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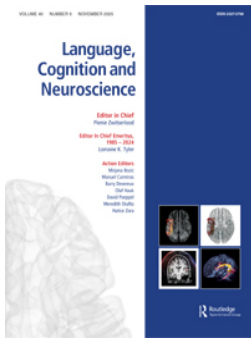
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The early ontogeny of expectations about communicative informativeness: from infants' exemplar frequency tracking to preschoolers' pragmatic inference

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ABSTRACT

This article investigates the early development of informativeness expectations in communication. We tested three- to five-year-olds ($n = 73$) and 18-month-olds ($n = 96$) in a label learning paradigm, pitting expectations of informativeness against the tracking of the frequency of possible referents. During a label-learning phase, a speaker uttered a novel label while pointing (Studies 1–2) or looking (Study 3) ambiguously toward two types of unfamiliar objects: one unique object and an array of several identical objects. Preschoolers paired the novel label with the unique object, an inference consistent with expectations of the speaker's informativeness. Conversely, infants paired the novel label with the object type found in several exemplars, a pattern consistent with disambiguating unfamiliar labels by linking them to more frequent possible referents. Additional conditions demonstrate that infants rely on the frequency of potential referents from the speaker's viewpoint rather than from their own egocentric viewpoint.

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Infants; pragmatics; lexical acquisition; statistical learning

1. Introduction

Infants learn labels very early in life (Bergelson & Swingley, 2012, 2015; Oviatt, 1980; Tincoff & Jusczyk, 1999; Werker et al., 1998; Werker & Yeung, 2005; Woodward et al., 1994). Their proficiency in this domain is remarkable, because any given label has an infinite number of potential referents. To adapt a classic example (Quine, 1960), imagine a learner who hears someone shouting “Gavagai” while pointing at a rabbit that is running away. From the learner's viewpoint, this label could refer to the rabbit itself, its tail, the colour of its fur, the reason the rabbit is running, and so on. Thus, discovering the referents of labels requires learners to use efficient strategies to navigate large hypothesis spaces. One of these strategies consists in drawing contextually guided inferences about what speakers intend to communicate – i.e. pragmatic inferences (Frank & Goodman, 2014; Goodman & Frank, 2016; Grice, 1989; Sperber & Wilson, 1986). Such pragmatic inferences guide label learning from a very early age. For instance, by toddlerhood, children infer that a speaker expressing excitement while using a novel label refer to a new object, not a pre-exposed one (e.g. Akhtar & Montague, 1999; Bleijlevens et al., 2023, 2025; Bohn et al., 2021). Moreover, children no longer draw these inferences if


the speaker has not already encountered the pre-exposed object, indicating that consider her perspective into their reasoning (Bleijlevens et al., 2023).

Another strategy involves monitoring statistical regularities in the occurrence of labels and potential referents. For instance, the more often a label and a potential referent co-occur, the more likely the label refers to that entity (Fazly et al., 2010; Siskind, 1996; Yu & Smith, 2007). Most of the time, pragmatic inferences, and monitoring statistical regularities complement one another, and learners likely use both. However, in some cases, learning strategies conflict, and the question of resolving this conflict arises. Here, we investigate how these two types of strategies interact during early development, focusing on learners' sensitivity to speakers' informativeness.

1.1. Pragmatic inferences

One way to take advantage of contextual information to disambiguate a novel label consists in relying on expectations about the intentions of communicative agents and the properties of communicated information. Expectations of communicative informativeness are often postulated to play a central role in this process.

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Indeed, several theories suggest that listeners expect speakers to be appropriately informative, e.g. to aim at reducing listeners' uncertainty over a set of relevant hypotheses (Frank & Goodman, 2014). This expectation is phrased in Grice's first quantity maxim, which enjoins speakers to make their contribution "as informative as is required (for the current purpose of the exchange)" (Grice, 1989). Similarly, expectations of informativeness play a central role in Rational Speech Act theory, which also provides a computational framework for quantifying expectations of informativeness (Frank et al., 2016; Goodman & Frank, 2016; Goodman & Stuhlmüller, 2013; Kao et al., 2014). Other accounts, such as relevance theory, imply that speakers should be appropriately informative – although in this framework, informativeness is a by-product of a more general tendency to be relevant (Sperber & Wilson, 1986; Wilson & Carston, 2007; Wilson & Sperber, 2012). In short, despite their differences, a substantial set of pragmatic theories posit that listeners expect speakers to be appropriately informative and use this expectation to infer the meaning of utterances.

Humans' sensitivity to communicative informativeness develops early. It significantly influences how children convey, interpret, and evaluate communicated information (Davies & Katsos, 2010; Eskritt et al., 2008; Gweon et al., 2018; Gweon & Asaba, 2018; Katsos & Bishop, 2011; Morisseau et al., 2013). On the production side, informativeness shapes what children choose to communicate. By three years of age, children are more likely to communicate unexpected, informative features than expected ones when describing pictures, and they balance informativeness with ease of production (Bannard et al., 2017). Informativeness also shapes young children's choice of communicative means. By 2.5 years, children adapt their gestures and speech to clarify their intended meaning for listeners (Abbot-Smith et al., 2016; Grigoroglou & Papafragou, 2019; O'Neill & Topolovec, 2001).

On the reception side, children are guided by informativeness in their interpretation of communication by toddlerhood. Two-year-olds are reluctant to learn the meaning of a novel communicative cue when it is insufficiently informative (Aguirre et al., 2023, Study 2). Moreover, when encountering novel ambiguous cues, 2-year-olds choose interpretations that optimise information gain, i.e. that effectively reduce their uncertainty over relevant hypotheses (Aguirre et al., 2023, Study 3). In short, by late toddlerhood, children aim for conveying new information, they choose communication means to avoid ambiguity and favour informative interpretations of novel cues.

Early developing expectations about communicative informativeness support learners' discovery of novel

labels' referents by preschool age (Bohn et al., 2021; Frank & Goodman, 2014; Trice et al., 2025). For example, in Frank and Goodman (2014) preschoolers saw two dinosaurs, both of which wore a bandanna, but only one wore a headband. A speaker signalled that she talked about the latter while calling it "a dinosaur with a dax". In principle, the novel label "dax" could refer to the dinosaur's headband or bandanna. However, using the label "dax" to refer to the bandanna was not informative enough to pick out the dinosaur with the headband (since both dinosaurs wore a bandanna). Conversely, given the context, referring to the headband was an efficient way to specifically target the dinosaur that the speaker was talking about. Thus, by applying an expectation of informativeness, learners could infer that the new label referred to the headband, the object uniquely present in this scene. In Frank and Goodman (2014), children demonstrated this ability by three years of age, linking the novel label to the object uniquely present in the scene. Other studies by Horowitz and Frank (2016) showed that preschoolers can infer properties based on the speaker's production choices (e.g. saying "small zib" implies that zibs are usually bigger than this one). Recent studies have also highlighted the capacity of preschoolers and adults to combine common ground information with expectations about speaker informativity when learning a new word (Bohn et al., 2022). Thus, expectations of informativeness shape preschoolers' learning of novel labels.

The present work focuses on the early development of this ability, during infancy. On the one hand, expectations of informativeness may be developmentally continuous – thus guiding label learning in infants – as suggested by toddlers' early sensitivity to informativeness (Aguirre et al., 2023; Bannard et al., 2017). On the other hand, infants may have difficulties using expectations of informativeness to disambiguate novel labels' meanings. As we will argue, this could be the case if infants process contextual information through mechanisms other than expectations of informativeness, such as their sensitivity to statistical properties of events and scenes.

1.2. Relying on statistical properties of scenes and events

In addition to pragmatic inferences, learners can also take advantage of contextual information by building on statistical properties of scenes and labelling events. Many mechanisms may support this type of learning, such as cross-situational statistical learning (e.g. Fazly et al., 2010; Ramscar et al., 2013; Siskind, 1996; Yu & Smith, 2007) or various types of hypothesis testing

(e.g. Berens et al., 2018; Medina et al., 2011; Trueswell et al., 2013; Woodard et al., 2016).

For instance, a sizeable set of studies provides evidence of infants' sensitivity to the co-presence of labels and potential referents. It shows that adults and children are capable of rapidly learning several label-referent pairs based on multiple and individually ambiguous label-scene pairings (Akhtar & Montague, 1999; Smith et al., 2014; Smith & Yu, 2008; Suanda et al., 2014; Vlach & Johnson, 2013; Vouloumanos & Werker, 2009; Yu & Smith, 2007). For instance, Smith and Yu (2008) used a preferential looking paradigm to examine cross-situational word learning in 12- and 14-month-olds. Infants were presented on each trial with two unfamiliar pseudo-words (e.g. "bosa" and "gasser") and two potential referents (e.g. two different unfamiliar shapes) without any information about which label went with which referent in a given trial. Although label word-referent pairings were ambiguous within individual trials, there were regularities in the association between labels and shapes across trials (e.g. a star shape was always present on the screen when the label "bosa" was uttered). During this study, infants learned to look significantly longer at the shape that co-occurred more often with a given label. This study suggests that word learning in infants is influenced by regularities in the co-occurrence between objects and labels. Additional studies show that statistical aggregation might influence label learning, even in more naturalistic contexts (Raz et al., 2019; Yurovsky et al., 2013; Zhang et al., 2020; Zhang & Yu, 2016). In short, several processes might support word learning by building on statistical regularities between the occurrence of a label and its potential referents. Such sensitivity to statistical regularities when learning the meanings of novel words emerges in early infancy.

Many classic studies have examined how infants associate labels with objects based on temporal co-occurrence (for a review, see Smith et al., 2014; Zhang et al., 2019). These studies typically manipulate how often a label is uttered in simplified scenes, with one exemplar per object category. For instance, in the study by Smith and Yu (2008) described above, only one exemplar of each unfamiliar shape was shown to infants when labels were uttered. This methodological choice effectively isolates the effect of label-object temporal co-occurrence without burdening infants with unnecessarily complex stimuli. However, it leaves many important questions unaddressed.

In real-world scenarios, the number of items belonging to a specific category varies across labelling events. Plainly put, when speakers utter "fork" or "bread", there is not always just one fork or one piece of bread

around. Instead, forks are abundant in kitchens, less so in bathrooms, bread is abundant in bakeries, but rare at clothing stores. Such differences in the frequency of co-present category exemplars are likely to impact lexical acquisition. For instance, consider a scenario in which a learner encounters a new label that could refer to two types of unfamiliar objects, with one type significantly outnumbering the other. If the learner has an equal chance of linking the label with any individual object, they will be more likely to link it to the more prevalent object type. Such a strategy would not be entirely irrational. The presence of many exemplars of a category might make speakers likely to refer to it. People are likely to talk about forks in kitchens, and about bread in bakeries, less so while in bathrooms or clothing stores. Importantly, while exemplar frequency might influence lexical acquisition, its effect on infants' label learning has not been empirically tested – an issue that we address in our studies.

1.3. Dealing with conflicts between pragmatic inferences and statistical regularities

It seems plausible that young children use a variety of strategies to discover the meanings of labels, including pragmatic inferences and tracking statistical regularities. However, these different strategies sometimes yield conflicting results. This type of conflict manifests in inferences guided by informativeness expectations. For instance, in the study by Frank and Goodman (2014) discussed above, when a learner hears "dax" while looking at one dinosaur with a bandana and another dinosaur with both a headband and a bandana, there are more bandanas than headbands. In this case, a strategy based on exemplar frequency suggests that the novel label is more likely to refer to the more frequent item – thus, to bandanas rather than to headbands. As we have seen, pragmatic inferences suggest the opposite, through the assumption that the speaker communicates in a way that allows the listener to uniquely identify the label's referent. In such situations, children favour pragmatic inferences by two years of age (Aguirre et al., 2023; Frank & Goodman, 2014).

By contrast, very little is known about infants' capacity to address this challenge, an issue that we explore in our studies. We aimed to distinguish two possibilities. According to the first hypothesis – that we favoured – infants might rely on expectations of informativeness when learning novel labels, rather than relying on exemplar frequency tracking. Alternatively, infants might rely heavily on exemplar frequency tracking when processing novel labels, leading to inferences markedly distinct from those of older children and

adults. Confirming the first hypothesis would demonstrate early pragmatic reasoning in infancy, while validating the second would reveal a striking developmental discontinuity in children's communicative development.

Study 1 served to validate our material with preschoolers, by providing a conceptual replication of past results (Aguirre et al., 2023; Bohn et al., 2022; Frank & Goodman, 2014). Studies 2–3 tested 18-month-old infants with the materials validated in Study 1. In addition, we assessed whether infants' and children's strategies were influenced by what was visible from the speaker's viewpoint.

1.4. Operationalisation principle

We tested how children handle conflicts between pragmatic inferences and exemplar frequency tracking in the “visible condition” of our studies. We familiarised the participants with videos in which an adult used a novel label while ambiguously pointing or looking towards a row of six unfamiliar objects. One object (henceforth referred to as the unique object) differed from the others. The other five unfamiliar objects were identical (henceforth referred to as the frequent objects). The speaker pointed (Studies 1 and 2) or looked (Study 3) ambiguously between the unique object and one of the frequent objects and uttered a novel label. The ambiguity of the speaker's pointing, or gaze could be resolved by assuming that she was informative enough to allow her audience to identify what she referred to. Indeed, if the speaker had wanted to convey information about one of the frequent objects, she could have pointed or looked towards one of the frequent objects further away from the unique object. Consequently, expectations of informativeness should lead participants to assume that the speaker refers to the unique object.

In contrast, relying on exemplar frequency should lead to the conclusion that the novel label refers to the most frequent object type. This might happen, for instance, if children assume that the speaker is equally likely to refer to any of the objects in the scene. In this case, children should estimate that the label has a higher probability of referring to the frequent object type rather than to the unique object (since there are one unique object and five frequent ones in the scene, $p_{\text{unique}} = 1/6$ vs. $p_{\text{frequent object}} = 5/6$, see Figure 1, Panel A). Thus, pragmatic processes based on expectations of informativeness and reliance on exemplar frequency tracking conflict in the visible condition of our experiments.

Our studies used two types of non-verbal communicative cues – communicative gaze (preceded by making eye contact with the infant, while raising

eyebrows) and distant index finger pointing (performed without touching objects). These two cues have several key features that make them appropriate for the present work. First, infants assume that they refer to objects – they expect to find objects at locations that have been pointed or gazed at (Behne et al., 2005; Csibra & Volein, 2008; Mascaro & Kovács, 2022; Okumura et al., 2013; Pätzold & Liszkowski, 2019). Second, infants use pointing and communicative gaze to associate novel labels with specific objects (e.g. Paulus & Fikkert, 2014; Pomiechowska & Csibra, 2022; Tsuji et al., 2020; Yurovsky & Frank, 2017). Third, infants and toddlers tend to process distant index finger pointing as relative to whole objects – as opposed to parts (Kobayashi et al., 2022), and as declarative – rather than imperative (Esteve-Gibert et al., 2017).

Moreover, we controlled for the effect of object type variability in our studies. Variability across exemplars significantly impacts infants' category formation, sound-object association, and label learning (Hartley & Whiteley, 2024; Kovack-Lesh & Oakes, 2007; Oakes & Ribar, 2005; Price & Sandhofer, 2021; Thom & Sandhofer, 2009; Twomey et al., 2014; Vukatana et al., 2015). For instance, in Twomey et al. (2014), toddlers were more likely to retain a label co-occurring with diverse looking exemplars of a category than with identical ones. To avoid confounds due to object type variability, our studies used the same picture to represent each instance of the frequent object type – ensuring identical variability across object types (unique vs. frequent).

We also used a “hidden condition” to assess whether infants' consider what speakers can see when processing novel labels. This condition builds on the early development of human sensitivity to gaze direction in the context of word learning (Baldwin, 1991, 1993), and on the ability to track what speakers saw to disambiguate an ambiguous utterance (Bloom, 2002; Bohn & Köymen, 2018; Grosse & Tomasello, 2012; Kampa & Papafragou, 2020; Khu et al., 2020; Mazzarella & Pouscoulous, 2021; Nadig & Sedivy, 2002; Nilsen & Graham, 2009; Nurmsoo & Bloom, 2008; Papafragou et al., 2017; Southgate et al., 2010). In the hidden condition of our Studies, the speaker could only see one exemplar of each of the two object types. The other exemplars of the frequent object type were hidden from the speaker while remaining visible to the participant. If children consider what the speaker can see, they should assume that the novel label is equally likely to refer to any of the two object types in this hidden condition. The hidden condition also aimed at controlling for possible visual saliency effects, since unique objects among homogeneous distractors have a special status in visual processing (e.g. Adler & Orprecio, 2006; Pashler

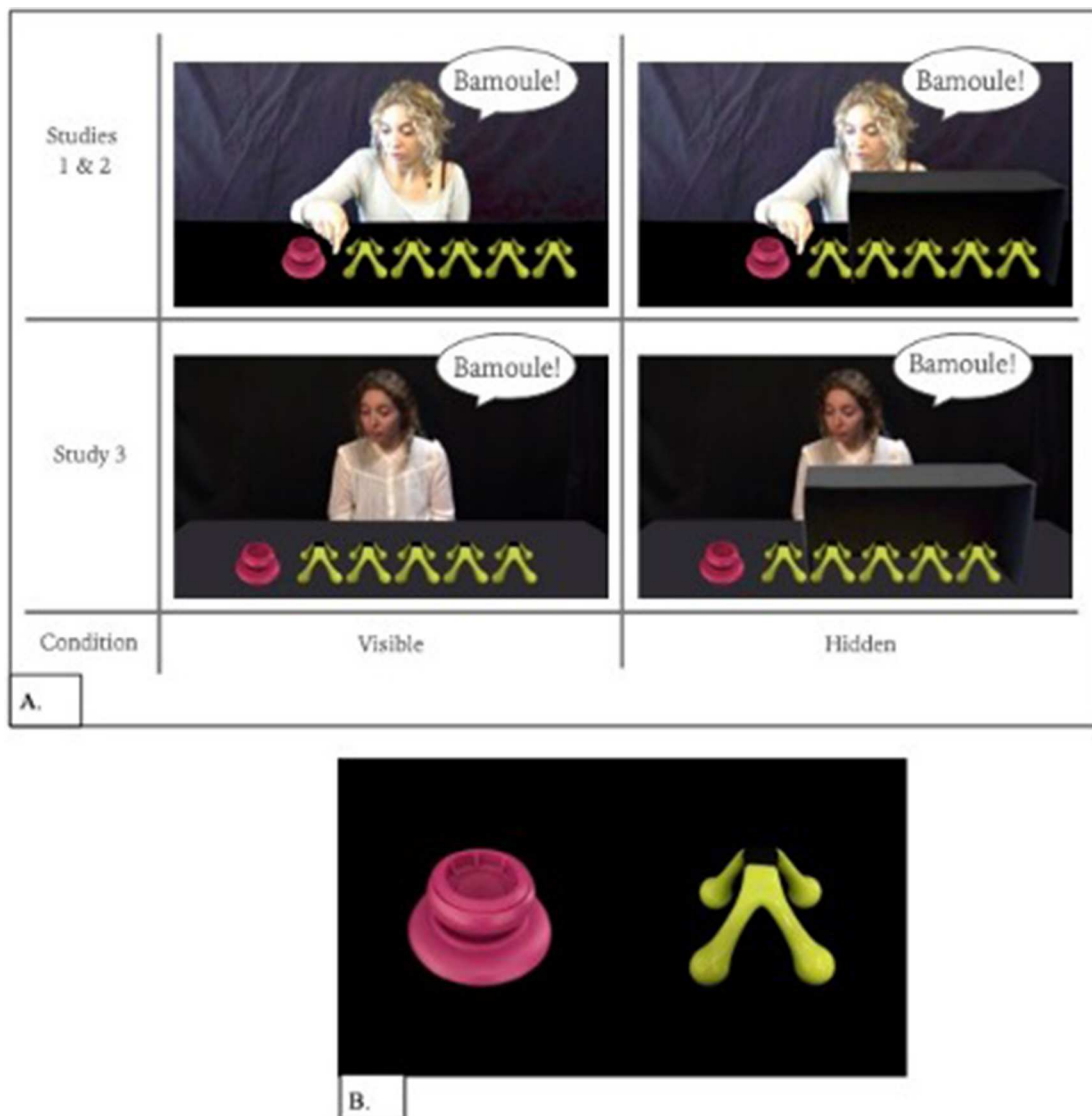


Figure 1. Schematic representation of stimuli across conditions in Studies 1–3. Note: Panel A: Schematic representation of the two conditions and stimuli of Studies 1, 2, and 3. Panel B: Picture from the test phase.

& Harris, 2001; Rajsic et al., 2016). In our studies, if participants merely react to the differential saliency of the unique and frequent objects, they should behave similarly in the visible and hidden conditions.

Across all conditions, we tested participants in a lexical decision test, in which they had to identify the referent of the novel label. We tested preschoolers (Study 1) and 18-month-old infants (Studies 2–3). Data and analysis scripts are accessible on an open repository (https://osf.io/6qw47/?view_only=85ea966b81b845dc990558dbb33c80f6).

1.5. Ethical statement

The research reported in this paper followed the guidelines of the Declaration of Helsinki and was approved by

the local board of preschools and an independent ethics committee for biomedical research (CPP Sud-Ouest et Outremer III, protocol number 2018-A02157-48). The parents of all participants provided written informed consent prior to their inclusion in the studies.

2. Study 1

2.1. Methods

2.1.1. Participants

We tested 3- to 5-year-old native French speakers from a large urban area (Lyon, France). We included as many available participants as possible within our age range from the preschools participating in the project, resulting in a total sample size of seventy-nine participants randomly assigned to one of two between-subject

conditions (visible condition: $n = 40$; $M_{age} = 52$ months; $SD = 7.23$ months; *age range*: 39–65 months; hidden condition: $n = 39$; $M_{age} = 52.4$ months; $SD = 8.68$ months; *age range*: 41–70 months). Two additional participants were excluded from the analysis as they refused to speak to the experimenter. The participants were recruited via an information letter sent through their preschool. A sensitivity power analysis performed using G*Power (Faul et al., 2007) revealed that the resulting sample sizes ($n > 38$ per group) were sufficient to detect effects of medium to large size ($>.47$) for comparisons against chance with a one-sample two-tailed Wilcoxon signed-rank test ($d = .8$, $\alpha = .05$).

2.1.2. Materials and procedure

Preschoolers were tested in a quiet room. They sat in front of the experimenter across a child-sized table. A tablet (10.5" 25.06 × 17.41 cm) was used to show the video stimuli. Before the test phase, the participants saw four times a sequence composed of a warm-up video followed by a label learning video. Then the participants were exposed to a test phase.

Warm-up video. This video was the same for all participants, in all conditions. It was used to familiarise the participants with the label learning situation and with the fact that the speaker did not use any determiner while referring to the objects in the scene. In the warm-up video, an actress named objects placed on a table in front of her. First, a red curtain rose to reveal the actress, and five objects placed on a table: a ball, a shoe, a cat plush toy, a spoon, and an unfamiliar object (a green round object with spikes and a black sort of handle). The actress greeted the viewer and looked at the objects while saying "Hello! Look at all these toys!". Then, she named the objects one by one from left to right (from the participant's viewpoint) while pointing at each one: "Ball, shoe, cat, spoon, nuve". We included an unfamiliar object (referred to by the pseudo-word "nuve") to familiarise the participants with the possibility that the actress might use novel labels. At the end of the warm-up video, the red curtain was lowered to hide the actress, and the objects disappeared from the table. After each warm-up video, the participants watched a label learning video.

Label learning video. At the beginning of all label learning videos, the curtain was lowered, thus hiding the actress. The next parts of the label learning videos differed across conditions. In the visible condition, a horizontal row of six unfamiliar objects appeared simultaneously on the table. Five of the unfamiliar objects were visually identical (henceforth referred to as frequent objects), while a single distinct object was

placed at one end of the row (henceforth referred to as the unique object). Next, the curtain was raised, revealing the actress. She looked toward the objects and expressed surprise by raising her eyebrows and saying "Oh!" Next, she pointed ambiguously between the unique object and one of the frequent objects (see Figure 1, Panel A) and uttered a pseudo-word "Bamoule!" (this novel label was selected because it sounded like a French word, see Havron et al., 2019). Next, she continued pointing at the objects while looking toward the viewer and repeating "Bamoule!" Last, she looked in the direction of her point and repeated once more "Bamoule!" (Figure 1, Panel A). At the end of the label learning videos, the red curtain was lowered to hide the actress, and the objects disappeared from the table.

In the hidden condition, the label learning videos were the same as in the visible condition, except that an occluding screen appeared on the table immediately before the curtain was raised. Both visible and hidden condition were based on the identical video material, by superimposing the image of a screen on the video for the hidden condition. The occluding screen hid all the identical objects from the actress, apart from the one located next to the unique object (see Figure 1, Panel A). Thus, the actress could see only two objects: one of the frequent objects and the unique object. All the objects remained visible from the participants' viewpoint.

In both conditions, we used two unfamiliar objects in the label learning videos: a green plastic object with four legs and a pink silicone oval-shaped object. For half of the participants, the green object was frequent, and the pink object was unique. For the other half of the participants, we used the opposite pattern. We also counterbalanced across participants the side of the screen on which the unique object was located (right vs. left). Each participant saw only one specific label learning video (shown four times, once per sequence starting with a warm-up video, followed a label learning video).

Test phase. After watching four warm-up videos, each followed by a label learning video, the participant was enrolled in the test phase, which consisted of a two-alternative forced-choice (2AFC) task. The test phase was identical under all conditions. In each of the test trials, the participants saw one exemplar of the frequent and unique objects, each on one side of the tablet's screen, on a black background (see Figure 1, Panel B). The experimenter invited the participant to point at the object referred to as the novel label by asking a test question (e.g. "Where is the bamoule?"). The trial ended once the participant answered the test question (if needed, the experimenter repeated the test question

until the participant answered). Next, a subsequent test trial was conducted. There were four consecutive test trials, resulting in four measurements (one after each test question). The test questions differed from trial to trial and were as follows: “Can you show me the bamoule?” (trials 1 and 3) and “Where is the bamoule?” (trials 2 and 4). During the test phase, we counterbalanced the side of the screen (right or left) on which each of the two unfamiliar objects appeared in different position across trials.

2.1.3 Data analysis

For each test trial, we coded whether the participants pointed at the picture of the unique object (coded as 1) or of the frequent object type (coded as 0). For each participant, we summed the binary scores from each of the four test trials, resulting in a global score ranging from 0 to 4. The data were coded by the first author. A second coder, unaware of the hypotheses of the study, double-coded 100% of the videos in each condition. Inter-rater agreement was maximal (Cohen’s $k = 1$, 100% of agreement). All the statistical analyses reported in this paper were two-tailed, and all frequentist statistics were computed using R (v.4.4.2; R Core Team, 2024) on RStudio (v.2024.12.0.467; Posit team, 2024) with the following packages: dplyr (v.1.1.4; Wickham et al., 2023), ggpubr (v.0.6.0; Kassambara, 2023), lme4 (v.1.1-35.5; Bates et al., 2015), lmerTest (v.3.1-3; Kuznetsova et al., 2017), rcompanion (v.2.4.36; Mangiafico, 2024), and zeallot package. In all Studies, we assessed the effect of our factors using Generalized Linear Mixed Models (GLMMs) or Linear Mixed Models (LMM) depending on the nature of our data. In all our models, we included the participant’s identity as a random intercept. We assessed effect sizes for Wilcoxon signed-rank tests and Mann Whitney U-tests using the “rcompanion” package (Study 1), while effect sizes for t-tests (Study 2 and 3) were calculated using core R syntax.

2.2. Results and discussion

We first assessed the effect of age by running GLMMs on test score as a binary repeated measure (binomial distribution, logit link). We fitted (1) a null model, which included subject identity as a random intercept, trials (four in total), and age (in months), as fixed effects to be controlled. We also fitted (2) a full model, which added the fixed effect of condition (visible vs. hidden) to the null model. The full model did not provide a significantly better fit than the null model ($\chi^2(1) = 0.14$, $p = .71$, likelihood ratio test). This model did not show a main effect of condition ($\beta = .64$, $SE = 1.70$, $z\text{-value} = 0.38$, $p = .71$), nor trial ($\beta = -.39$, $SE = 0.30$, $z\text{-value} = -1.28$, $p = .20$). It also revealed no main effect of age

($\beta = .059$, $SE = 0.12$, $z\text{-value} = 0.51$, $p = .61$). Thus, we pooled all the participants, irrespective of their age, in subsequent analyses.

Next, we compared participants’ global test scores (ranging from 0 to 4) to the value predicted by chance (2). As Figure 2 shows, in the visible condition, preschoolers pointed toward the unique object more often than predicted by chance ($M = 2.78$, $M_d = 4$, $SD = 1.70$, $V = 537$, $p = .009$, $r = .45$; Wilcoxon signed-rank test). In contrast, in the hidden condition, the participants’ level of performance did not differ significantly from what was predicted by chance ($M = 2.31$, $M_d = 4$, $SD = 1.94$, $V = 432$, $p = .32$, $r = .17$; Wilcoxon signed-rank test).

In the visible condition of Study 1, the actress uttered a novel label while performing an ambiguous communicative action that could refer to both type of novel objects. Crucially, if the speaker had wanted to refer to the frequent object type, she could have been more informative by using a different gesture, e.g. pointing toward one of the frequent objects that were far away from the unique object, or swaying the hand over the entire set of frequent objects. Thus, if preschoolers expected the speaker to be informative, they should have assumed that she was referring to the unique object. The results for the visible condition confirmed this hypothesis and align with previous findings (Bohn et al., 2022; Frank & Goodman, 2014). The results for the hidden condition indicate that when only two alternative objects are visible from the actress’s viewpoint, preschoolers no longer assume that the speaker refers to the unique object. Importantly, since there was no significant difference in performance between the visible and hidden conditions, our data do not indicate whether preschoolers’ sensitivity to informativeness is influenced by what speakers can see. Study 2 builds upon Study 1 to test how younger participants resolve the conflict between pragmatic processes based on an expectation of informativeness and exemplar frequency tracking. Study 2 uses the same materials as Study 1. However, it was adapted to collect looking responses, a more suitable measure for infants. We chose to test 18-month-olds because by this age infants can already use contextual information to identify the referents of labels (Briganti & Cohen, 2011; Woodward et al., 1994).

3. Study 2

3.1. Methods

3.1.1. Participants

We tested 18-month-old native French learners recruited from two large urban areas (Lyon and Paris, France). The

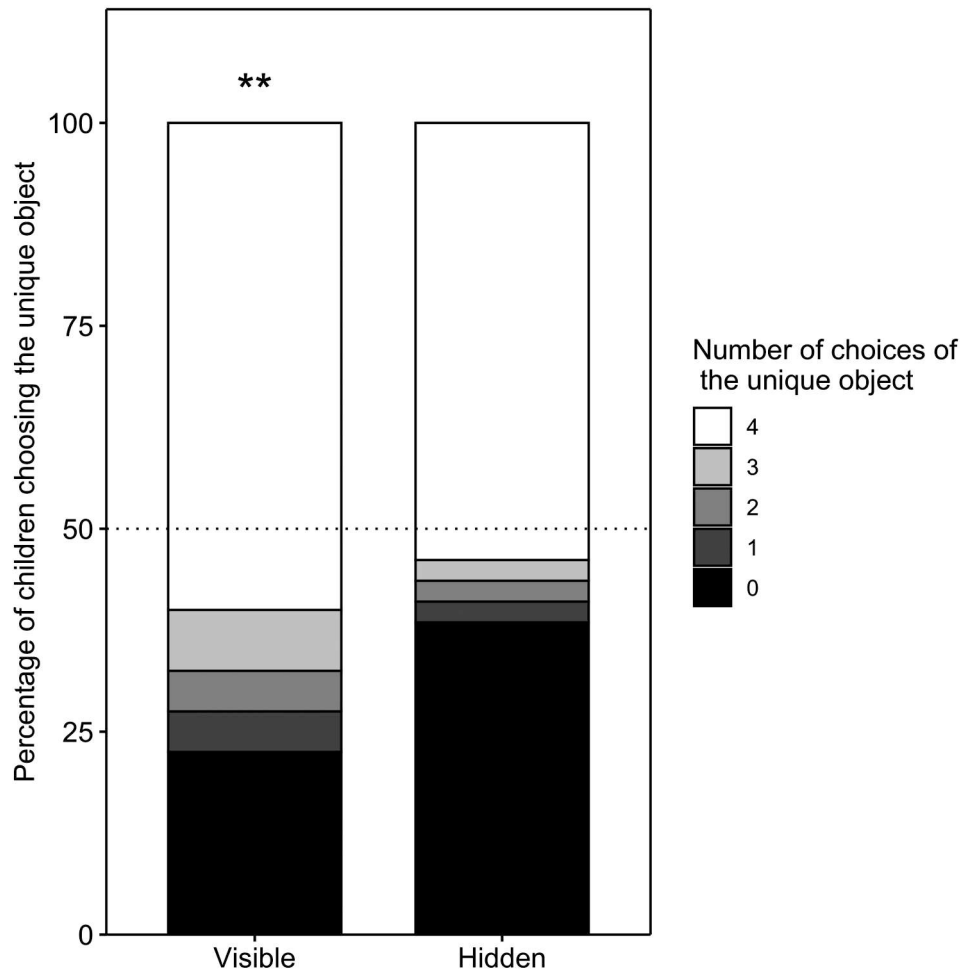


Figure 2. Proportion of participants selecting the unique object during the test phase by condition (visible vs. hidden). Note: Comparisons against chance by one-sample Wilcoxon test. $**p < .01$.

participants were recruited by sending letters to a randomly selected sample of children born in the area. Forty-eight participants were retained in the analysis and randomly assigned to one of two between-subject conditions (visible condition: $n = 24$; $M_{age} = 566$ days; $SD = 10.0$ days; *age range*: 540–580 days; hidden condition: $n = 24$; $M_{age} = 565$ days; $SD = 8.25$ days; *age range*: 549–584 days). Parental reports indicated that the percentage of French in the participants' linguistic environment (relative to any other language) was high (visible condition: $M = 93.2\%$; $SD = 12.1\%$; hidden condition: $M = 95.8\%$; $SD = 9.23\%$). Additional participants were excluded from the analysis for the following reasons: crying (4), technical failure (5), failure to calibrate the eye-tracker (6), or incomplete eye-tracking data with more than 50% missing data in more than two trials (10). Our sample sizes were based on previous studies investigating infants' word learning (de Carvalho et al., 2021; Woodward et al., 1994). A sensitivity power analysis performed using G*Power (Faul et al., 2007) revealed that the resulting sample sizes ($n = 24$ per

group) were sufficient to detect medium-to-large-sized effects ($> .61$) when testing comparisons against chance with one-sample, two-tailed t -tests ($d = .8$, $\alpha = .05$).

3.1.2. Materials and procedure

Study 2 followed the same procedure as Study 1, with the following exceptions. First, the participants did not see the stimuli on a tablet. Instead, the videos were shown on an eye-tracking screen (27", resolution: 2560 × 1440 pixels). Infants sat on their parents' laps in a soundproofed booth 60 cm from the eye-tracking screen (sampling rate: 60 Hz). We used PsychoPy (v.3.0.4; Peirce et al., 2019) for stimulus presentation (associated with Python v.2.7) and the Tobii Pro SDK package (v.1.7). A five-point calibration adapted from the psychopy-tobii controller package was performed for each participant before the presentation of the experimental stimuli.

Second, in Study 2, the utterances used as prompts during the test phase were delivered by a prerecorded

voice integrated into the video, with the exact timing predefined – especially the new-label onset (see Figure 3). During the alternative-forced-choice test of Study 2, we collected data on the participants' gaze behaviour. As in Study 1, the two unfamiliar objects from the preceding label learning video were presented side-by-side on a black background – one on the left and the other on the right of the screen.

Third, in Study 2, a colourful transition animation was played at the centre of the screen before launching each video. These transition animations served to ensure that infants were focusing on the screen when videos were launched. They were played until the participant looked at the screen continuously for 500 ms.

3.1.3. Data analysis

Study 2's data were pre-processed using the eyetrackingR package (v.0.2.1; Forbes et al., 2023). For each forced-choice trial we measured infants' responses to the unfamiliar label over a time window classically used in two-alternative forced-choice tasks, from 367 ms to 2000ms after the onset of the novel label ("Bamoule"). Gaze behaviour occurring outside this time window are typically assumed to be unrelated to target label processing (Swingley, 2007; Swingley & Aslin, 2000).

To analyse the eye-tracking data, we divided the screen through its centre, along a vertical axis, into two areas of equal size (i.e. the left and right halves of the screen). For each participant, we computed the proportion of looks toward the unique object for each 20 ms time bin by summing the time spent looking at the side of the unique object and dividing it by the total time spent looking at the entire screen over that time bin. Next, for each participant, and each trial, we averaged these proportions for each time bin, and then across all time bins. We also aggregated looking proportion of the four trials per subject. We excluded the data from forced-choice trials where more than 50% of the data was missing during the measurement time-window (5 trials out of 192: 2 in the visible condition and 3 in the hidden condition). After exclusions, each participant contributed an average of 3.92 (SD = 0.28) out of 4 forced-choice trials in the visible condition and 3.88 (SD = 0.34) out of 4 forced-choice trials in the hidden condition. To compare average looking proportions to chance level, we used data averaged across trials. The normality of the response variable and residuals was assessed using Q-Q plots and Shapiro–Wilk tests. Both visual inspection and statistical results indicated no substantial deviations from normality (all p s > .05), supporting the use of linear mixed models (LMMs) and subsequent parametric t -tests.

3.2. Results

First, we assessed the effect of our factors by running LMMs on the participants' mean proportion of looks toward the unique object during forced-choice trials. We fitted (1) a null model, which included subject identity as a random intercept, the percentage of French language in the child's environment, trials and age (in days), as fixed effects to be controlled for. We also fitted (2) a full model, which added the fixed effect of condition (visible vs. hidden) to the null model. The goodness of fit of the full model was better than that of the null model ($\chi^2(1) = 5.52$, $p = .019$, likelihood ratio test). The full model revealed a significant main effect of condition ($\beta = 0.11$, $SE = 0.05$, $p = .020$) indicating that the participants' mean proportion of looks toward the unique object was significantly lower in the visible condition than in the hidden condition. The full model revealed no other significant effects.

As shown in Figure 4, during the test phase of Study 2, the participants' mean proportion of looks toward the unique object was significantly lower than predicted by chance in the visible condition only, whereas it did not differ from chance in the hidden condition (visible condition: $M = 0.43$, $SD = 0.14$, $t(23) = -2.43$, $p = .023$, $d = -0.50$; hidden condition: $M = 0.55$, $SD = 0.20$, $t(23) = 1.25$, $p = .22$, $d = 0.26$; one-sample t -tests).

Additionally, we ran three exploratory analyses (see details in the Supplemental Materials). First, complementary analyses confirmed that the pattern of significant results from Study 2 were unique to the 367–2000 ms post-labelling window, and not present outside of this time window or before the novel label onset. Additionally, in Study 2's visible condition, participants looked significantly more at the unique object during the test time window than outside of it ($p = .001$). The same descriptive tendency was observed when comparing participants' mean proportion of looks during the test time window and before the label onset, but it was non-significant ($p = .17$). Thus, results provide some evidence that the effects observed in Study 2 might be specifically triggered by the novel label's onset. Yet, they leave open the possibility that they might be distributed before and after the label onset.

Second, cluster-based permutation analyses confirmed Study 2's results, without appealing to a pre-defined analysis time window. Third, we conducted a post hoc analysis of participants' looking behaviour during the label-learning phase. This analysis revealed that during the label-learning phase of both conditions, infants followed the actress's pointing gesture – they looked more at the two objects that the actress

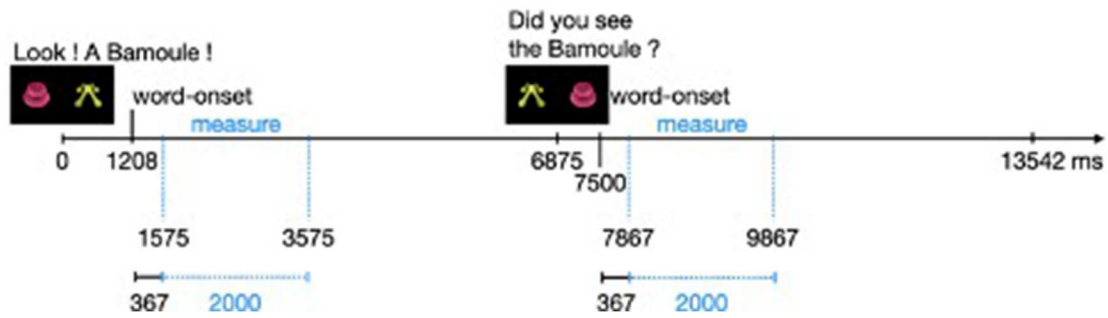


Figure 3. Schematic Timeline of Studies 2 and 3. Note: At the start of the test video, the objects appeared on the screen, and a voice-over asked a prompt question containing the novel label (e.g. “Did you see the bamoule?”). The novel label “bamoule” was pronounced 1208 ms after the video’s onset. Following the prompt question, there was a 5-second silent interval during which the objects remained visible. Subsequently, the objects switched sides – the one previously on the left moved to the right, and vice versa – marking the start of the second trial. The second prompt question began simultaneously with the second trial, where the critical word “bamoule” was pronounced at 7500 ms (625 ms after the onset of the second trial). As with the first trial, the prompt question was followed by a 5 second silent interval with the objects still visible. This test video was repeated twice, resulting in a total of four trials and therefore four measurements (one per prompt question). The prompt questions differed from trial to trial and were as follows: “Look! A bamoule!” (trials 1 and 3) and “Did you see the bamoule?” (trials 2 and 4).

pointed towards ambiguously than at the other objects. Moreover, infants’ proportion of looks at the unique object during the label-learning phase did not correlate with their looking behaviour during the test phase (see Supplemental Materials).

3.3. Discussion

In the visible condition of Study 2, infants’ strategies were consistent with exemplar frequency tracking. Moreover, infants considered what the speaker could

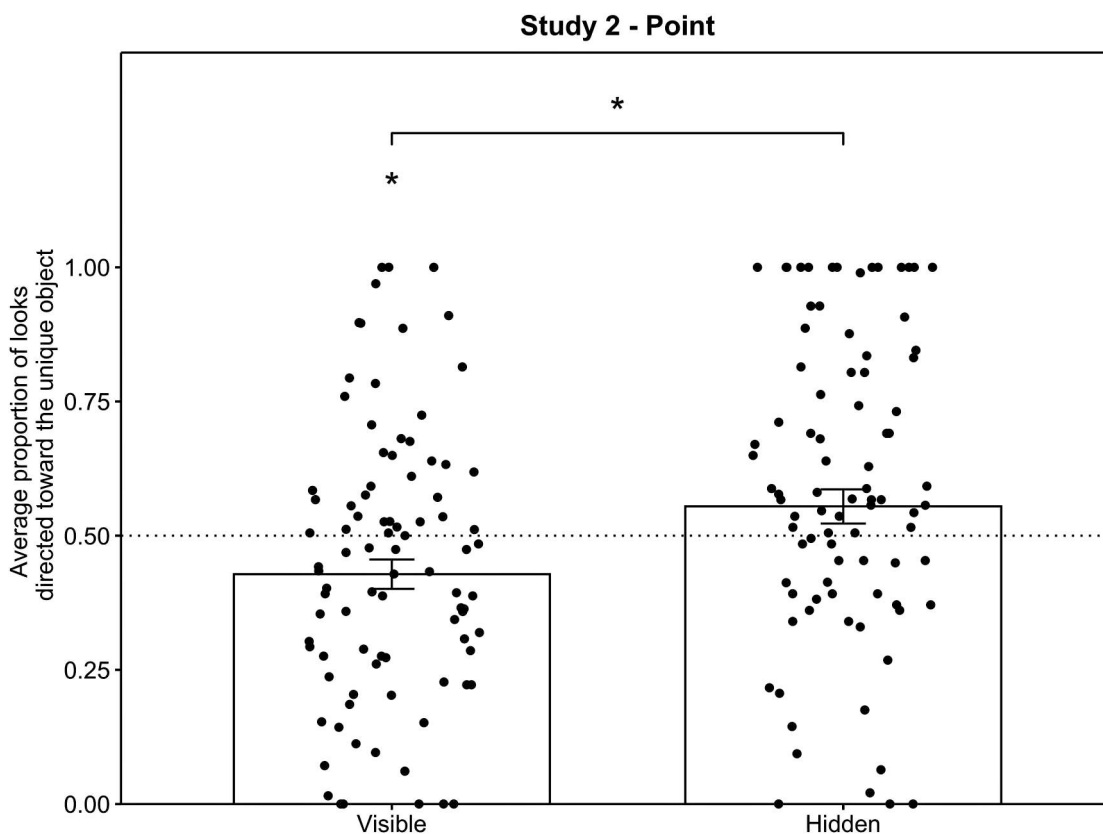


Figure 4. Mean proportion of looks toward the unique object in forced-choice trials of study 2, by condition (visible vs. hidden). Note: Error bars represent SEM. Data from individual participants are represented by dots. Comparisons against chance by one-sample *t*-tests and comparisons between conditions by independent samples *t*-tests. **p* < .05.

see, as indicated by the effect of condition (visible vs. hidden). Thus, when applying strategies of exemplar frequency tracking, infants are not purely egocentric, and they consider what is visible for speakers.

Study 2's findings are remarkable, as they indicate infants employ a strategy drastically different from that of preschoolers. In Study 3, we sought to replicate these results conceptually using a slightly modified situation. In Study 2, the speaker communicated by pointing ambiguously toward a set of objects. However, this communicative action was unusual because the actress pointed between two objects, even though she could have touched the specific object she was referring to. Thus, in Study 3, we modified our stimuli to make the communicative gestures more familiar by removing ambiguous pointing.

4. Study 3

4.1. Methods

4.1.1. Participants

We tested 18-month-old French learners recruited in the Paris area, following the same procedure as in Study 2. Forty-eight participants were retained for analysis and assigned to one of two between-subject conditions (visible condition: $n = 24$; $M_{age} = 561$ days; $SD = 10.0$ days; *age range*: 549–585 days; hidden condition: $n = 24$; $M_{age} = 560$ days; $SD = 10.9$ days; *age range*: 545–585 days). Parental reports indicated a high percentage of French in the participants' linguistic environment (visible condition: $M = 85.4\%$; $SD = 18.1\%$; hidden condition: $M = 85.7\%$; $SD = 16.7\%$).

Additional participants were tested but excluded from the analysis due to crying (2), technical failure (1), failure to calibrate the eye-tracker (2), incomplete eye-tracking data in more than two trials with over 50% missing data (8), or in the absence of a French native-speaking primary caregiver (2).

4.1.2. Materials and procedure

Study 3 followed the same procedure as Study 2, with the following exceptions. In the label-learning video, the experimenter did not use any pointing gesture. Instead, she simply looked toward the unique object and one of the frequent objects, making the target of her gaze ambiguous (see Figure 1, Panel A). During Study 3's label-learning videos, after the curtain was raised, the actress said "Oh!" while looking toward the unique object and the neighbouring frequent object. Next, she looked toward the viewer before looking again at the unique object and the neighbouring frequent object, uttering the pseudo-word "Bamoule!"

only once (see Figure 1, Panel B). Moreover, in Study 3, the actress wore a different outfit than in Study 2, and the position of the array of unfamiliar objects on the screen was more centred than in Study 2.

4.1.3. Data analysis

Study 3's data analysis procedure was the same as in Study 2, with the addition of cross-Studies performance comparisons (Study 2 vs. 3). We excluded the data from forced-choice trials where more than 50% of the data was missing during the 367–2000 ms post-labelling phase (16 trials out of 192: 5 in the visible condition and 11 in the hidden condition). After exclusions, each participant contributed an average of 3.79 ($SD = 0.41$) out of 4 forced-choice trials in the visible condition and 3.54 ($SD = 0.78$) in the hidden condition. As in Study 2, both Q-Q plots visual inspection and Shapiro–Wilk tests indicated no significant deviations from normality (all $ps > .05$).

4.2. Results

We began assessing the effect of our factors by running LMMs on the participants' mean proportion of looks toward the unique object. We fitted the same models as in Study 2 and observed a comparable pattern of statistically significant results. In Study 3, the fit of the full model was better than that of the null model ($\chi^2(1) = 10.60$, $p = .001$, likelihood ratio test). Similar to Study 2, the full model showed a significant main effect of condition ($\beta = 0.20$, $SE = 0.06$, $p = .002$), indicating that the participants' mean proportion of looks toward the unique object was significantly lower in the visible condition than in the hidden condition. The full model did not reveal any other significant effect.

As shown in Figure 5, during the test phase of Study 3, participants' mean proportion of looks toward the unique object was significantly lower than predicted by chance in the visible condition ($M = 0.40$, $SD = 0.18$, $t(23) = -2.79$, $p = .010$, $d = -0.57$, one-sample t -test). Conversely, it was significantly higher than predicted by chance in the hidden condition ($M = 0.60$, $SD = 0.23$, $t(23) = 2.23$, $p = .036$, $d = 0.45$, one-sample t -test).

In short, the results of Studies 2 and 3 were very similar, with one exception. In the hidden condition, participants' average proportion of looks towards the unique object differed from the chance level only in Study 3 ($M = 0.60$, $SD = 0.23$, $p = .036$), and not in Study 2 ($M = 0.55$, $SD = 0.20$, $p = .22$). Thus, we assessed whether infants' looking behaviour differed across Studies. These additional analyses revealed that Study (2 vs. 3) had no significant effect on infants' average proportion of looks towards the unique object during the

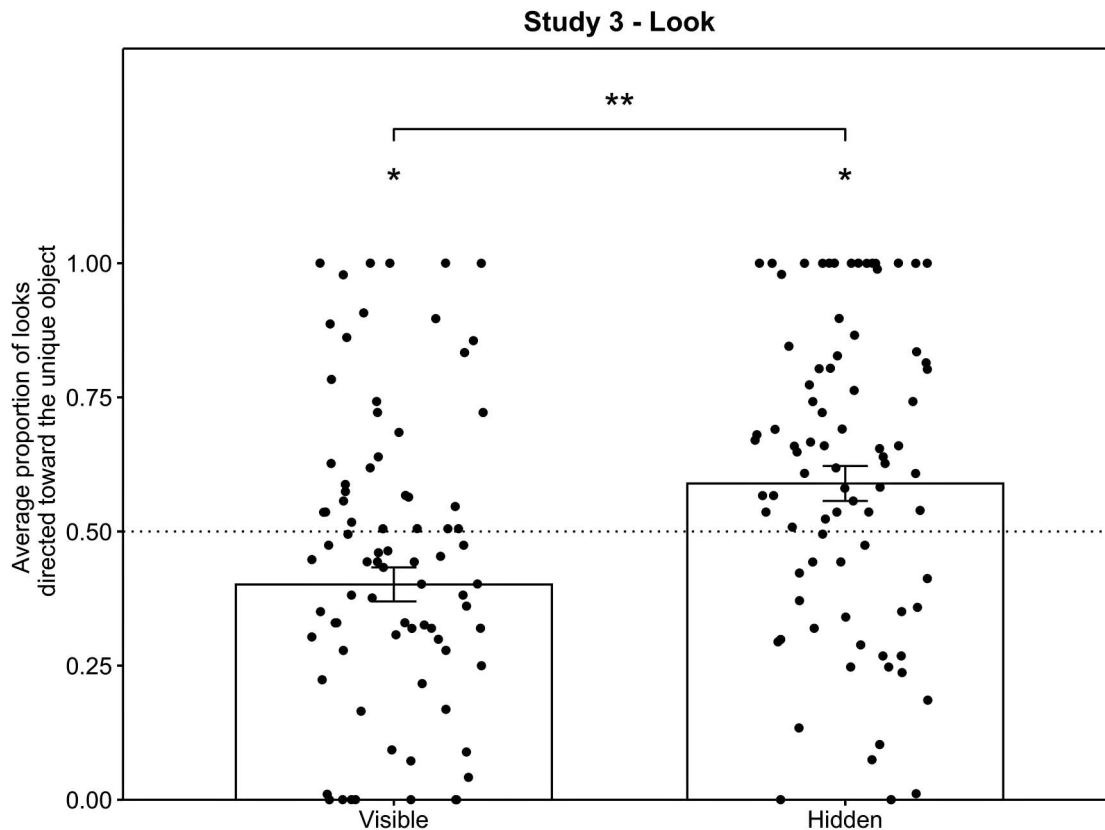


Figure 5. Mean proportion of looks toward the unique object in forced-choice trials of study 3, by condition (visible vs. hidden). Note: Error bars represent SEM. Data from individual participants are represented by dots. Comparisons against chance by one-sample t -tests and comparisons between conditions by independent samples t -tests. * $p < .05$; ** $p < .01$.

post-labelling time window, in any of the conditions (visible: $t(43.70) = 0.68$, $p = .50$, $d = 0.35$; hidden: $t(45.43) = -0.82$, $p = .41$, $d = -0.43$; independent samples t -tests).

In Study 3, we also ran the same exploratory analyses as in Study 2, with comparable results (see details in the Supplemental Materials). The pattern of significant results from Study 3 was unique to the pre-defined time window, and it was not observed outside of it nor before the label onset. Furthermore, in Study 3's visible condition, participants looked significantly less at the unique object during the test time window than outside of it ($p < .001$), or before the novel label onset ($p = .013$). Thus, there is strong evidence that in Study 3, the effects observed during the test time window were specifically triggered by the novel label onset.

Just like for Study 2, cluster-based permutation analyses confirmed that Study 3's results, without appealing to a predefined analysis time window. During the label-learning phase of Study 3, infants followed the actress's ambiguous communicative gaze, in both conditions. As in Study 2, infants' average proportion of looks at the unique object during label-learning videos did not correlate with their test phase behaviour in Study 3.

4.3. Discussion

The results of Study 3 complement those of Study 2. First, infants' behaviour was consistent with an exemplar-frequency-tracking strategy. During the test phase of the visible condition of both Studies, infants' average proportions of looks at the unique object were significantly lower than predicted by chance. Moreover, in Study 3, participants' tendency to look at the unique object was significantly stronger during the test time window (right after label onset), than outside of it, or before the novel label onset. Thus, Study 3 provides strong evidence that participants linked the novel label to the frequent object type. Additionally, in Study 3, as in Study 2, infants were sensitive to what the speaker could see, as indicated by the effect of condition (visible vs. hidden) during the test phase. These results also indicate that infants' behaviour in the visible condition of Studies 2–3 cannot be explained by the visual saliency of the unique and repeated exemplars. If this had been the case, we would have observed the same pattern of responses across the visible and hidden conditions.

In the hidden condition of Studies 2–3, infants' average proportion of looks at the unique object

tended to be higher than the .50 value predicted by chance ($M = .55$ and $M = .60$, respectively). Although this tendency was significant only in Study 3, Study (2 vs. 3) had no effect on infants' tendency to look at the unique object in the hidden condition. These data are consistent with infants having a moderate baseline visual preference for the unique object during the test phase of the hidden condition, in which the novel label was fully ambiguous. This result underscores the importance of controlling for visual saliency, which was achieved, in our studies, by comparing the visible and hidden conditions.

5 General discussion

We investigated the early development of pragmatic inferences based on expectations of informativeness. First, we found evidence that, in a context in which these pragmatic inferences and exemplar frequency tracking yielded conflicting results, 3- to 4-year-old preschoolers relied on pragmatic inferences to discover the meaning of an ambiguous novel label (Study 1), in line with previous results (Aguirre et al., 2023; Bohn et al., 2022; Frank & Goodman, 2014). In contrast, 18-month-old infants showed the opposite pattern, suggesting that they relied more on exemplar frequency tracking (Studies 2–3). In short, we observed a developmental switch in the use of expectations of communicative informativeness from infancy to preschool age.

Several factors might make it difficult for infants to use informativeness-based pragmatic inference. Classic accounts of these inferences rely on sophisticated abilities that may not be present in infancy. For example, the Rational Speech Act model requires listeners to reason about a speaker's representation of the listener's internal model (Goodman & Frank, 2016). It is unclear if infants can handle such complex, recursively embedded representations. Additionally, the type of informativeness-based pragmatic inferences that we investigated might rest on counterfactual reasoning. For instance, in the present work, children might reason that if the speaker intended to reference the frequent objects, she could have used clearer gestures, such as pointing to a frequent object far from the unique one. This kind of reasoning, which involves contemplating what might have happened, may be challenging for very young children (Nyhout & Ganea, 2019a, 2019b). The ability to engage in such sophisticated cognitive processes might not be fully developed in infancy, potentially limiting their capacity for informativeness-based pragmatic inference.

Young children's word learning strategies sometimes differ markedly from those of older children and adults.

For instance, Ramsar et al. (2013) observed that toddlers rely more strongly on statistical regularities (taking into account background rates) than older children and adults when attempting to identify the referents of novel labels. Our data provide further evidence suggesting that young children use statistical regularities differently from older participants. In Studies 2–3, 18-month-old infants did not perform at chance. Instead, they appear to link the novel label to the frequent object type in the visible condition, with Study 3, in particular, providing unequivocal evidence for this conclusion. These results indicate that exemplar frequency can influence lexical acquisition from infancy. They open perspectives for the study of the way infants capitalise on statistical regularities in their environment, beyond cross-situational temporal co-occurrences. Exemplar frequency effects may apply to a variety of processes – they need not be reduced to associative processes. For example, the propose-but-verify hypothesis posits that, after encountering a new label, learners form a single explicit hypothesis about its meaning. This hypothesis is then carried forward unless disconfirmed later (Berens et al., 2018; Medina et al., 2011; Trueswell et al., 2013; Woodard et al., 2016; for comparable models involving a ranking of a small set of hypotheses, see also Dautriche & Chemla, 2014; Koehne et al., 2013; Roembke & McMurray, 2016; Stevens et al., 2017; Yurovsky et al., 2014).

Hypothesis-testing processes are likely influenced by co-occurrence between labels and the frequency of object types at labelling. Consider a scenario where a learner hears a novel label while surrounded by two types of novel objects, with one type being more numerous. If the learner assumes equal probability for the label to refer to any present object, they should be more likely to hypothesise that the label refers to the more abundant object type. Note this process does not necessarily require infants to consider multiple hypotheses simultaneously. Instead, infants might randomly select one of the available objects as a potential referent and provisionally assume the label refers to it. Using this approach, infants would be more likely to attach labels to object types that are more abundant in their environment.

Our studies also provide information about the way speakers' visual access affects young children's processing of novel labels. In Study 1, the manipulation of speakers' visual access had mixed effects on preschoolers' performance. When only two objects were visible from the speaker's viewpoint, preschoolers no longer selected the unique object as the referent of the novel label. However, they did not behave in a significantly different manner when the speaker could see all the

objects (in the visible condition) or only two of them (in the hidden condition). In short, the results of Study 1 are compatible with the view that preschoolers can use what speakers see when engaging in pragmatic inferences. However, they do not provide conclusive evidence to support this claim.

By contrast, in Studies 2–3, the effect of condition (visible vs. hidden) was significant, indicating that by 18 months, infants consider what speakers can see in a referential task. Thus, infants are not egocentric when linking labels to referents. Instead, they take into account the speaker's visual perspective, not just objects present during labelling events. Previous studies have established that young children take into account not only gaze direction but also what is visible or hidden for speakers in the context of word learning (Aguirre et al., 2022; Nadig & Sedivy, 2002; Nurmsoo & Bloom, 2008). Studies 2–3 provide evidence for comparable capacity at a much younger age, in line with recent evidence (Bernard et al., 2025). Infants' capacity to use information about what others can see when learning labels makes sense given their sensitivity to what is visible to others, which develops from the first months of life onward (Choi et al., 2018; Liszkowski et al., 2007; Luo & Baillargeon, 2007; Moll & Tomasello, 2006; O'Neill, 1996; Sodian et al., 2007). By monitoring what speakers can see, infants can restrict the range of potential referents for novel labels, thus making word learning a much more tractable problem.

The effect of referent visibility in Studies 2–3 might have several non-mutually exclusive bases. First, infants may have extended the space of possible referents for the actress' gesture beyond the two objects she ambiguously pointed or looked at. As a result, infants would have considered several visible frequent objects as possible referents for the pointing or gaze gesture of the speaker. By contrast, in the hidden condition, infants arguably restricted the set of possible referents only to the two objects visible to the actress. Second, infants might use frequency information to infer what the speaker might comment on, based on which objects she is aware of being present. For instance, infants might expect speakers to be equally likely to comment on any of the objects that she knows to be present. In the visible condition, this would lead infants to expect the speaker to refer to one of the frequent objects rather than to the unique one.

For practical reasons, we collected pointing behaviour in preschoolers and eye-tracking measures in toddlers. We acknowledge that this is a methodological limitation – using uniform measures across age groups would have been preferable. Yet, research on children's

word learning shows a strong correlation between pointing accuracy and looking proportions, with comparable developmental patterns (Creel, 2025). Thus, in word-learning paradigms, pointing measures can serve as a reliable proxy for children's visual behaviour, justifying the comparison of performance between different age groups in our studies.

In short, our studies revealed three key findings regarding the early development of communicative and linguistic abilities. First, we observed a developmental shift in the use of pragmatic inferences based on expectations of informativeness, suggesting significant changes occur within the first years of life regarding this capacity. Second, our results highlight the influence of exemplar frequency on infants' lexical acquisition, an area that warrants further investigation. Finally, we found compelling evidence that infants consider a speaker's visual perspective when interpreting novel labels, demonstrating that this ability significantly impacts their word-learning process.

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Disclosure statement

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References

- Abbot-Smith, K., Nurmsoo, E., Croll, R., Ferguson, H., & Forrester, M. (2016). How children aged 2;6 tailor verbal expressions to interlocutor informational needs. *Journal of Child Language*, 43(6), 1277–1291. <https://doi.org/10.1017/S0305000915000616>
- Adler, S. A., & Orprecio, J. (2006). The eyes have it: Visual pop-out in infants and adults. *Developmental Science*, 9(2), 189–206. <https://doi.org/10.1111/j.1467-7687.2006.00479.x>

- Aguirre, M., Brun, M., Morin, O., Reboul, A., & Mascaró, O. (2023). Expectations of processing ease, informativeness, and accuracy guide toddlers' processing of novel communicative cues. *Cognitive Science*, 47(11), e13373. <https://doi.org/10.1111/cogs.13373>
- Aguirre, M., Brun, M., Reboul, A., & Mascaró, O. (2022). How do we interpret questions? Simplified representations of knowledge guide humans' interpretation of information requests. *Cognition*, 218, 104954. <https://doi.org/10.1016/j.cognition.2021.104954>
- Akhtar, N., & Montague, L. (1999). Early lexical acquisition: The role of cross-situational learning. *First Language*, 19(57), 347–358. <https://doi.org/10.1177/014272379901905703>
- Baldwin, D. A. (1991). Infants' contribution to the achievement of joint reference. *Child Development*, 62(5), 875–890. <https://doi.org/10.1111/j.1467-8624.1991.tb01577.x>
- Baldwin, D. A. (1993). Early referential understanding: Infants' ability to recognize referential acts for what they are. *Developmental Psychology*, 29(5), 832–843. <https://doi.org/10.1037/0012-1649.29.5.832>
- Bannard, C., Rosner, M., & Matthews, D. (2017). What's worth talking about? Information theory reveals how children balance informativeness and ease of production. *Psychological Science*, 28(7), 954–966. <https://doi.org/10.1177/0956797617699848>
- Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, 67(1), 1–48. <https://doi.org/10.18637/jss.v067.i01>
- Behne, T., Carpenter, M., & Tomasello, M. (2005). One-year-olds comprehend the communicative intentions behind gestures in a hiding game. *Developmental Science*, 8(6), 492–499. <https://doi.org/10.1111/j.1467-7687.2005.00440.x>
- Berens, S. C., Horst, J. S., & Bird, C. M. (2018). Cross-situational learning is supported by propose-but-verify hypothesis testing. *Current Biology*, 28(7), 1132–1136.e5. <https://doi.org/10.1016/j.cub.2018.02.042>
- Bergelson, E., & Swingle, D. (2012). At 6–9 months, human infants know the meanings of many common nouns. *Proceedings of the National Academy of Sciences*, 109(9), 3253–3258. <https://doi.org/10.1073/pnas.1113380109>
- Bergelson, E., & Swingle, D. (2015). Early word comprehension in infants: Replication and extension. *Language Learning and Development*, 11(4), 369–380. <https://doi.org/10.1080/15475441.2014.979387>
- Bernard, C., Depierreux, A., Huet, V., & Mascaró, O. (2025). Infants assume questions serve an information-seeking function, link them to interrogative sentences and differentiate them from assertions. *Child Development*, 96(5), 1605–1618. <https://doi.org/10.1111/cdev.14267>
- Bleijlevens, N., Ciesla, A.-L., & Behne, T. (2025). When language background does not matter: Both mono- and bilingual children use mutual exclusivity and pragmatic context to learn novel words. *Developmental Science*, 28(3), e13618. <https://doi.org/10.1111/desc.13618>
- Bleijlevens, N., Contier, F., & Behne, T. (2023). Pragmatics aid referent disambiguation and word learning in young children and adults. *Developmental Science*, 26(4), e13363. <https://doi.org/10.1111/desc.13363>
- Bloom, P. (2002). Mindreading, communication and the learning of names for things. *Mind & Language*, 17(1–2), 37–54. <https://doi.org/10.1111/1468-0017.00188>
- Bohn, M., & Köymen, B. (2018). Common ground and development. *Child Development Perspectives*, 12(2), 104–108. <https://doi.org/10.1111/cdep.12269>
- Bohn, M., Tessler, M. H., Merrick, M., & Frank, M. C. (2021). How young children integrate information sources to infer the meaning of words. *Nature Human Behaviour*, 5(8), 1046–1054. <https://doi.org/10.1038/s41562-021-01145-1>
- Bohn, M., Tessler, M. H., Merrick, M., & Frank, M. C. (2022). Predicting pragmatic cue integration in adults' and children's inferences about novel word meanings. *Journal of Experimental Psychology: General*, 151(11), 2927–2942. <https://doi.org/10.1037/xge0001216>
- Briganti, A. M., & Cohen, L. B. (2011). Examining the role of social cues in early word learning. *Infant Behavior and Development*, 34(1), 211–214. <https://doi.org/10.1016/j.infbeh.2010.12.012>
- Choi, Y., Mou, Y., & Luo, Y. (2018). How do 3-month-old infants attribute preferences to a human agent? *Journal of Experimental Child Psychology*, 172, 96–106. <https://doi.org/10.1016/j.jecp.2018.03.004>
- Creel, S. C. (2025). Connecting the tots: Strong looking-pointing correlations in preschoolers' word learning and implications for continuity in language development. *Child Development*, 96(1), 87–103. <https://doi.org/10.1111/cdev.14157>
- Csibra, G., & Volein, Á. (2008). Infants can infer the presence of hidden objects from referential gaze information. *British Journal of Developmental Psychology*, 26(1), 1–11. <https://doi.org/10.1348/026151007X185987>
- Dautriche, I., & Chemla, E. (2014). Cross-situational word learning in the right situations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 40(3), 892–903. <https://doi.org/10.1037/a0035657>
- Davies, C., & Katsos, N. (2010). Over-informative children: Production/comprehension asymmetry or tolerance to pragmatic violations? *Lingua*, 120(8), 1956–1972. <https://doi.org/10.1016/j.lingua.2010.02.005>
- de Carvalho, A., Crimon, C., Barrault, A., Trueswell, J., & Christophe, A. (2021). “Look! It is not a bamoule!”: 18- and 24-month-olds can use negative sentences to constrain their interpretation of novel word meanings. *Developmental Science*, 24(4), e13085. <https://doi.org/10.1111/desc.13085>
- Eskritt, M., Whalen, J., & Lee, K. (2008). Preschoolers can recognize violations of the Gricean maxims. *British Journal of Developmental Psychology*, 26(3), 435–443. <https://doi.org/10.1348/026151007X253260>
- Esteve-Gibert, N., Prieto, P., & Liszkowski, U. (2017). Twelve-month-olds understand social intentions based on prosody and gesture shape. *Infancy*, 22(1), 108–129. <https://doi.org/10.1111/inf.12146>
- Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, 39(2), 175–191. <https://doi.org/10.3758/BF03193146>
- Fazly, A., Alishahi, A., & Stevenson, S. (2010). A probabilistic computational model of cross-situational word learning. *Cognitive Science*, 34(6), 1017–1063. <https://doi.org/10.1111/j.1551-6709.2010.01104.x>
- Forbes, S., Dink, J., & Ferguson, B. (2023). *eyetrackingR*. <http://www.eyetracking-r.com/>

- Frank, M. C., Emilsson, A. G., Peloquin, B., Goodman, N. D., & Potts, C. (2016). *Rational speech act models of pragmatic reasoning in reference games*. PsyArXiv. <https://doi.org/10.31234/osf.io/f9y6b>
- Frank, M. C., & Goodman, N. D. (2014). Inferring word meanings by assuming that speakers are informative. *Cognitive Psychology*, *75*, 80–96. <https://doi.org/10.1016/j.cogpsych.2014.08.002>
- Goodman, N. D., & Frank, M. C. (2016). Pragmatic language interpretation as probabilistic inference. *Trends in Cognitive Sciences*, *20*(11), 818–829. <https://doi.org/10.1016/j.tics.2016.08.005>
- Goodman, N. D., & Stuhlmüller, A. (2013). Knowledge and implicature: Modeling language understanding as social cognition. *Topics in Cognitive Science*, *5*(1), 173–184. <https://doi.org/10.1111/tops.12007>
- Grice, P. (1989). *Studies in the way of words*. Harvard University Press.
- Grigoroglou, M., & Papafragou, A. (2019). Interactive contexts increase informativeness in children’s referential communication. *Developmental Psychology*, *55*(5), 951–966. <https://doi.org/10.1037/dev0000693>
- Grosse, G., & Tomasello, M. (2012). Two-year-old children differentiate test questions from genuine questions. *Journal of Child Language*, *39*(1), 192–204. <https://doi.org/10.1017/S0305000910000760>
- Gweon, H., & Asaba, M. (2018). Order matters: Children’s evaluation of underinformative teachers depends on context. *Child Development*, *89*(3), e278–e292. <https://doi.org/10.1111/cdev.12825>
- Gweon, H., Shafto, P., & Schulz, L. (2018). Development of children’s sensitivity to overinformativeness in learning and teaching. *Developmental Psychology*, *54*(11), 2113–2125. <https://doi.org/10.1037/dev0000580>
- Hartley, C., & Whiteley, H. A. (2024). Do multiple exemplars promote preschool children’s retention and generalisation of words learned from pictures? *Cognitive Development*, *70*, 101459. <https://doi.org/10.1016/j.cogdev.2024.101459>
- Havron, N., de Carvalho, A., Fiévet, A.-C., & Christophe, A. (2019). Three- to four-year-old children rapidly adapt their predictions and use them to learn novel word meanings. *Child Development*, *90*(1), 82–90. <https://doi.org/10.1111/cdev.13113>
- Horowitz, A. C., & Frank, M. C. (2016). Children’s pragmatic inferences as a route for learning about the world. *Child Development*, *87*(3), 807–819. <https://doi.org/10.1111/cdev.12527>
- Kampa, A., & Papafragou, A. (2020). Four-year-olds incorporate speaker knowledge into pragmatic inferences. *Developmental Science*, *23*(3). <https://doi.org/10.1111/desc.12920>
- Kao, J., Bergen, L., & Goodman, N. D. (2014). Formalizing the pragmatics of metaphor understanding. *Proceedings of the Annual Meeting of the Cognitive Science Society*, *36*(36). <https://escholarship.org/uc/item/09h3p4cz>
- Kassambara, A. (2023). *ggpubr: « ggplot2 » based publication ready plots*. <https://CRAN.R-project.org/package=ggpubr>
- Katsos, N., & Bishop, D. V. M. (2011). Pragmatic tolerance: Implications for the acquisition of informativeness and implicature. *Cognition*, *120*(1), 67–81. <https://doi.org/10.1016/j.cognition.2011.02.015>
- Khu, M., Chambers, C. G., & Graham, S. A. (2020). Preschoolers flexibly shift between speakers’ perspectives during real-time language comprehension. *Child Development*, *91*(3), e619–e634. <https://doi.org/10.1111/cdev.13270>
- Kobayashi, H., Kobori, O., Ihara, Y., Yaguchi, H., & Yasuda, T. (2022). Understanding ostensive behavior in making inferences of referential intentions. *Letters on Evolutionary Behavioral Science*, *13*(1), 1–5. <https://doi.org/10.5178/lebs.2022.90>
- Koehne, J., Trueswell, J. C., & Gleitman, L. R. (2013). Multiple proposal memory in observational word learning. *Proceedings of the Annual Meeting of the Cognitive Science Society*, *35*(35). <https://escholarship.org/uc/item/5gp8j5qs>
- Kovack-Lesh, K. A., & Oakes, L. M. (2007). Hold your horses: How exposure to different items influences infant categorization. *Journal of Experimental Child Psychology*, *98*(2), 69–93. <https://doi.org/10.1016/j.jecp.2007.05.001>
- Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). LmerTest package: Tests in linear mixed effects models. *Journal of Statistical Software*, *82*(13), 1–26. <https://doi.org/10.18637/jss.v082.i13>
- Liszkowski, U., Carpenter, M., & Tomasello, M. (2007). Pointing out new news, old news, and absent referents at 12 months of age. *Developmental Science*, *10*(2), F1–F7. <https://doi.org/10.1111/j.1467-7687.2006.00552.x>
- Luo, Y., & Baillargeon, R. (2007). Do 12.5-month-old infants consider what objects others can see when interpreting their actions? *Cognition*, *105*(3), 489–512. <https://doi.org/10.1016/j.cognition.2006.10.007>
- Mangiafico, S. (2024). *Rcompanion: Functions to support extension education program evaluation*. Rutgers Cooperative Extension. <https://CRAN.R-project.org/package=rcompanion/>
- Mascaro, O., & Kovács, ÁM. (2022). The origins of trust: Humans’ reliance on communicative cues supersedes firsthand experience during the second year of life. *Developmental Science*, *25*(4), e13223. <https://doi.org/10.1111/desc.13223>
- Mazzarella, D., & Pouscoulous, N. (2021). Pragmatics and epistemic vigilance: A developmental perspective. *Mind & Language*, *36*(3), 355–376. <https://doi.org/10.1111/mila.12287>
- Medina, T. N., Snedeker, J., Trueswell, J. C., & Gleitman, L. R. (2011). How words can and cannot be learned by observation. *Proceedings of the National Academy of Sciences*, *108*(22), 9014–9019. <https://doi.org/10.1073/pnas.1105040108>
- Moll, H., & Tomasello, M. (2006). Level 1 perspective-taking at 24 months of age. *British Journal of Developmental Psychology*, *24*(3), 603–613. <https://doi.org/10.1348/026151005X55370>
- Morisseau, T., Davies, C., & Matthews, D. (2013). How do 3- and 5-year-olds respond to under- and over-informative utterances? *Journal of Pragmatics*, *59*, 26–39. <https://doi.org/10.1016/j.pragma.2013.03.007>
- Nadig, A. S., & Sedivy, J. C. (2002). Evidence of perspective-taking constraints in children’s on-line reference resolution. *Psychological Science*, *13*(4), 329–336. <https://doi.org/10.1111/j.0956-7976.2002.00460.x>
- Nilsen, E. S., & Graham, S. A. (2009). The relations between children’s communicative perspective-taking and executive functioning. *Cognitive Psychology*, *58*(2), 220–249. <https://doi.org/10.1016/j.cogpsych.2008.07.002>

- Nurmsoo, E., & Bloom, P. (2008). Preschoolers' perspective taking in word learning: Do they blindly follow eye gaze? *Psychological Science*, 19(3), 211–215. <https://doi.org/10.1111/j.1467-9280.2008.02069.x>
- Nyhout, A., & Ganea, P. A. (2019a). Mature counterfactual reasoning in 4- and 5-year-olds. *Cognition*, 183, 57–66. <https://doi.org/10.1016/j.cognition.2018.10.027>
- Nyhout, A., & Ganea, P. A. (2019b). The development of the counterfactual imagination. *Child Development Perspectives*, 13(4), 254–259. <https://doi.org/10.1111/cdep.12348>
- Oakes, L. M., & Ribar, R. J. (2005). A comparison of infants' categorization in paired and successive presentation familiarization tasks. *Infancy*, 7(1), 85–98. https://doi.org/10.1207/s15327078in0701_7
- Okumura, Y., Kanakogi, Y., Kanda, T., Ishiguro, H., & Itakura, S. (2013). The power of human gaze on infant learning. *Cognition*, 128(2), 127–133. <https://doi.org/10.1016/j.cognition.2013.03.011>
- O'Neill, D. K. (1996). Two-year-old children's sensitivity to a parent's knowledge state when making requests. *Child Development*, 67(2), 659–677. <https://doi.org/10.2307/1131839>
- O'Neill, D. K., & Topolovec, J. C. (2001). Two-year-old children's sensitivity to the referential (in)efficacy of their own pointing gestures. *Journal of Child Language*, 28(1), 1–28. <https://doi.org/10.1017/S0305000900004566>
- Oviatt, S. L. (1980). The emerging ability to comprehend language: An experimental approach. *Child Development*, 51(1), 97–106. <https://doi.org/10.2307/1129595>
- Papafragou, A., Fairchild, S., Cohen, M. L., & Friedberg, C. (2017). Learning words from speakers with false beliefs. *Journal of Child Language*, 44(4), 905–923. <https://doi.org/10.1017/S0305000916000301>
- Pashler, H., & Harris, C. R. (2001). Spontaneous allocation of visual attention: Dominant role of uniqueness. *Psychonomic Bulletin & Review*, 8(4), 747–752. <https://doi.org/10.3758/BF03196213>
- Pätzold, W., & Liszkowski, U. (2019). Pupillometry reveals communication-induced object expectations in 12- but not 8-month-old infants. *Developmental Science*, 22(6), e12832. <https://doi.org/10.1111/desc.12832>
- Paulus, M., & Fikkert, P. (2014). Conflicting social cues: Fourteen- and 24-month-old infants' reliance on gaze and pointing cues in word learning. *Journal of Cognition and Development*, 15(1), 43–59. <https://doi.org/10.1080/15248372.2012.698435>
- Peirce, J., Gray, J. R., Simpson, S., MacAskill, M., Höchenberger, R., Sogo, H., Kastman, E., & Lindeløv, J. K. (2019). Psychopy2: Experiments in behavior made easy. *Behavior Research Methods*, 51(1), 195–203. <https://doi.org/10.3758/s13428-018-01193-y>
- Pomiechowska, B., & Csibra, G. (2022). Nonverbal action interpretation guides novel word disambiguation in 12-month-olds. *Open Mind*, 6, 51–76. https://doi.org/10.1162/opmi_a_00055
- Posit team. (2024). *RStudio: Integrated development environment for R* (Posit Software). PBC. <http://www.posit.co/>
- Price, G. F., & Sandhofer, C. M. (2021). One versus many: Multiple examples in word learning. *Journal of Experimental Child Psychology*, 209, 105173. <https://doi.org/10.1016/j.jecp.2021.105173>
- Quine, W. V. O. (1960). *Word and object*. MIT Press.
- Rajsic, J., Sun, S. Z., Huxtable, L., Pratt, J., & Ferber, S. (2016). Pop-out and pop-in: Visual working memory advantages for unique items. *Psychonomic Bulletin & Review*, 23(6), 1787–1793. <https://doi.org/10.3758/s13423-016-1034-5>
- Ramscar, M., Dye, M., & Klein, J. (2013). Children value informativity over logic in word learning. *Psychological Science*, 24(6), 1017–1023. <https://doi.org/10.1177/0956797612460691>
- Raz, H. K., Abney, D. H., Crandall, D., Yu, C., & Smith, L. B. (2019). How do infants start learning object names in a sea of clutter?. *Cogsci*, 41, 521–526.
- R Core Team. (2024). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. <https://www.R-project.org/>
- Roembke, T. C., & McMurray, B. (2016). Observational word learning: Beyond propose-but-verify and associative bean counting. *Journal of Memory and Language*, 87, 105–127. <https://doi.org/10.1016/j.jml.2015.09.005>
- Siskind, J. M. (1996). A computational study of cross-situational techniques for learning word-to-meaning mappings. *Cognition*, 61(1), 39–91. [https://doi.org/10.1016/S0010-0277\(96\)00728-7](https://doi.org/10.1016/S0010-0277(96)00728-7)
- Smith, L. B., Suanda, S. H., & Yu, C. (2014). The unrealized promise of infant statistical word-referent learning. *Trends in Cognitive Sciences*, 18(5), 251–258. <https://doi.org/10.1016/j.tics.2014.02.007>
- Smith, L. B., & Yu, C. (2008). Infants rapidly learn word-referent mappings via cross-situational statistics. *Cognition*, 106(3), 1558–1568. <https://doi.org/10.1016/j.cognition.2007.06.010>
- Sodian, B., Thoermer, C., & Metz, U. (2007). Now I see it but you don't: 14-month-olds can represent another person's visual perspective. *Developmental Science*, 10(2), 199–204. <https://doi.org/10.1111/j.1467-7687.2007.00580.x>
- Southgate, V., Chevallier, C., & Csibra, G. (2010). Seventeen-month-olds appeal to false beliefs to interpret others' referential communication. *Developmental Science*, 13(6), 907–912. <https://doi.org/10.1111/j.1467-7687.2009.00946.x>
- Sperber, D., & Wilson, D. (1986). *Relevance: Communication and cognition*. Harvard University Press.
- Stevens, J. S., Gleitman, L. R., Trueswell, J. C., & Yang, C. (2017). The pursuit of word meanings. *Cognitive Science*, 41(S4), 638–676. <https://doi.org/10.1111/cogs.12416>
- Suanda, S. H., Mugwanya, N., & Namy, L. L. (2014). Cross-situational statistical word learning in young children. *Journal of Experimental Child Psychology*, 126, 395–411. <https://doi.org/10.1016/j.jecp.2014.06.003>
- Swingle, D. (2007). Lexical exposure and word-form encoding in 1.5-year-olds. *Developmental Psychology*, 43(2), 454–464. <https://doi.org/10.1037/0012-1649.43.2.454>
- Swingle, D., & Aslin, R. N. (2000). Spoken word recognition and lexical representation in very young children. *Cognition*, 76(2), 147–166. [https://doi.org/10.1016/S0010-0277\(00\)00081-0](https://doi.org/10.1016/S0010-0277(00)00081-0)
- Thom, E. E., & Sandhofer, C. M. (2009). More is more: The relationship between vocabulary size and word extension. *Journal of Experimental Child Psychology*, 104(4), 466–473. <https://doi.org/10.1016/j.jecp.2009.07.004>
- Tincoff, R., & Jusczyk, P. W. (1999). Some beginnings of word comprehension in 6-month-olds. *Psychological Science*, 10(2), 172–175. <https://doi.org/10.1111/1467-9280.00127>

- Trice, K., Saratsli, D., Papafragou, A., & Qi, Z. (2025). The unforgettable “mel”: Pragmatic inferences affect how children acquire and remember word meanings. *Developmental Science*, 28(3), e70013. <https://doi.org/10.1111/desc.70013>
- Trueswell, J. C., Medina, T. N., Hafri, A., & Gleitman, L. R. (2013). Propose but verify: Fast mapping meets cross-situational word learning. *Cognitive Psychology*, 66(1), 126–156. <https://doi.org/10.1016/j.cogpsych.2012.10.001>
- Tsuji, S., Jincho, N., Mazuka, R., & Cristia, A. (2020). Communicative cues in the absence of a human interaction partner enhance 12-month-old infants’ word learning. *Journal of Experimental Child Psychology*, 191, 104740. <https://doi.org/10.1016/j.jecp.2019.104740>
- Twomey, K. E., Ranson, S. L., & Horst, J. S. (2014). That’s more like it: Multiple exemplars facilitate word learning. *Infant and Child Development*, 23(2), 105–122. <https://doi.org/10.1002/icd.1824>
- Vlach, H. A., & Johnson, S. P. (2013). Memory constraints on infants’ cross-situational statistical learning. *Cognition*, 127(3), 375–382. <https://doi.org/10.1016/j.cognition.2013.02.015>
- Vouloumanos, A., & Werker, J. F. (2009). Infants’ learning of novel words in a stochastic environment. *Developmental Psychology*, 45(6), 1611–1617. <https://doi.org/10.1037/a0016134>
- Vukatana, E., Graham, S. A., Curtin, S., & Zepeda, M. S. (2015). One is not enough: Multiple exemplars facilitate infants’ generalizations of novel properties. *Infancy*, 20(5), 548–575. <https://doi.org/10.1111/inf.12092>
- Werker, J. F., Cohen, L. B., Lloyd, V. L., Casasola, M., & Stager, C. L. (1998). Acquisition of word–object associations by 14-month-old infants. *Developmental Psychology*, 34(6), 1289–1309. <https://doi.org/10.1037/0012-1649.34.6.1289>
- Werker, J. F., & Yeung, H. H. (2005). Infant speech perception bootstraps word learning. *Trends in Cognitive Sciences*, 9(11), 519–527. <https://doi.org/10.1016/j.tics.2005.09.003>
- Wickham, H., François, R., Henry, L., Müller, K., & Vaughan, D. (2023). *dplyr: A grammar of data manipulation*. <https://CRAN.R-project.org/package=dplyr>
- Wilson, D., & Carston, R. (2007). A unitary approach to lexical pragmatics: Relevance, inference and ad hoc concepts. In N. Burton-Roberts (Ed.), *Pragmatics* (pp. 230–259). Palgrave Macmillan UK. https://doi.org/10.1057/978-1-349-73908-0_12
- Wilson, D., & Sperber, D. (2012). *Meaning and relevance*. Cambridge University Press.
- Woodard, K., Gleitman, L. R., & Trueswell, J. C. (2016). Two- and three-year-olds track a single meaning during word learning: Evidence for propose-but-verify. *Language Learning and Development*, 12(3), 252–261. <https://doi.org/10.1080/15475441.2016.1140581>
- Woodward, A. L., Markman, E. M., & Fitzsimmons, C. M. (1994). Rapid word learning in 13- and 18-month-olds. *Developmental Psychology*, 30(4), 553–566. <https://doi.org/10.1037/0012-1649.30.4.553>
- Yu, C., & Smith, L. B. (2007). Rapid word learning under uncertainty via cross-situational statistics. *Psychological Science*, 18(5), 414–420. <https://doi.org/10.1111/j.1467-9280.2007.01915.x>
- Yurovsky, D., & Frank, M. C. (2017). Beyond naïve cue combination: Saliency and social cues in early word learning. *Developmental Science*, 20(2), e12349. <https://doi.org/10.1111/desc.12349>
- Yurovsky, D., Fricker, D. C., Yu, C., & Smith, L. B. (2014). The role of partial knowledge in statistical word learning. *Psychonomic Bulletin & Review*, 21(1), 1–22. <https://doi.org/10.3758/s13423-013-0443-y>
- Yurovsky, D., Smith, L. B., & Yu, C. (2013). Statistical word learning at scale: The baby’s view is better. *Developmental Science*, 16(6), 959–966. <https://doi.org/10.1111/desc.12036>
- Zhang, Y., Amatuni, A., Cain, E., & Yu, C. (2020). Seeking meaning: Examining a cross-situational solution to learn action verbs using human simulation paradigm. *Proceedings of the Annual Meeting of the Cognitive Science Society*, 42, 2854–2860.
- Zhang, Y., Chen, C., & Yu, C. (2019). Mechanisms of cross-situational learning: Behavioral and computational evidence. *Advances in Child Development and Behavior*, 56, 37–63. <https://doi.org/10.1016/bs.acdb.2019.01.001>
- Zhang, Y., & Yu, C. (2016). Examining referential uncertainty in naturalistic contexts from the child’s view: Evidence from an eye-tracking study with infants. *Proceedings of the 38th Annual Conference of the Cognitive Science Society*, 38, 2027–2032.