoever can help resolve epistemic uncertainty).

**Total looks.** The proportion of infants' total looks at the Informant was significantly higher during the test phase as compared to the familiarization phase,  $t(29) = -2.91$ ,  $p = .007$ , 95% CI (-.23, -.04), Cohen's  $d = .55$ ,  $BF_{10} = 8.9$  (Figure 2b). To follow up on this comparison more specifically, we selected two familiarization and two test trials, which differed on whether or not the infant was facing referential uncertainty when presented with equally novel toys. The average proportion of infants' total looks to the Informant during the last two familiarization trials (where the caregiver presented novel toys without asking the infant for the objects' names) was significantly lower than the proportion of total looks to the Informant during the first two test trials (where the caregiver also presented novel toys but now asked the infant to identify a

label in a pair of two novel toys),  $t(29) = 3.39$ ,  $p = .002$ , 95% CI (.09, .37), Cohen's  $d = .53$ ,  $BF_{10} = 26$  (Figure 2b).

**Length of fixations.** Infants did not spend significantly longer fixating on the Informant during the test phase as compared to the familiarization phase,  $t(14) = .94$ ,  $p = .36$ ,  $BF_{01} = 1.95$ .

**Regression analyses.** To test whether infants' looks at test were influenced by their looks at familiarization, we fitted two linear regression models. The proportion of infants' first looks towards the Informant generated at familiarization was not predictive of their preferential first looks at the Informant at test ( $\beta = .03$ ,  $t(28) = .16$ ,  $p = .88$ ), and there was no effect of the total looks in the familiarization phase on total looks at test ( $\beta = .25$ ,  $t(28) = .68$ ,  $p = .50$ ).

### Discussion

To understand pre-verbal infants' active role in social transmission of knowledge, we introduced 12-months-olds to two unfamiliar adults, an Informant and a Non-Informant. At test, in a situation of referential uncertainty, it was impossible for infants to independently discover the missing information (a novel label's actual referent), but they could seek it from available social partners. Infants selectively referred to the previously knowledgeable rather than an equally socially engaging but ignorant adult. Infants showed no such preference at other phases where they did not require information, providing strong evidence that their social referencing was selective and served an information seeking function (see Supplementary Materials for additional control analyses). We conclude that infants were able to reliably assess the informative potential of the available social partners and selectively queried the best source when information was needed.

In line with our hypothesis, these results demonstrate that social referencing serves as a communicative means to solicit epistemic knowledge from others. While there is convincing

evidence that interrogative pointing (where infants request information about an object by pointing at it, e.g., Begus & Southgate, 2012; Kovács et al., 2014; Lucca & Wilbourn, 2016; 2018) indexes infants' ability to pose epistemic requests (Southgate et al., 2007; Tomasello et al., 2007), we find that infants are cognitively ready to do so by use of social referencing, which overall emerges earlier in development and is available to pre-pointing infants. In our new paradigm we actively elicited a different behavior, where information was sought by specifying the informant rather than the referent. While our results do not speak to whether interrogative social referencing is a developmental precursor to interrogative pointing or emerges independently, the current study highlights the early emerging cognitive mechanisms enabling epistemic interrogation. One way to interpret these social looks is as intentional communicative acts *triggering* epistemic help from cooperative and interactive social partners, in contrast to merely gathering information from a passive source such as a book. However, to further delineate whether infants actually posed epistemic requests (as in interrogative pointing) with their social looks, we would require clear evidence that they would persist in their communicative attempts triggering information elicitation, such as repeated pointing or vocalizations when their initial requests are not responded to (Southgate et al., 2007; Tomasello et al., 2007). Some data from our study supports such an interpretation: as experimenters remained unresponsive during the "opportunity to seek information" episode, infants continued to generate repeated social looks as if they were not satisfied with a lack of answers and thus continued to demonstrate their interest in obtaining a response. Designing an experimental situation to specifically answer this question is an important future step in this line of research.

Previously, selectivity in social referencing in ambiguous situations has been most commonly attributed to gathering emotional rather than epistemic information (e.g., Stenberg &

Hagekull, 2007; Schieler, Koenig, & Buttelmann, 2018; Striano, Vaish, & Benigno, 2006).

While social referencing has been shown to index infants' response to the violation of expectation in cognitive and perceptual scenarios (Dunn & Bremner, 2016; Koenig & Echols, 2003; Walden, Kim, McCoy, & Karrass, 2007), here we demonstrate that infants are capable of strategically seeking pertinent epistemic information about the immediate environment from someone who can be regarded as knowledgeable about it. This finding is in line with the expertise rather than the comfort-seeking hypothesis of social referencing (Feinman, Roberts, Hsieh, Sawyer, & Swanson, 1992; Stenberg, 2009, 2013), but also extends it for the first time, to the best of our knowledge, specifically to referential ambiguity in word learning situations. Only a small number of recent studies investigated social referencing during epistemic uncertainty, and all did so with older children (Harris, Bartz, & Rowe, 2017, 16-33 months; Goupil et al., 2016, 20 months; Hembacher et al., 2017, 24 months; Vaish et al., 2011, 13 months). Unlike previous studies, our experimental manipulation placed infants in a more naturalistic situation where they had a mutually exclusive choice of who to look at - rather than whether or not to look at the social partners at all when facing high epistemic uncertainty (e.g., Kovács et al., 2014; Vaish et al., 2011), or doing so only after being experimentally trained rather than spontaneously (e.g., Goupil et al., 2016).

The current study shows that social referencing serves the function to actively seek relevant information when such information is actually needed. In spite of the Informant being knowledgeable throughout all experimental phases, infants preferentially looked at them only at test when asked a question they themselves could not answer, ruling out the possibility that the Informant was overall more engaging than the Non-Informant just because they were always providing specific and relevant information, including exclusively pointing to the object

as part of the information provision. Crucially, the same result emerged when directly comparing a subset of the familiarization trials with novel objects (last two familiarization trials) with an equal subset of the test trials with novel objects (first two test trials). Additionally, infants' hold-outs and gives as an early developing active communicative behavior (Boundy, Cameron-Faulkner, & Theakston, 2016) were not preferentially directed at the Informant at any stage (see Supplementary Materials), supporting our interpretation of interrogative selectivity of social looks at the opportunity to seek information episode only. These results suggest that infants generated social looks to the Informant not because they realized that they have specific and relevant information overall, but because they were the best source of such information when it was needed. This may also be explained by infants' general, rather than specific to situational knowledgeability, preference for seeking epistemic help from competent social partners (for a discussion see Mascaro & Sperber, 2009). Future studies should investigate whether infants pay attention to general competence cues as opposed to epistemic competence per se, as well as whether competence in one domain is generalized to other knowledge domains.

An alternative interpretation to our results, following a reinforcement learning process, could be that infants' looking was not driven by information seeking but instead by anticipation of the correct response from the Informant. We believe this to be the less favorable explanation: infants' looks to the Informant did not increase as the trials progressed (in contrast to Kovács et al., 2014) and were selective to test trials only, but not familiarization, warm-up training, and reinforcement familiarization trials, some of which were interspersed with the test trials (Figure 1d, see Supplementary Materials for these results). Furthermore, our results suggest that social looks and duration of looks index different cognitive mechanisms at different phases of the procedure, such as attention to the adults as infants formed their respective epistemic profiles at

familiarization, and intentional communication soliciting information-gathering at test. The meaning of infants' looks and looking time is generally debated (Aslin, 2007; Dunn & Bremner, 2016; Sim & Xu, 2019). These underlying differences may explain why our results were evident in the proportion of total looks, but not first looks, which were directed at the experimenter speaking first at each familiarization trial, or the length of visual fixations, which indexed encoding of experimenters' identity at familiarization, but underlined the lack of attention at the Non-Informant at test when seeking information selectively from the Informant.

We believe that the field is ripe for future investigations of information seeking through social referencing in pre-verbal infants. Our new paradigm would be easily applicable down to 6-month-old infants, and would enable a better understanding of how early this cognitive capacity emerges. Additionally, our paradigm could be improved by interleaving at test the trials with familiar objects (no uncertainty) with the trials with unfamiliar objects (epistemic uncertainty), further ruling out the possibility that infants look more at the knowledgeable informant because they anticipate the knowledge transmission to occur rather than actively soliciting it.

In sum, we have shown that infants reliably identify knowledgeable social partners and actively use social referencing to selectively seek information from them over others when required. Our results show that this capacity, at the heart of human cultural transmission, is available at least from 12 months of age. Infants know who to ask when information that is impossible to acquire otherwise, such as a label, is specifically relevant to them: they refer to a benevolent, knowledgeable and informative conspecific who can promptly satisfy their epistemic needs. Far from being passive recipients of top-down information from others' testimony, infants actively participate in the cultural interpersonal process of knowledge transmission, and they do so with all the basic communicative tools at their disposal.

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Figure 1:

Example of the stimuli (1a), experimental set up (1b), procedure (1c), and structure of the test trials (1d).

## 1a. Examples of experimental stimuli

Familiarization trials familiar and novel objects examples:  
Caregiver asked: "What is this?"



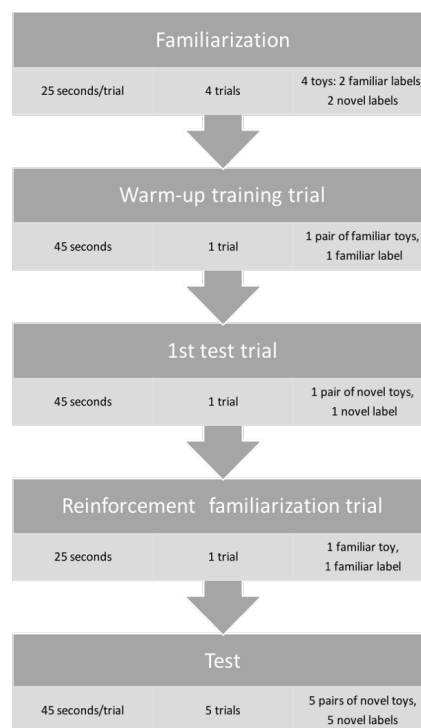
Warm-up training trial objects:  
Caregiver asked: "Which one is the duck?"



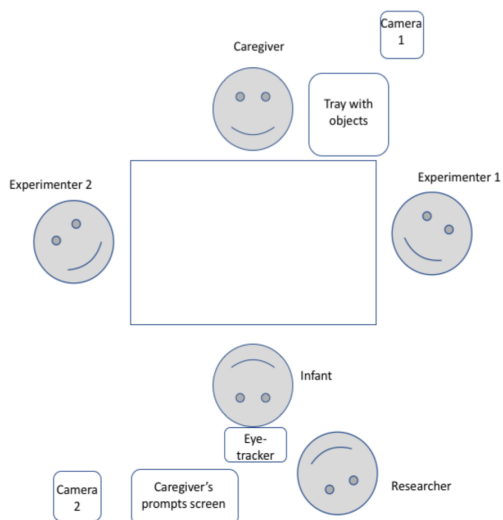
Test trials objects examples:  
Caregiver asked: "Which one is the [pseudoword]?"



## 1c. Procedure phases flow chart



## 1b. Experimental set up



## 1d. Structure of the test trials

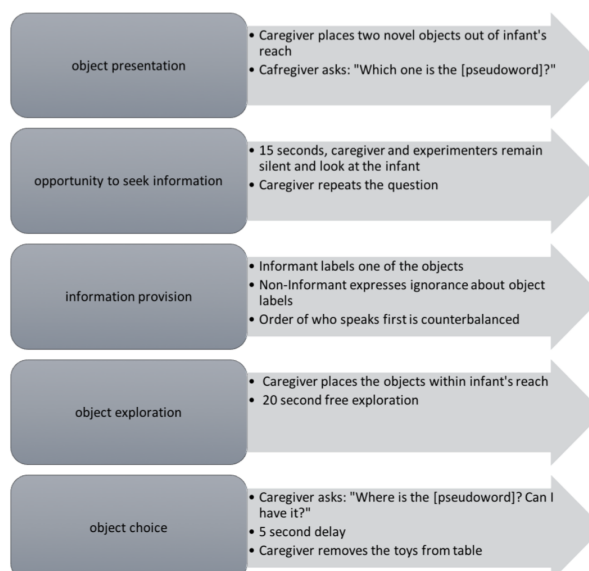
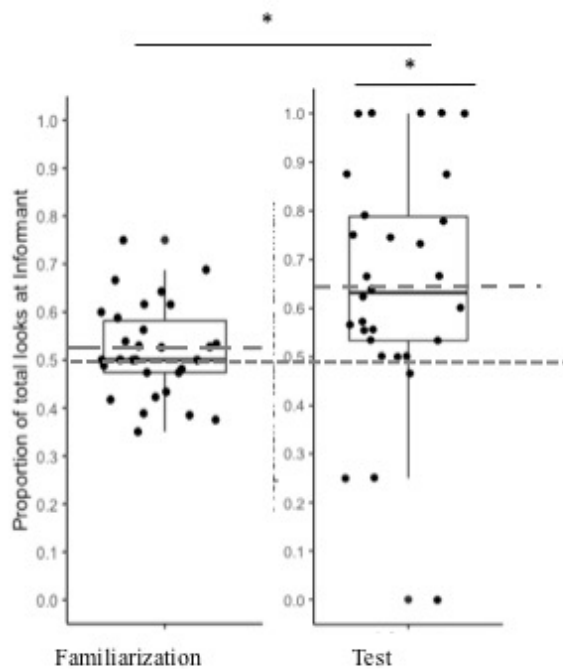


Figure 2: Proportion of total looks at Informant (versus Non-Informant) at familiarization (2a) and test (2b) phases of the experiment. The dots represent the distribution of individual participants' proportion of total looks at the Informant during the Familiarization and Test phases (2a), and a subset of two novel toy trials during the Familiarization and Test phases (2b). Bold dashed lines represent the Mean values, chance level at .5 is represented by frequent dashed line; solid lines of the box plots show the median with the first and the third quartiles, the upper and lower whiskers represent scores outside the middle 50%.

\* represent statistical significance at  $p < .01$ .

2a: Proportion of total looks at the Informant



2b: Proportion of total looks at the Informant: Novel Toy trials comparison

