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The what and the how: Information-seeking pointing gestures facilitate learning labels and functions

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ABSTRACT

Infants' pointing gestures are clear and salient markers of their interest. As a result, they afford infants with a targeted and precise way of eliciting information from others. The current study investigated whether, similar to older children's question asking, infants' pointing gestures are produced to obtain information. Specifically, in a single experimental study, we examined whether 18-month-olds ($N = 36$) point to request *specific types* of information and how this translates into learning across domains. We elicited pointing from infants in a context that would naturally lend itself to information seeking (i.e., out-of-reach novel objects). In response to infants' points, an experimenter provided a label, a function, or no information for each pointed-to object. We assessed infants' persistence after receiving different types of information and their subsequent ability to form label–object or function–object associations. When infants pointed and received no information or functions, they persisted significantly more often than when they pointed and received labels, suggesting that they were most satisfied with receiving labels for objects compared with functions or no information. Infants successfully mapped both labels and functions onto objects. When infants expressed their interest in a novel object in a manner other than pointing, such as reaching, they (a) were equally satisfied with receiving object labels, functions, or no information and (b) did not successfully learn either labels or functions. Together, these findings demonstrate that infants' pointing gestures are specific requests for labels that facilitate the acquisition of various types of information. In doing so, this work connects the research on information seeking

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during infancy to the established literature on question asking during childhood.

Introduction

Infants dive into language hands first. Months before they produce their first words, infants begin to communicate with their gestures. Recent evidence suggests that, similar to question asking in older children, infants' pointing gestures afford them with a way to request information from others (Begus & Southgate, 2012; Kovács, Tauzin, Téglás, Gergely, & Csibra, 2014). Compelling evidence for an informative-seeking, or interrogative, motive of pointing comes from experimental research demonstrating that infants are significantly more satisfied when individuals respond to their pointing gestures with new information (i.e., infants stop pointing after receiving a novel description for a known object) than when individuals do not respond with new information (i.e., infants continue pointing after receiving a familiar label of a known object) (Kovács et al., 2014). In addition, infants are more likely to point for individuals they know to be knowledgeable rather than ignorant (Begus & Southgate, 2012). Similarly, Masataka (2003) found that infants are significantly more likely to point in situations where they potentially might need information (e.g., in the presence of novel objects) than in situations where they would not need information (e.g., in the presence of familiar objects). Taken together, these findings demonstrate that infants' pointing gestures are modulated by both their desire for information and the potential of their communicative partner to provide that information, indicating that infants point interrogatively to request information. Despite the recent rise in attention to interrogative pointing, to date research has yet to examine whether infants have expectations about the kind of information their points will elicit. The current study set out to answer this question and, in doing so, to lay the groundwork for bridging the research on information seeking during infancy with the established literature on question asking during later development.

The development of information-seeking behaviors

The finding that infants point to obtain information is not surprising given that infants, from a very young age, demonstrate biases suggesting that they are highly motivated to acquire information (Csibra & Gergely, 2006; Morton & Johnson, 1991; Vouloumanos & Werker, 2004). For instance, by 8 months of age, infants tend to focus on and interact with objects that have the potential to be highly informative (e.g., objects that have previously violated their expectations) compared with other interesting, but less informative, objects (Kidd, Piantadosi, & Aslin, 2012; Stahl & Feigenson, 2015). However, it is not until infants begin pointing that they have a precise and targeted tool to *request* information from their caregivers.

The precision of the index finger allows infants to clearly highlight an object or referent of interest to their caregivers, making pointing a reliable and effective tool for gathering information. Indeed, observational research has documented that early in development (i.e., between 10 and 12 months) infants' points are typically translated and elaborated on by caregivers (Kishimoto, Shizawa, Yasuda, Hinobayashi, & Minami, 2007). For example, caregivers consistently respond to infants' points by contingently providing information for those objects (e.g., "It's a ball!"; Hannan, 1992; Leung & Rheingold, 1981; Wu & Gros-Louis, 2015). Importantly, caregivers are more likely to provide information in response to infants' pointing gestures compared with other communicative behaviors such as reaching and object-directed vocalizations (Kishimoto et al., 2007; Wu & Gros-Louis, 2015). Thus, caregivers' tailored responses to early pointing likely play a vital role in shaping infants' pointing gestures into explicit and unique requests for information, particularly throughout the first half of the second year of life (e.g., 12–18 months).

Do infants point to obtain specific types of information?

A critical question for understanding the nature of early information seeking is whether infants' requests for information are global nonspecific requests for information or whether infants already have expectations about the kind of information their pointing gestures will elicit. Two rich and meaningful sources of information that help infants to learn about the world around them are object labels and object functions (Bloom, 1998; Booth & Waxman, 2002; Gentner, 2003; Nelson, 1974). Learning the label for an object provides infants with a way to appropriately communicate about their environment, whereas learning the function of an object equips infants with a way to appropriately interact with their environment. Although labels and functions can serve distinct roles, they both are integral to how infants form representations of objects (Booth & Waxman, 2002; Keil, 1989; Piaget, 1952). For instance, infants routinely use both labels and functions to form categories of objects (Riggs, Mather, Hyde, & Simpson, 2015), individuate objects (Kingo & Krøjgaard, 2012; Xu, Cote, & Baker, 2005), and extend category membership to new objects (Childers & Tomasello, 2003; Riggs et al., 2015). By their first birthday, infants recognize that both labels and functions can be used in a decontextualized manner (Riggs et al., 2015; Schafer, 2005). In other words, infants know that labels and functions are not always tied to the specific objects they refer to or the specific contexts in which they were first introduced. However, to date there is currently no evidence that infants privilege certain types of information over others.

Despite the lack of research into the nature of information requesting during infancy, much research has been done on the analogous behavior during later development—question asking. Children ask a lot of questions, and many of these questions are specifically tailored to request information. One seminal article on question asking revealed that, on average, children ask 76 information-seeking questions per hour (Chouinard, 2007). Children's information-seeking questions typically take the form of "What is it?" In 2004, a study conducted by Kemler Nelson and colleagues found that although ambiguous in form, children's "What is it?" questions are aimed at eliciting the functions, rather than the labels, of objects (Kemler Nelson, Egan, & Holt, 2004). In other words, children ask fewer follow-up questions when they ask "What is it?" and are given a function, instead of a label, for an object—a signal that they were more concerned with learning the object's function than with learning its label.

An open question concerns the continuity of this specificity: When infants request information, are they also more satisfied with receiving functions, or are they more concerned with receiving labels, for objects? One way to gain insights into why children of different ages may request the same or different types of information is by examining what type of information children are typically given when they request information in naturalistic contexts. Observational research has documented that before children's second birthday, caregivers respond to their children's requests for information with labels more often than with functions (Chouinard, 2007). This is not surprising given that labels are particularly important for infants during their first 2 years of life; infants produce their first words around their first birthday and are able to proficiently and rapidly form word–object associations by 14 months (Bloom, 1973; Werker, Cohen, Lloyd, Casasola, & Stager, 1998). Just a few months later, at 18 months, infants experience a dramatic surge in the number of words they know, leading researchers to pinpoint this age as the hallmark for the "vocabulary burst" (Bloom, 1973; Nelson, 1973). It is plausible that caregivers' systematic responses to infants' pointing gestures with labels contribute to this rapid expansion in vocabulary. One possible and unintended consequence of these early bidirectional pointing-and-labeling experiences is that infants develop expectations that their pointing gestures will not only reliably elicit attention from caregivers but also reliably elicit labels. In this way, infants' pointing gestures may be shaped and narrowed into explicit requests for labels. After children's second birthday, caregivers appear to have a different strategy for responding to their children's bids for information, systematically providing functions over labels (Chouinard, 2007). It is possible that after their second birthday, when children have acquired many of the labels for the objects in their environment, infants transition from focusing on labels to seeking out additional and more conceptual information about those objects (Chouinard, 2007).

Pointing and learning

If infants point to request information, then their learning should be enhanced when they point. Research has shown that a desire to obtain information is related to an enhanced processing of that information (Gruber & Otten, 2010). In adults, research from cognitive neuroscience has shed some light on one mechanism by which a desire for information facilitates the subsequent learning of information. For example, Kang and colleagues (2009) found that when adults are highly motivated to acquire information, compared with when they are not as motivated to acquire information, they demonstrate (a) increased pupil dilation, a marker of increased cognitive effort and attention, (b) heightened activation in brain regions associated with reward anticipation and memory, and (c) better retention of that information both immediately and 2 weeks later.

Consistent with these findings, researchers have documented that infants are best equipped to learn an object's label (Lucca & Wilbourn, 2016) or function (Begus, Gliga, & Southgate, 2014) in the moment they point toward that object. For instance, Lucca and Wilbourn (2016) found that when infants express their interest in an object in a manner other than pointing, such as reaching, and object label information is presented, infants do not readily learn the label–object relation. Moreover, when infants point toward an object, but information is provided about a non-pointed-to object, they do not successfully learn the provided information (Begus et al., 2014; Lucca & Wilbourn, 2016). Because infants may have acquired an expectation that when they point toward objects, information about those objects is provided in response, this expectation may help explain why infants' pointing gestures reflect a heightened readiness to learn new information. Infants' ability to learn best in the moment they produce a pointing gesture has been argued to underlie the well-known and robust link between infants' early pointing gestures and early vocabulary development (Colonnesi, Stams, Koster, & Noom, 2010; Goldin-Meadow, 2007; Lucca & Wilbourn, 2016).

The current study

The current study provides the first test of what type of information 18-month-olds request when they point. Although research has documented the types of information older children request when they engage in information-seeking behaviors (e.g., question asking), research has yet to examine what types of information infants are motivated to receive when they *first* begin to request information by pointing. To explore this, we examined whether, when infants point, they are more satisfied (i.e., they stop pointing) after receiving certain types of information (i.e., functions vs. labels vs. no information at all). Given that caregivers systematically provide labels, as opposed to other types of information (Chouinard, 2007; Kishimoto et al., 2007), in response to infants' bids for information, we hypothesized that infants' pointing gestures would not be global requests for information but rather specific requests for labels.

Although it is clear that infants point to request information (Kovács et al., 2014; Southgate, van Maanen, & Csibra, 2007), it is unknown whether pointing is unique in this function. Thus, the second major goal of the current study was to test the unique role of pointing as an information-seeking behavior. To do so, we tested infants' satisfaction with various types of information if they did not first point (e.g., produce an alternative communicative behavior such as reaching) before receiving that information. To further test the hypothesis that infants' pointing gestures are unique requests for labels, we also assessed whether infants systematically produced speech-like vocalizations alongside their pointing gestures and nonpointing gestures. If pointing gestures, but not other communicative behaviors (e.g., reaching), are used to transmit additional linguistic information (i.e., request information [and labels in particular]), pointing gestures should be produced in combination with other forms of linguistic communication (e.g., speech-like vocalizations; Grünloh & Liszkowski, 2015; Leavens & Hopkins, 1998) significantly more often than with other communication attempts such as reaches.

A final aim of the current study was to replicate prior research, and provide additional evidence, that infants' pointing gestures reflect an optimal state for learning. Although issues pertaining to replication have garnered a great deal of attention recently in the scientific literature, and in the public sphere more broadly, psychologists (and developmental psychologists in particular) have been slow to integrate it into their research practices (Frank et al., 2017; Zwaan, Etz, Lucas, & Donnellan, 2017). Thus, in the current study, we sought to replicate two previous studies (Begus et al., 2014, and Lucca & Wilbourn, 2016) and to determine whether infants' pointing gestures are more likely to lead to successful learning of labels and functions when information is presented in response to their pointing gestures as opposed to when information is presented in response to other gestures (i.e., reaching) or no gestures at all. In doing so, we also directly compared infants' ability to learn functions and labels in response to their pointing gestures. We hypothesized that although infants may have an expectation that their pointing gestures elicit certain types of information from their caregivers, this should not limit their ability to learn different kinds of information. Thus, we predicted that infants would successfully learn both functions and labels for objects that they had first pointed toward.

Method

Participants

The current research was conducted following American Psychological Association ethical standards with approval from the institutional review board at Duke University. Participants were recruited from public birth records in the southeastern United States. The final sample consisted of 36 full-term, healthy, 18-month-old infants (18 girls; M_{age} = 18.15 months, SD = .22, range = 17.60–18.45). Data were collected between April and October 2016. The sample was composed of monolingual English-speaking infants from predominantly middle-class households (70% White, 9% biracial, 6% African American, and 15% not reporting). Data from an additional 4 infants were excluded because they refused to participate (n = 2) or there was equipment failure (n = 2).

Materials, stimuli, and apparatus

Caregivers completed consent, the MacArthur Communicative Development Inventory (MCDI; Fenson et al., 1994), and a demographic survey. After completing these forms, participants and their caregivers were taken into a 3.7 by 2.6-m testing room (Fig. 1A). High-definition cameras placed at two different angles captured the entire scene. Infants were seated at a small table (60 × 60 cm) across from the experimenter. A bookshelf (71 × 36 × 91 cm) was positioned directly behind the experimenter. Two remote-operated flashing lights were placed on each side of the bookshelf.

During the task, infants were presented with nine pairs of toy-like novel objects (Fig. 1B). These objects were rated for equal attractiveness by an independent sample of 10 adults. Before participating, parents confirmed that their infants had no preexisting labels for or previous experience with any of these objects. During the experiment, the objects were given a nonsense label (i.e., *blicket*, *modi*, or *toma*), a novel function (i.e., head tap, arm scratch, or slide a piece of paper), or no information. Nonsense labels were selected from a novel noun/novel label database (Horst & Hout, 2015). These labels are phonotactically similar to English words and are frequently used in word learning studies (Soja,

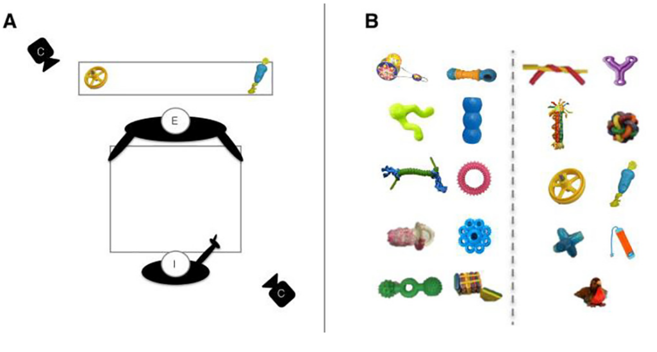


Fig. 1. (A) Experimental setup. (B) Pairs of stimuli and plush toy, "Sam," used in experiment.

Carey, & Spelke, 1991). Novel functions were also selected based on their frequent use in previous word learning studies (e.g., Childers & Tomasello, 2002) and pilot data confirming that infants could easily perform them.

Procedure

In the testing room, parents sat beside their infants and were instructed to remain completely neutral and to not interfere with their infants' behavior in any way. There was a brief warm-up phase before each experiment began, lasting approximately 2.5 min, to acclimate the infant to the room and experimenter. During the warm-up, the experimenter and infant played with a wooden latch-board puzzle. The experimenter introduced a stuffed animal (bird) named "Sam" to play the "game" with the infant.

The experimental session was divided into four phases: familiarization, choice, training, and test (Fig. 2). The four phases were repeated nine times so that each infant had the potential to provide data across 9 trials. A total of 38 trials were excluded because infants were fussy and/or unwilling to participate. The experiment lasted approximately 20 min per participant.

Familiarization phase

Infants were presented with two novel objects, one at a time, and allowed to play with each object for approximately 18 s. This was done to ensure that infants explored each object, visually and physically, before being asked to select one.

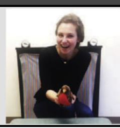
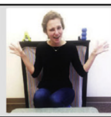
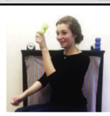
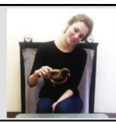
PHASE	EXPERIMENTAL ACTIVITY		SCRIPT	
1) WARM UP (60s)	Infant introduced to puppet		"Meet Sam!"	
2) FAMILIARIZATION (60s)	Infant explores novel objects.		"Wow! Look at this! See! Wow!"	
2) **CHOICE** (12s)	Infant prompted to point to an object		"Wow! Point to one of these! Which one?"	
3) **TRAINING** (20s)	Experimenter teaches infant about object		*Label Trial*	" It's a */label/!*"(x6)
			Function Trial	"It goes like this! */action*
			No Info Trial	"Wow! Look at this!" (x6)
4) **DISTRACTOR** (10s)	Puppet flies across table		"Look, it's Sam! Wow! */child's name/,* look!"	
5) **TEST** (13s)	Preferential looking paradigm tests memory of information		*Label Trial*	"Find the */label/!*" (x4)
			Function Trial	"Find the one that goes like this! */action/*" (x4)

Fig. 2. Experimental procedure.

Choice phase

After removing the objects from the familiarization phase, the experimenter reintroduced both objects, placing them on the shelf directly behind her (Fig. 1). The experimenter used a remote control to turn on a set of flashing lights that were positioned on each side of the shelf, directly behind where each toy was placed. To encourage infants to choose one of the objects, the experimenter prompted, "Wow! See these! Point to one of these! Which one?" while maintaining eye contact with infants. Once infants clearly chose an object, by either pointing or reaching toward the object, the experimenter initiated the training phase with the selected object (hereafter *target object*). On average, it took infants 8 s to choose an object. The nonselected object (hereafter *nontarget object*) remained on the shelf in infants' view. If infants did not produce a manual gesture toward an object after 10 s, the experimenter initiated the training phase with the object that infants looked toward for the majority of the 10-s period. All videos were recoded offline to establish interrater reliability on infants' choice of object. Any trial in which there was disagreement about infants' choice of object (i.e., the experimenter misinterpreted infants' choice of object during the task or infants did not clearly establish interest in one of the two objects) was excluded from the analyses ($n = 6$ of 286).

Training phase

The training phase lasted approximately 10 s and consisted of three trial types: Label, Function, and No Information. Participants were exposed to all three trial types. The experimenter initiated the training phase only once infants were fully attentive to both the experimenter and target object.

During Label trials, the experimenter taught infants the target object's label (e.g., "This is a blicket! See the blicket! Look, it's a blicket! Look at this blicket!"). During Function trials, the experimenter taught infants the target object's function (e.g., "It goes like this [head tap]! See [head tap]! Look what it does [head tap]! Wow [head tap]!"). During No Information trials, the experimenter acknowledged infants' interest in the target object (e.g., "Oh wow! See this one! You like this one, huh? Yeah! See this one!") but did not provide any information about the object. Across all conditions, the experimenter held the target object while engaging in joint attention with children, using the same type of enthusiastic child-directed speech. This was to ensure that regardless of the type of information being given or how infants initially referenced the target object (i.e., by pointing or not), they were equally attentive during training. As soon as the experimenter finished the training phase, she used a remote control to turn off the flashing lights on the bookshelf behind her.

Each participant received each trial type three times in a three-block design. Trial type order within each block was counterbalanced (e.g., Function–Label–No Information, Label–No Information–Function, No Information–Label–Function). In No Information trials, the experimenter did not proceed to the test phase because there was no information for infants to be tested on. Rather, the experimenter ended the trial immediately after training by putting the target and nontarget objects away and initiating a new trial with a new set of objects.

Test phase

After putting away the target and distractor objects from the training phase, the experimenter presented a 12-s distraction by flying Sam, the bird from the warm-up, across the table, allowing infants to pet Sam, prompting, "Wow! Here's Sam! Do you want to play with Sam? Ooo! Would you like to pet Sam? Look!" Following this distraction, infants were tested on their ability to map the target label or function onto the target object (following the methodology of Lucca & Wilbourn, 2016). The experimenter placed the target and distractor objects on each side of the table directly in front of her, with Sam placed in the middle. During Function trials, the experimenter prompted, "Wow, see these! Which one goes like this [head tap]? Like this [head tap]? Where is the one that goes like this [head tap]? Like this [head tap]?" using Sam to perform the function's movement. During Label trials, the experimenter prompted, "Wow, see these! Which one is the blicket? The blicket? Where is the blicket? The blicket?" To equate Label and Function trials, the experimenter bounced Sam each time she said the target label. The experimenter ended the test phase by putting Sam, the target object, and distractor objects away and initiated a new trial with a new set of novel objects.

Coding

We coded three categories of infants' behavior during the experiment: (a) the type of initial communicative behavior infants produced during the choice phase, (b) the type and frequency of additional communicative behaviors they produced during training, and (c) the amount of time spent looking toward the target and nontarget objects during the test phase.

Initial communicative behavior

The initial communicative behavior that infants produced during the choice phase, in response to the experimenter's prompt, "Point to one of these!" was coded as either a point, a reach, or a look (based on Lucca & Wilbourn, 2016, and Matthews, Behne, Lieven, & Tomasello, 2012). Behaviors were coded as a *point* if infants extended both their arm and index finger toward the target object, as a *reach* if infants extended all fingers in an open hand toward the target object or extended their body toward the target object with all fingers extended, or as a *look* if infants looked toward the object but did not produce a manual gesture. See Table 1.

We also coded whether infants paired their initial communicative behavior with a vocalization. Based on previous research (Grünloh & Liszkowski, 2015; Snow, 2004), infants' vocalizations were coded as either speech-like or non-speech-like. Vocalizations were classified as speech-like if they resembled adult-like phonetics with vowel and syllabic consonants (e.g., *baba, wa, ga*). Vocalizations were classified as non-speech-like if they followed no speech-like transcriptions or were single long vowels (e.g., comfort sounds).

One fifth (20%) of videos were recoded offline to establish high interrater reliability on infants' type of initial communicative behavior (point, reach, or look: Cohen's kappa = .85) (Landis & Koch, 1977) and type of vocalization (speech-like or non-speech-like: Cohen's kappa = .80).

Persistence during the training phase

The type and frequency of behaviors that infants produced during the 10-s training phase (i.e., directly following the onset of training) were coded. The types of communicative behaviors (hereafter *persistence behaviors*) were coded as points, reaches, vocalizations, or table hits. As in prior research, these behaviors were chosen as persistence behaviors because they represent infants' dissatisfaction with the experimenter's response to their initial communicative behavior (Golinkoff, 1986; Liszkowski, Carpenter, Henning, Striano, & Tomasello, 2004). One fifth (20%) of videos were recoded offline to establish excellent interrater reliability on the frequency of infants' persistence behaviors (intraclass correlation = .91; Bartko, 1966).

Looking time during the test phase

Infants' visual fixation during test, in which the experimenter prompted infants to look toward the target object, was coded offline using DataVyu (http://www.datavyu.org). At each 33-ms block of time, coders identified whether infants were fixated on the target object, on the distractor object, on the experimenter, or elsewhere. Interrater reliability was high (intraclass correlation = .88). Any block of

Table 1
Coding of infants' communicative behaviors during the choice phase.

Communicative behavior	Description
Point	Infants extended their arm and finger toward an object of interest while maintaining an upright posture (i.e., infants did not learn toward the object)
Reach	Infants extended their arms and fingers toward an object of interest while leaning their entire body forward as if attempting to grab the object, often accompanied by a grasping motion of the hand
Look	Infants did not produce a manual gesture. Interest in object was defined as the object infants looked at longer. If infants did not clearly fixate their attention on one object, the target object was defined as the object infants looked at first

time in which infants were not attending to one of the two novel objects was excluded from the analyses.

For the purpose of analysis, we divided the test phase into two portions: a pre-information (baseline) period and a post-information period (Mather & Plunkett, 2012). The pre-information period consisted of the first 5 s of the test phase before the experimenter presented the target information. During this time, infants could freely look at the target and distractor objects while the experimenter prompted, "Wow, see these! Which one is the . . .?" As in prior word learning studies (e.g., Yurovsky, Hidaka, Yu, & Smith, 2010), the post-information period consisted of the last 8 s of the test phase, immediately following the onset of the target information, in which the experimenter prompted, ". . . blicket! The blicket? Where is the blicket? The blicket?" (Label trials) or ". . . [head tap]? Like this [head tap]? Where is the one that goes like this [head tap]? Like this [head tap]?" (Function trials).

We calculated the proportion of time infants spent looking at the target object, compared with the distractor object, during both the pre- and post-information periods of the test phase. We then calculated a difference score for each participant by subtracting the proportion of time the infant spent looking at the target object, compared with the distractor object, during the post-information period from the proportion of time the infant spent looking at the target object, compared with the distractor object, during the baseline period. Consistent with prior research (Shukla, White, & Aslin, 2011), successful fast mapping was operationalized as a significant increase in looking toward the target object during the post-information period relative to the pre-information period. This method ensures that infants' looking toward the target object during the test phase was not a result of selective interest in the target object but rather due to infants' association of the object with its respective label or function (Reznick & Goldfield, 1992).

Results

All analyses were performed in the R statistical programming package (R Development Core and Team, 2014) using the functions chisq.test, cor.test, aov, wilcox.test, shapiro.test, glmer, and lmer of the package lme4 (Bates & Maechler, 2010). Shapiro–Wilk tests were used prior to each analysis to test for normality. When normality assumptions were violated, nonparametric tests were used.

Which communicative behaviors did infants produce during the choice phase?

During the choice phase, in response to the experimenter's prompt, "Point to one of these," infants pointed ($n = 75$), reached ($n = 47$), or looked ($n = 158$) toward the desired object (Table 2). The majority of infants ($n = 24$, 67%) did not produce the same communicative behavior across all 9 trials (e.g., switched from pointing to looking).

There were seven types of behavioral combinations ("gesture profiles") infants could have made across the 9 trials: point only (8% of infants), look only (25%), reach only (0%), point + reach (11%), point + look (19%), reach + look (14%), and point + reach + look (22%) (Fig. 3).

Do infants point to receive certain types of information?

Co-occurrence of gestures and vocalizations

During training, infants paired their communicative behaviors (i.e., point, reach, or look) with one of three types of vocalizations: (a) speech-like vocalizations (40% of trials), (b) non-speech-like vocalizations (14%), or (c) no vocalizations (46%). Of interest was whether speech-like vocalizations were

Table 2
Proportion of trials ($N = 280$) in which each communicative behavior was produced.

Communicative behavior	% Trials
Point	27
Reach	17
Look	56

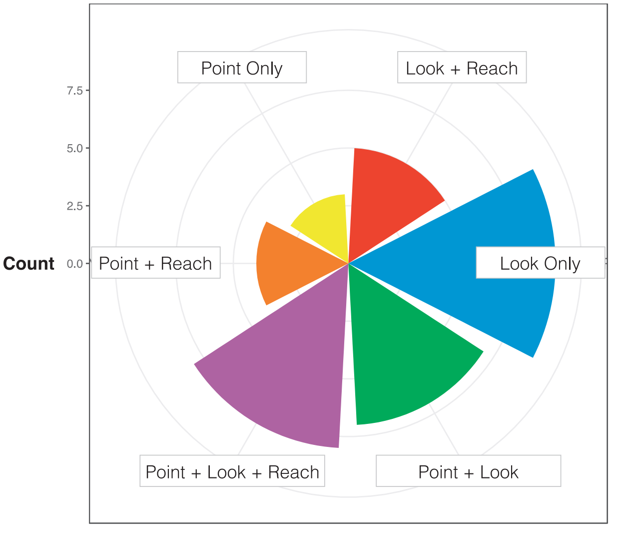


Fig. 3. Number of infants (represented by triangle area size) producing each gesture profile.

more likely to occur during pointing trials (i.e., trials in which infants produced a pointing gesture during the choice phase) or nonpointing trials (i.e., trials in which infants did not point). A chi-square test revealed that the percentage of trials produced with a speech-like vocalization differed significantly based on whether infants had also pointed, $\chi^2(1) = 13.83$, $p = .0002$. Pointing trials were paired with speech-like vocalizations 59% of the time, whereas nonpointing trials were paired with speech-like vocalizations only 33% of the time (Fig. 4).

Communicative persistence during training

The next set of analyses tested whether infants persisted in their communicative attempts (i.e., produced additional communicative behaviors) during the training phase. Specifically, we tested whether infants' persistence varied as a function of (a) the initial communicative behavior they produced during the corresponding choice phase of that trial (point, reach, or look) and (b) the type of information (function, label, or no information) they were given in response. The count data were analyzed by fitting a generalized linear mixed-effects model with a Poisson distribution function. The dependent variable in this model was the number of persistence behaviors produced during the training phase. Fixed effect predictors included infants' initial communicative behavior during the choice phase (point vs. reach vs. look), information type (function vs. label vs. no information), interaction between initial communicative behavior and information type, and sex. Infants' ID was included in the model as a random effect to account for repeated observations of infants across the 9 trials. We controlled for infants' preexisting vocabulary size and fatigue in later trials by including productive MCDI scores and trial number (1–9) in the model.

A significant interaction between initial communicative behavior and information type emerged. The effect of infants' initial communicative behavior on persistence behaviors produced varied as a function of the type of information infants received during training ($Z = -2.31$, $p = .02$) (Fig. 5). Trial number was also a significant predictor of persistence; infants were more likely to persist in later trials compared with earlier trials ($Z = 3.88$, $p = .0001$). Thus, trial number was included as a covariate in all subsequent analyses. No main effects of sex or MCDI scores emerged ($p > .05$). The model including trial number and the interaction of information type and communicative behavior as a predictor fit substantially better than the model without these terms [likelihood ratio tests, $\chi^2(9) = 38.42$, $p < .0001$]. The model did not improve in fit when sex and MCDI scores were included [likelihood ratio tests, $\chi^2(2) = 1.98$, $p > .05$). As a result, these predictors were removed from subsequent analyses. To

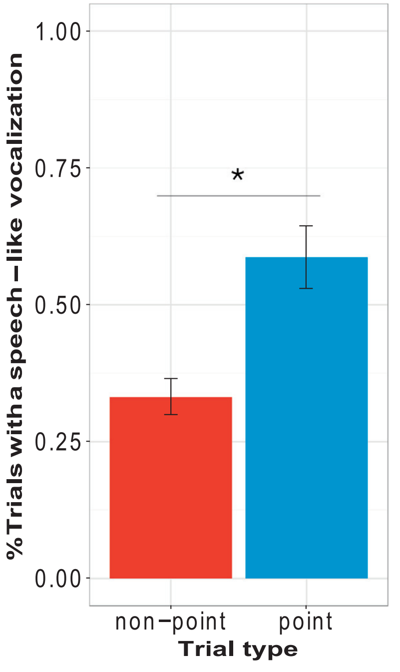


Fig. 4. Choice phase behaviors. Proportions of trials paired with a speech-like vocalization based on whether infants had also pointed or not are shown *$p < .05$.

probe the interaction between communicative behavior and information type, the next sets of analyses tested the influence of information type on persistence within each type of initial communicative behavior that was produced.

During *point* trials, there was a significant main effect of information type, such that infants were significantly more likely to persist in No Information trials (mean number of persistence behaviors = 2.89, $SE = 0.30$, $Z = 3.34$, $p = .0008$) and Function trials ($M = 2.77$, $SE = 0.63$, $Z = 3.03$, $p = .002$) compared with Label trials ($M = 1.50$, $SE = 0.49$) (see Fig. 5B). There was no significant difference in persistence during Function trials compared with No Information trials ($p > .05$). During *reach* trials, there was no significant main effect of information type, such that infants did not differ in their likelihood of persisting as a function of the type of information given ($M_{no\text{-}info} = 2.92$, $SE = 0.54$, $M_{function} = 1.64$, $SE = 0.28$, $M_{label} = 2.05$, $SE = 0.31$, all *ps* > .05) (Fig. 5C). Similarly, during *look* trials, there was no significant main effect of information type ($M_{no\text{-}info} = 1.48$, $SE = 0.19$, $M_{function} = 1.53$, $SE = 0.21$, $M_{label} = 1.55$, $SE = 0.23$, all *ps* > .05) (Fig. 5A). Thus, it is only when infants pointed toward an object that the presentation of different types of information led to differential persistence.

Although the order in which infants received different types of information was counterbalanced across infants, one possible interpretation of the findings is that across the experiment infants may have formed contingencies between their pointing gestures and labels provided by the experimenter. Thus, we examined infants' behavior on the very first trial of the experiment. On infants' first trial, if they had spontaneously pointed and then received *no information,* they produced an additional 4.25 behaviors on average. If infants did *not* first point on their first trial and received no information, they produced an additional 0.58 behaviors on average.

As described in Method, we included four different types of behaviors as persistence behaviors. Infants produced vocalizations most frequently ($n = 285$ instances), followed by pointing gestures ($n = 98$), reaching gestures ($n = 91$), and table hits ($n = 47$). Infants were more likely to vocalize after receiving functions ($n = 100$) or no information ($n = 109$) compared with after receiving labels

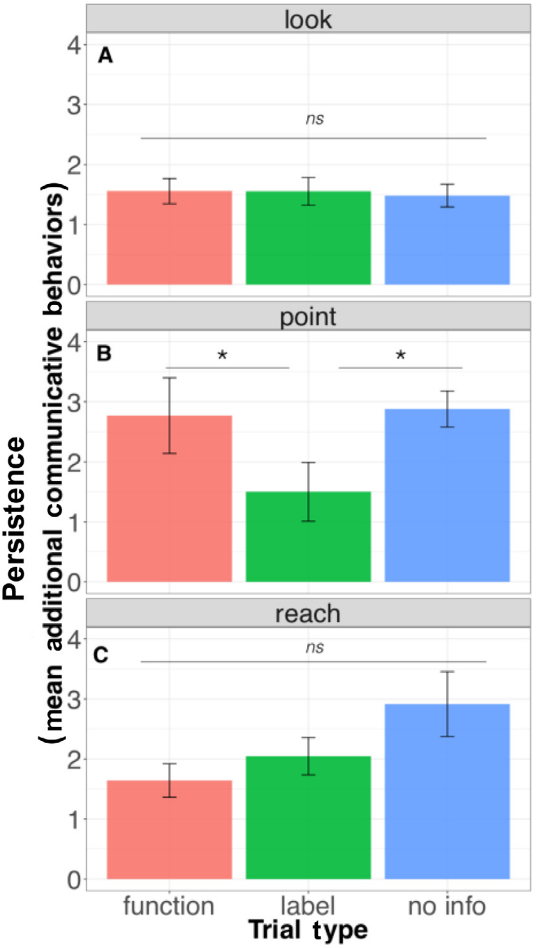


Fig. 5. Persistence results. Mean numbers of additional communicative behaviors infants produced during the training phase of each trial type as a function of the initial communicative behavior they produced toward the target object during the choice phase are shown: look (A), point (B), and reach (C). Error bars represent standard errors.

(n = 76). Patterns of table hitting, pointing, and reaching did not differ as a function of information type or initial communicative behavior.

How did infants perform during the test phase?

Pre-information phase (baseline)

Infants' proportion of looking toward the target object *prior* to the onset of the label or function was calculated by dividing the total amount of time spent looking at the target object by the total amount of time spent looking at both the target and nontarget objects. Tests against chance (.50) revealed that during point trials infants looked at the target object at rates marginally below chance (mean proportion of target looks = .38, SE = .04, W = 146, p = .04) (Fig. 6). During look and reach trials (i.e., nonpoint trials), infants also tended to look at the target object less than the distractor object, but these values did not differ significantly from chance (M_{look} = .46, SE = .03, M_{reach} = .47, SE = .05, all ps > .05) (Fig. 6). Infants' initial bias for looking at the nontarget object is not surprising. During the training phase, infants were directed to look *only* at the target object. Thus, when the target and nontarget objects reappeared during the test phase, the nontarget object may have been more novel to infants, leading them to look at it first and longer.

Post-information phase

To determine whether pointing reflects a readiness to learn, the next sets of analyses were conducted controlling for infants' baseline preferences for the distractor object and tested whether infants successfully mapped the target information onto the target object during the portion of the test phase *after* the onset of the target information. To adjust for infants' baseline preferences, we analyzed whether infants significantly increased their looking toward the target object during this portion of the test phase relative to the pre-information portion of the test phase.

A Shapiro–Wilk test revealed that infants' looking time did not follow a normal distribution ($W = 0.91$, $p < .0001$). Infants' looking time followed a bimodal distribution (i.e., infants tended to look either only at the target object or only at the nontarget object). Thus, as in prior research (Goldin-Meadow, Shield, Lenzen, Herzig, & Padden, 2012; Novack, Congdon, Hemani-Lopez, & Goldin-Meadow, 2014; Wakefield & James, 2015), for purpose of analysis we recoded infants' looking time into a binary value: target looking (i.e., proportion of target looking greater than .50) or nontarget looking (i.e., proportion of target looking less than .50).

We ran generalized linear mixed models with infants' target looking (yes vs. no) as the dependent variable. Our key fixed effect was test phase portion (pre-information vs. post-information period). Sex, productive MCDI scores, information type (function vs. label), and trial number (1–9) were also included as fixed effects in the model. Infants' ID was included in the model as a random effect to

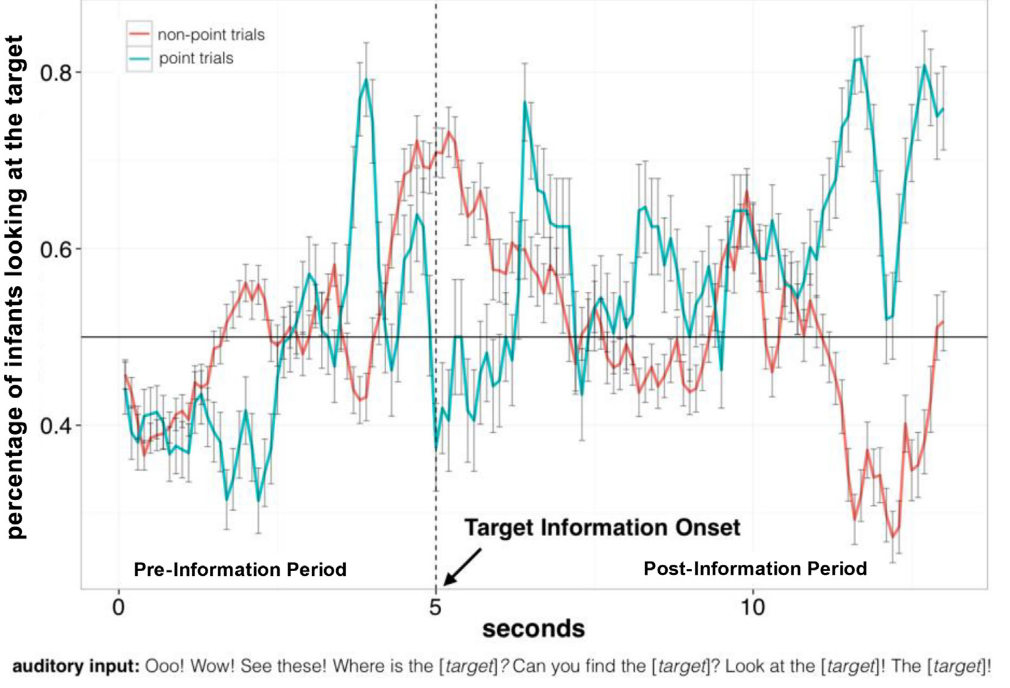


Fig. 6. Time course of infants' looking toward the target object during the pre-information period (i.e., the first 5 s) and the post-information period (i.e., the last 8 s) based on whether infants had pointed (blue line) or not (red line) during the choice phase. Values greater than .50 signify a preference for the target object, whereas values less than .50 signify a preference for the nontarget object. For the purpose of visualization, nonpoint trials (i.e., reach and look) have been collapsed. Groups were analyzed separately. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

control for repeated observations of infants across the 9 trials. Three models were run, one for each communicative behavior infants produced during the choice phase (point, reach, and look).

During *point* trials, there was a significant main effect of test phase, such that infants significantly increased their looking toward the target object during the post-information period of the test phase compared with the pre-information period (i.e., mean increase in proportion of looks to the target object = .17, *SE* = .08, $Z = -2.07$, $p = .04$) (Fig. 7). There were no main effects of sex, MCDI scores, information type, or trial number (all *ps* > .05). The model including the effect of test phase fit substantially better than the model without this term [likelihood ratio test, $\chi^2(1) = 4.46$, $p = .03$]. During *reach* trials, there was not a significant main effect of test phase, such that infants did not make significant increases toward the target object during the post-information period of the test phase compared with the pre-information period ($M = .05$, $SE = .11$, $Z = -0.88$, $p = .38$) (Fig. 7). There were also no main effects of sex, information type, trial number, or MCDI scores (all *ps* > .05). During *look* trials, there was again not a significant main effect of test phase, such that infants did not significantly increase their looking toward the target object during the post-information period of the test phase relative to the pre-information period ($M = .04$, $SE = .06$, $Z = -0.18$, $p = .85$) (Fig. 7). There was a main effect of trial number, such that infants looked longer at the target object during later trials compared with earlier trials ($Z = 2.34$, $p = .02$). There were no main effects of sex, information type, or MCDI scores (all *ps* > .05). Together, these findings confirm that infants look significantly longer to the target object when prompted to during point trials, but not during reach or look trials.

What is the relation between communicative persistence and learning?

The final analysis tested whether infants' persistence behaviors during the training phase were related to their ability to map information onto objects during the corresponding test phase of that trial. To do so, we ran a linear mixed model with infants' test phase performance (i.e., their difference score, the proportion of time looking toward the target object during the pre-information period subtracted from the proportion of looking time toward the target object during the post-information period) as the dependent variable. Fixed effect predictors included infants' initial communicative behavior during the choice phase (point vs. reach vs. look), information type (function vs. label vs. no information), number of persistence behaviors produced during the training phase, and interaction

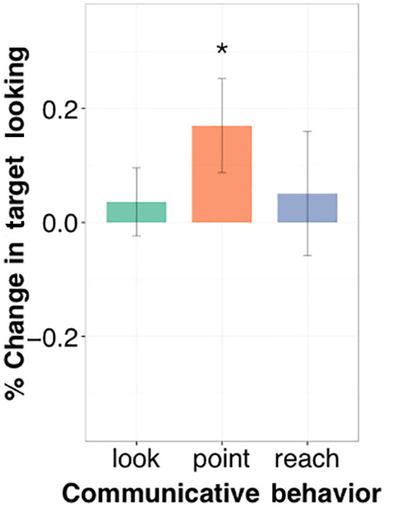


Fig. 7. Test performance results based on whether infants had first looked, pointed, or reached toward the target object during the choice phase. Values greater than zero indicate an increase in looking to the target object during the post-information period of the test phase relative to baseline looking * $p < .05$.

among these three variables. This allowed us to test whether infants' persistence affected learning only during certain trial types or only if infants had pointed before receiving information or not. Sex was also included as a fixed effect predictor. Infants' ID was included in the model as a random effect to account for repeated observations of infants across the 9 trials. We controlled for infants' preexisting vocabulary size and fatigue in later trials by including productive MCDI scores and trial number (1–9) in the model.

No significant interactions or main effects emerged. The only marginal main effect to emerge was of MCDI scores, such that infants with higher MCDI scores also had slightly higher difference scores, $t(118) = 1.98$, $p = .05$.

Individual differences in pointing and learning

The positive relation between infants' preexisting vocabulary sizes and fast mapping scores suggests that one possible explanation for the current findings is that infants who pointed more frequently in our task are simply better learners because they potentially have more advanced communicative skills than infants who never pointed. Thus, it might not be pointing per se that drove the current results but rather the fast mapping skills that infants came to the task with. To test whether learning is driven by individual differences in fast mapping abilities, as opposed to an expectation for information (reflected in the act of pointing), we subset our data to include only infants who switched from pointing to nonpointing during our task. If infants with higher vocabularies point more often, and are in general better learners, then we would expect these infants to successfully learn regardless of whether they pointed in a given trial or not. This was not the case; infants had higher difference scores on trials in which they pointed ($M = .26$, $SE = .13$) compared with trials in which *those same infants* did not point ($M = .08$, $SE = .09$) (see Fig. 8). Although this effect was not statistically significant ($p > .05$), because our power was substantially reduced to include only infants who switched from pointing to not pointing (see Fig. 3), these findings suggest that it is the act of pointing, as opposed to individual differences in fast mapping abilities, that drove the current results.

Discussion

The findings from the current study provide the first evidence that, by 18 months of age, infants produce pointing gestures to obtain labels for pointed-to objects. These findings document an important developmental shift in information-seeking behaviors, namely that older children are most

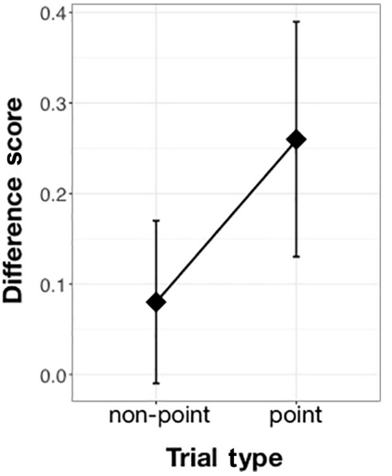


Fig. 8. Individual differences in fast mapping scores as a function of whether infants pointed in a given trial or not.

concerned with receiving functions for objects when they request information about them (Kemler Nelson et al., 2004), whereas earlier in development infants are more focused on receiving labels. In the current study, when infants pointed toward an object and an experimenter responded with labels, infants did not persist in their communicative attempts (i.e., they ceased communicating), indicating that they were satisfied with this information (Kovács et al., 2014; Liszkowski et al., 2004). However, when an experimenter responded to infants' pointing gestures with functions or no information, infants persisted in their communicative attempts, producing additional communicative behaviors (e.g., vocalizations, pointing gestures), suggesting that they were not satisfied with the provided information. Importantly, when infants first reached or looked toward an object of interest, they did not demonstrate the same differential persistence depending on the type of information they received. Instead, infants appeared to be equally satisfied with receiving the object's function, label, or no information. Thus, the current findings reveal that infants' pointing gestures are unique in their information-requesting function.

A second major finding from the current study is that infants' pointing gestures reflect an overall readiness to learn new information across domains. When infants pointed toward an object of interest and received information about that object, they learned that information—regardless of whether the information presented was a label or a function. This was not the case when infants produced other behaviors toward objects (e.g., reaching). If infants did not spontaneously point prior to receiving information, they failed to provide evidence of successfully mapping labels or functions onto objects. Taken together, the current findings extend prior research by demonstrating that infants can successfully learn *both* label information (Lucca & Wilbourn, 2016) and function information (Begus et al., 2014) more readily when they point toward a referent than when they reach or look toward a referent.

Interestingly, infants' communicative persistence was not related to their ability to learn labels and functions. The nonsignificant relation between infants' communicative persistence and learning indicates that even when infants received a type of information they were not explicitly requesting (i.e., a function), they were still able to successfully learn that information. Ultimately, the finding that infants were open and receptive to information in contrast to their expectations underscores the strength of infants' pointing gestures as a potent learning mechanism.

The uniqueness of this pointing–learning relationship is also highlighted by the finding that when infants pointed toward an object, they were significantly more likely to coarticulate speech-like vocalizations as opposed to other types of vocalizations (e.g., grunts). Again, this was not the case when infants either reached or looked toward an object, suggesting that infants' pointing gestures may have been deployed with a more linguistic objective (e.g., to obtain labels). This finding is in line with previous research demonstrating that infants pair speech-like vocalizations with pointing gestures more often when engaging in cooperative communicative exchanges with others (e.g., in informative contexts: "See that!") than in contexts in which infants are using adults as a tool to get their needs met (e.g., in requestive contexts, "I want that!"; Liszkowski et al., 2015).

Taken together, these findings provide compelling evidence to suggest that infants' pointing gestures are directly and uniquely related to their ability to map information onto objects. Given that fast mapping is a critical skill underlying early word learning (Carey, 2010; Woodward, Markman, & Fitzsimmons, 1994), these studies help to explain how pointing gestures work to shape infants' early vocabulary and cognitive development. These findings also provide new insights into why infants may be motivated to produce pointing gestures. In addition to many other functions, infants' pointing gestures may also serve as a unique way for them to request information about objects, and labels in particular, from their caregivers.

Information seeking as a driver of cognitive development

Infants' inclination to explicitly request information is not surprising. Decades of research have shown that infants, from a very early age, demonstrate biases that suggest a motivation to acquire information (Csibra & Gergely, 2006; Morton & Johnson, 1991; Vouloumanos & Werker, 2004). For instance, by 8 months of age, infants tend to focus on and interact with stimuli that have the potential for the most information gain (e.g., objects that have previously violated their expectations, objects that are not too simple or too complex) compared with other interesting stimuli (Kidd et al., 2012; Stahl & Feigenson, 2015). Because objects that are not overly simple or overly complex, and objects that are not in line with infants' existing knowledge structures, are ideally suited to learn from, these biases strongly suggest that infants allocate their attention in ways that maximize their potential for information gain. By the end of the first year of life, infants acquire the understanding that human adults are particularly vital and abundant sources of information (Homer & Tamis-Lemonda, 2013; Vaish, Demir, & Baldwin, 2011). This understanding is quite sophisticated; infants have an expectation that speakers of their native language are more likely to provide them with information than speakers of a foreign language (Begus, Gliga, & Southgate, 2016). Although these biases may help infants attend to informative sources in their environment, it is not until they point that they can explicitly *request* information from their caregivers.

Children's motivation to request information has long been regarded as a key driving force of cognitive development and the acquisition of culture (Davis, 1932; Gopnik & Meltzoff, 1997; Piaget, 1926). However, much of the research on information requesting has been focused on older children in the form of question asking (Chouinard, 2007). This research has centered on the types of questions children ask, when they ask them, and the types of responses they receive (Frazier, Gelman, & Wellman, 2009; Gelman, 2009; Kemler Nelson et al., 2004; Ronfard, Zambrana, Hermansen, & Kelemen, 2018). Young children's questions about objects tend to be focused on understanding the functions of those objects or what they do (Asher & Kemler Nelson, 2008; Kemler Nelson, Frankenfield, Morris, & Blair, 2000). Here, we demonstrate that early in development infants' information requesting is focused on obtaining labels rather than functions.

Although these contrasting findings have emerged from different methodologies, thereby limiting our ability to make direct comparisons, they nonetheless suggest that there may be important developmental differences in the types of information infants and young children request. These developmental differences directly map onto children's cognitive and linguistic development. At 18 months of age, infants are entering the "vocabulary burst" and are rapidly adding new labels to their vocabulary (Bloom, 1973; Nelson, 1973). Thus, it is not surprising that they would prefer to receive labels over other types of information. Older children, alternatively, already know many labels and may be transitioning to seeking out additional supplementary information about objects.

Importantly, the current findings directly correspond with how caregivers respond to their children's requests for information at different points in development (Chouinard, 2007). Before children's second birthday, caregivers tend to respond to information requests with labels more often than functions. After children's second birthday, caregivers switch strategies and respond with functions more often than labels. A question for future research is to disentangle why these developmental patterns exist. Are infants' requests for information specific to labels because that is the type of information they are accustomed to receiving when they request information, or are parents attuned to the types of requests their infants are making and tailoring their responses to fulfill those requests? More research, especially with participants outside of Western educated industrialized rich democratic (WEIRD) societies, is needed to answer this question (Henrich, Heine, & Norenzayan, 2010). Indeed, despite its prevalence in Western societies, the reliance on pointing with an index finger pointing during adulthood is not universal (Cooperrider, Slotta, & Núñez, 2018). Revealing how infants and adults from more diverse groups use and respond to different types of pointing (e.g., chin pointing) may help to elucidate which factors drive early pointing.

Another way in which future research might provide insights into the mechanisms that drive early pointing is by examining infants' pointing gestures in more naturalistic contexts such as those in which infants' pointing gestures are spontaneously produced as opposed to experimentally elicited. In the current study, infants were instructed by an experimenter to point, leaving open questions about whether this same pattern of findings would hold when infants are not being requested to point. Future work in this vein will also help to reveal the extent to which individual differences in language abilities modulate the relation between pointing and learning. In the current study, we found a link between infants' preexisting vocabulary sizes and their fast mapping abilities. However, we also found a trend to suggest that *within individuals* learning is enhanced when infants point compared with when they do not point, lending support to the idea that the act of pointing reflects a readiness to learn new information. Additional work in this domain, particularly with larger sample sizes, will help to further test these ideas.

Conclusion

The findings presented here provide compelling evidence to suggest that pointing, but not other communicative behaviors (e.g., reaching), results in successful learning of both functions and labels. In doing so, these findings highlight the strength of infants' pointing gestures as a unique and domain-general learning mechanism. These results also provide important insights into infants' motivation for pointing, a topic that has been extensively debated (Gómez, 2007; Southgate et al., 2007; Tomasello, Carpenter, & Liszkowski, 2007). The current findings deliver new insights into this ongoing debate by providing evidence that infants' pointing gestures may be a unique way for infants to request information, and labels in particular, from caregivers. Overall, this work demonstrates that infants' pointing gestures are an early-developing, information-requesting behavior that facilitates the acquisition of new information.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jecp.2018.08.003.

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