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Communicating to Learn: Infants' Pointing Gestures Result in Optimal Learning

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Infants' pointing gestures are a critical predictor of early vocabulary size. However, it remains unknown precisely how pointing relates to word learning. The current study addressed this question in a sample of 108 infants, testing one mechanism by which infants' pointing may influence their learning. In Study 1, 18-month-olds, but not 12-month-olds, more readily mapped labels to objects if they had first pointed toward those objects than if they had referenced those objects via other communicative behaviors, such as reaching or gaze alternations. In Study 2, when an experimenter labeled a not pointed-to-object, 18-month-olds' pointing was no longer related to enhanced fast mapping. These findings suggest that infants' pointing gestures reflect a readiness and, potentially, a desire to learn.

Months before infants produce their first words, they begin to initiate communicative interactions with their gestures. Researchers have long argued that these early gestures lay the foundation for later language development (Bates, Camaioni, & Volterra, 1975; Goldin-Meadow, 2007). Pointing gestures specifically, because of their universality and ability to consistently predict infants' later vocabulary size, are considered to be of special importance to language development—particularly in the domain of early word learning (Colonnesi, Stams, Koster, & Noom, 2010). For instance, the age at which infants first begin to point and the rate at which they point at age 12 months reliably predicts their vocabulary knowledge at 14 months (Fenson et al., 1994) and speech production at 24 months (Camaioni, Castelli, Longobardi, & Volterra, 1991). Importantly, the robust relation between early pointing and vocabulary size persists throughout development; pointing at 14 months predicts subsequent vocabulary size at 42 months (Rowe, Özçalişkan, & Goldin-Meadow, 2008). Although it is clear that pointing plays a fundamental role in early vocabulary development (Iverson & Goldin-Meadow, 2005), important questions remain as to how and in what contexts pointing influences early word learning. The goal of the current studies is to investigate these questions.

One way that infants' early pointing may influence word learning is by providing infants with increased exposure to language. Through pointing, infants signal to their caregivers a referent of interest. In turn, these signals provide caregivers opportunities to offer labels, translations, or commentary tailored to their infants' interests, desires, or goals (Golinkoff, 1986). This type of tailored linguistic input is particularly advantageous for early word learning. Indeed, infants learn word–object relations more readily when they are attending to an object being labeled than when their attention is redirected to a new object (Baldwin, 1991; Goldstein, Schwade, Briesch, & Syal, 2010; Tomasello & Farrar, 1986). Consequently, the more infants point toward objects, the more likely it is that the labels or words for those objects will enter their vocabularies (Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007). Together, these findings suggest that by guiding their language input, infants' pointing gestures provide the "royal road to language" (Butterworth, 2003).

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Infants as Information Seekers

Infants do not passively absorb the input they receive in response to their pointing gestures. In fact, it is likely that infants play a constructive role in their learning by actively *seeking* out that information (Csibra & Gergely, 2006; Piaget, 1954). Indeed, from early on in development, infants display perceptual biases and attentional patterns that strongly suggest a motive to acquire information (Xu & Kushnir, 2013). For instance, in a series of studies, Kidd, Piantadosi, and Aslin (2012, 2014) found that 8-month-old infants selectively attend to patterns of stimuli that are of intermediate complexity compared to patterns of stimuli that are too simple (overly predictable) or too complex (overly unpredictable). Patterns of stimuli with this particular level of intermediate complexity are likely ideally suited for infants to learn from because they are (a) not overly simple such that infants could quickly understand them and (b) not overly taxing such that they exceed infants' information-processing capacity, making them too difficult to learn from. Thus, Kidd et al. (2012, 2014) conclude that by 8 months, infants prefer to examine stimuli that have the potential for the most information gain.

Additional support for infants as active contributors to their development comes from research demonstrating that even newborns have been shown to differentially allocate their attention depending on the complexity of the stimuli. For instance, Morton and Johnson (1991) found that from the first few days of life, infants selectively attend to human faces compared to other salient stimuli (e.g., a face with scrambled features). Likewise, young infants tend to selectively listen to human voices, as opposed to other dynamic sounds (Vouloumanos & Werker, 2004). As faces and voices are important sources of information (Csibra & Gergely, 2006), these biases strongly suggest that infants allocate their attention in ways that maximize their potential for information gain. Infants' early manual exploration also supports this claim in that infants, by around 12 months, spend more time exploring objects that may potentially provide new information (i.e., objects that have previously violated their expectations; Stahl & Feigenson, 2015). There is compelling evidence to suggest that infants understand that their caregivers are particularly important sources of information and are highly motivated to access that information (Gergely, Egyed, & Kiraly, 2007; Homer & Tamis-Lemonda, 2013; Vaish, Demir, & Baldwin, 2011). For instance, in ambiguous learning situations (e.g., when a referent of a spoken label is unclear), infants will consult an adult's gaze direction to assist them in locating the correct object (Baldwin, 1991; Vaish et al., 2011).

Infants do not only attend to and prefer stimuli that are highly informative, they will also explicitly *request* information. One potent way for infants to request information is through pointing. Pointing gestures, because of their salient nature, afford infants with a particularly powerful means of eliciting information (Southgate, van Maanen, & Csibra, 2007). Recent experimental studies have provided compelling support for the hypothesis. For instance, 16-month-old infants are significantly more likely to point for knowledgeable recipients (i.e., someone they had seen correctly label a familiar object) than for ignorant recipients (i.e., someone they had seen incorrectly label a familiar object; Begus & Southgate, 2012). Infants are also more likely to point for recipients that respond with informing behavior (i.e., providing valence information about an object) rather than with noninforming behavior (i.e., sharing attention around objects; Kovács, Tauzin, Téglás, Gergely, & Csibra, 2014). Not surprisingly, this is an effective communicative strategy: Observational research has demonstrated that caregivers respond to infants' pointing gestures with information for what was pointed to (Kishimoto, Shizawa, Yasuda, Hinobayashi, & Minami, 2007). Together, this work has led researchers to suggest that infants use their pointing gestures as a way to obtain information from others.

Although research has suggested that infants will point to request information (i.e., interrogatively; Begus & Southgate, 2012; Kovács et al., 2014), it is certainly not the only way that infants' pointing has been interpreted. For decades, researchers have provided compelling evidence to suggest that infants will point imperatively, to establish their preference and request objects (Bates et al., 1975), as well as declaratively, to engage in joint attention with others (Liszkowski, Carpenter, Henning, Striano, & Tomasello, 2004). Thus, infants' early pointing gestures (interrogative, imperative, and declarative) appear to both overlap with and be distinct from other ways in which infants express preference for objects (e.g., reaching or looking; Thelen et al., 1993) and engage in joint attention (e.g., gaze alternating; Carpenter, Nagell, & Tomasello, 1998). For instance, infants' pointing for imperative reasons may also be accomplished through reaching or looking behaviors. Moreover, infants' pointing for declarative reasons may also be accomplished through gaze alternating behaviors. Thus, although infants' pointing gestures appear to be similar to other early communicative behaviors in their imperative (e.g., "I want that!") and declarative (e.g., "Look at that!") functions, pointing appears to be *unique* in that it is also a tool for requesting information from adults (e.g., "What is that?").

Pointing as Information Seeking May Enhance Learning

Why might infants use their pointing gestures but not other communicative behaviors to obtain information from adults? Observational research on parent–child interactions has demonstrated that caregivers are significantly more likely respond to infants' pointing gestures compared to other communicative behaviors (e.g., reaching), with information about what the infant referenced (Kishimoto et al., 2007; Leung & Rheingold, 1981). Extending this work to word learning, Wu and Gros-Louis (2014a) found that caregivers provide more labels in response to infants' pointing gestures than to other communicative behaviors. Together, this research suggests that infants' pointing gestures are unique in their ability to reliably elicit information from adults. Thus, it would not be surprising if infants selectively utilize pointing gestures as a tool to obtain information from adults (Csibra & Gergely, 2006).

This interest in obtaining information may directly support memory of that information. Research has demonstrated that when individuals are curious about (i.e., specifically interested) or motivated to obtain certain types of information, they are better able to remember that information (Adcock, Thangavel, Whitfield-Gabrieli, Knutson, & Gabrieli, 2006; Gruber & Otten, 2010; Kang et al., 2009; Loewenstein, 1994). For instance, Kang et al. (2009) discovered that when subjects reported interest in obtaining information they were more likely to retain that information compared to when they did not report a specific interest in receiving that information. The researchers measured participants' electrical brain activity and found that an increased desire to obtain information was associated with increased activity in memory areas of the brain, which may have promoted subsequent memory formation. Thus, pointing may not only drive infants' learning by increasing their exposure to language. Because research has provided compelling evidence that infants use their pointing gestures as a way to seek out information, these gestures may also signal that infants are in an optimal state to learn new information.

To explore this possibility, Begus, Gliga, and Southgate (2014) tested infants' ability to learn about objects immediately after they had pointed toward those objects. When the function of an object was presented immediately after infants pointed toward that object, they were significantly more likely to learn that object's function than when this information was provided for an object that infants had not pointed toward. This finding is consistent with the interpretation that infants use their pointing gestures as a way to actively seek out information and are therefore in an optimal state to assimilate it (Begus et al., 2014).

The Current Study

The purpose of the current study was to explore developmental changes in the relation between infants' pointing and early word learning. Although the Begus et al. (2014) findings demonstrate that infants learn best when information is provided in response to their pointing gestures, it remains unknown as to whether this effect generalizes to early word learning. Moreover, it is unclear whether and how the relation between pointing and learning differs across development. In addition, research has yet to pinpoint the mechanism driving the relation between pointing and learning.

Testing whether infants' pointing gestures *uniquely* reflect an optimal state for learning may shed light on and isolate a potential mechanism influencing this relation. As infants' pointing gestures have also been interpreted as a way for infants to express their preference for objects (Bates et al., 1975) and desire to engage in joint attention with others around objects (Liszkowski et al., 2004), it is important to pit infants' ability to learn in response to their pointing gestures against their ability to learn in response to other communicative behaviors known to reflect preference (e.g., reaching) and a desire to engage in joint attention (e.g., gaze alternation). For instance, if infants' pointing gestures reflect an optimal state for learning, above and beyond other ways of expressing their preference for objects (reaching, looking) or desire to engage in joint attention around objects (gaze alternating), it would suggest that infants' heightened attention when seeking information about objects (as opposed to heightened attention associated with preference for objects or engaging in joint attention around objects) may play a role in the relation between pointing and learning.

Infants express their preference for objects in numerous ways. For instance, infants may produce reaching gestures (Carpenter et al., 1998; Thelen et al., 1993), looking behaviors (Fantz & Nevis, 1967), or pointing gestures (Bates et al., 1975). Similarly, there are multiple ways for infants to express their desire to engage in joint attention around objects. In addition to pointing, infants' gaze alternations (i.e., alternation of gaze between an object of interest and another individual who is jointly attending to that object) also provide a means for them to engage in joint attention with others around objects (Carpenter et al., 1998). Indeed, infants' gaze alternations are often regarded as the "hallmark" of joint attention because they demonstrate infants' desire to share attention with a partner (Bruner, 1983; Tomasello, 1995). Although there is compelling evidence that infants' pointing gestures, reaching, looking and gaze alternating behaviors may all reflect their preference for and desire to engage in joint attention around objects, pointing gestures may be unique in that they may *also* reflect infants' desire to obtain information about objects. Infants' pointing gestures may be unique in this way because they are the only known preverbal behavior that reliably elicits information from caregivers (Kishimoto et al., 2007; Wu & Gros-Louis, 2014a). If infants have ascertained that information is most often provided in response to their pointing gestures, but not in response to other behaviors (e.g., reaching, looking, gaze alternating), then pointing gestures, but not other behaviors, should reflect a readiness or expectation to obtain information. As a result, if infants point to receive information about objects this should then heighten their attention to the information provided in response, which should in turn scaffold their encoding of that information (Gruber & Otten, 2010; Kang et al., 2009). Support for this hypothesis comes from research demonstrating that while infants' early pointing is highly predictive of their vocabulary development, other expressions of preference and engagement in joint attention are not related to infants' overall vocabulary growth (Blake, Osborne, Cabral, & Gluck, 2003). Although we cannot directly pinpoint *why* an infant points, we can assess the degree to which learning is enhanced when they produce a point compared to when they produce other behaviors. We reasoned that, if different behaviors (e.g., pointing vs. reaching or looking) reflect different learning outcomes (e.g., successful vs. unsuccessful fast mapping), then it is possible that (a) infants produce these behaviors for different reasons, and (b) these behaviors differentially influence infants' ability to learn. To explore these possibilities, the current studies examined 12- and 18-month-old infants' fast mapping of labels onto objects in direct response to their pointing gestures compared to other expressions of preference (i.e., reaching, looking) and joint attention (i.e., gaze alternating), toward objects.

Study 1

Infants were tested in a novel experimental paradigm designed to elicit communicative behaviors. Infants' spontaneous communicative behavior toward different objects was observed and then categorized twice, along two different dimensions: expressions of preference or engagement in joint attention. Expressions of preference were operationalized as points, reaches, or looks, whereas engagement in joint attention was operationalized as pointing gestures or gaze alternations produced without gesturing. As fast mapping is an essential precursory skill that underlies more sophisticated and symbolic word learning (Carey & Bartlett, 1978), this study represents a first step toward understanding the immediate effects of pointing on word learning. To emulate fast mapping "in the wild," and maximize infants' ability to map labels onto objects, we had an interactive human experimenter teach infants labels (Koenig & Echols, 2003). In this study, an experimenter labeled the object infants referred to (by pointing, reaching, or looking) and then tested infants' ability to form the label–object association. This procedure was repeated three times with each infant. Across trials, infants spontaneously altered how they referred to the novel object (e.g., Trial 1 = point, Trial 2 = reach, Trial 3 = point), allowing us to directly assess infants' fast mapping as a function of the behavior exhibited *within* a given trial. Infants' preexisting vocabulary size was also measured using the MacArthur Communicative Development Inventory (MCDI; Fenson et al., 1994). This allowed us to ensure that it was infants' behavior during the experiment, as opposed to the linguistic abilities that infants came to the experiment with, that was driving fast mapping success.

We assessed infants at two strategic time points: (a) at 12 months, as infants are beginning to produce their first words and pointing gestures (Bates et al., 1975), and (b) at 18 months, after infants have acquired many new words, and have had months of experience pointing and receiving information in response (Kishimoto et al., 2007). As 12-month-olds are just beginning to produce pointing gestures, they may not have had sufficient

experience pointing and receiving information from caregivers in response to understand the information-eliciting function of their points. Thus, we predicted that
12-month-olds would use pointing in the same way as other expressions of preference (i.e., reaching, looking) and joint attention (i.e., gaze alternating), and as a result, their pointing gestures toward objects would not lead to superior fast mapping. However, because 18-month-olds have had several more months of experience pointing and receiving information from caregivers in response (Kishimoto et al., 2007), we hypothesized that by 18 months infants have acquired an understanding that their pointing gestures, but not other ways of expressing preference and joint attention, reliably elicit information from adults. Moreover, as the relation between infants' pointing gestures and vocabulary development is most robust at 18 months (Colonnesi et al., 2010), we predicted that 18-month-olds' pointing gestures toward objects compared to other expressions of preference and joint attention would reflect an optimal state to map labels onto those objects.

Method

Participants

Participants were recruited from birth records from three counties in the southeastern part of the United States. Once infants reached the selected age range, caregivers were notified and invited to participate. The final sample included 72 infants: 36 full-term, healthy 18-month-olds (18 female, M = 18.0 months, SD = .62, range = 16.2–18.8 months) and 36 full-term, healthy 12-month-olds (18 female, M = 12.2 months, SD = .92, range = 10.1–13.5 months). Data were collected between February 2014 and July 2015. The sample comprised monolingual, English-speaking infants from predominantly middle-class households (80% Caucasian, 8% African American, 7% other, 3% Asian, 1% American Indian, 1% did not report). Data from six additional infants were excluded due to fussiness (n = 5; three 18-month-olds, two 12-month-olds) or parental interference (n = 1).

Stimuli and Apparatus

Caregivers completed consent, the MCDI, an early gesture and demographic survey. After completing these forms, participants and their caregivers were taken into a 3.7 × 2.6 m testing room. Infants were seated on their parent's lap in front of a 76 × 50 cm table across from the experimenter (Figure 1A). Infants were presented with three pairs of novel toys (rated for equal attractiveness), one pair at a time (Figure 1B). The toys were given the nonsense labels "Blicket," "Modi," or "Dax," selected based on their phonotactic similarity to English words and frequent use in previous word learning studies. The presentation order of labels and toys was counterbalanced.

Procedure

In the testing room, parents were instructed to remain completely neutral and to not interfere with their infants' behavior in any way. The experimental session was divided into four phases: familiarization, choice, labeling, and testing (Figure 1C).

Familiarization phase. Infants were presented with two novel objects, one at a time, and allowed to play with each toy for approximately 30 s. This ensured that infants both visually and physically explored each object before choosing one of them.

Choice phase. The experimenter reintroduced both objects, on opposite sides of the table, just out of infants' reach (Figure 1A). To encourage infants to choose one of the objects, the experimenter prompted, *Wow! See these! Point to one of these! Which one? Point to the one you want!* Once infants clearly chose an object, by pointing, reaching, or looking toward one of the objects, the experimenter initiated the labeling phase with that object (i.e., target object). Although all videos were recoded offline to establish interrater reliability on infants' choice of object. Any trial in which there was disagreement about the object of infants' choice of object (i.e., the experimenter misinterpreted the infants' choice of object during the task, the infant did not clearly establish interest in one of the two objects, or the infant was fussy) was excluded from the analyses (n = 2 of 216). It took infants an average of 7 s to choose an object.

Labeling phase. During the labeling phase (12 s), the experimenter brought the target object close to infants and labeled it four times, engaging in joint attention and using enthusiastic, child-directed speech (e.g., *This is a Modi! See the Modi! Wow, it's a Modi! Look at the Modi*!). This was designed to be highly engaging to ensure that regardless of how infants initially referenced the target object (i.e., by pointing or not), they were equally attentive to it while it was labeled. The experimenter only initiated labeling when it was clear that infants were fully attentive to both the experimenter and target object. Throughout the labeling phase, the

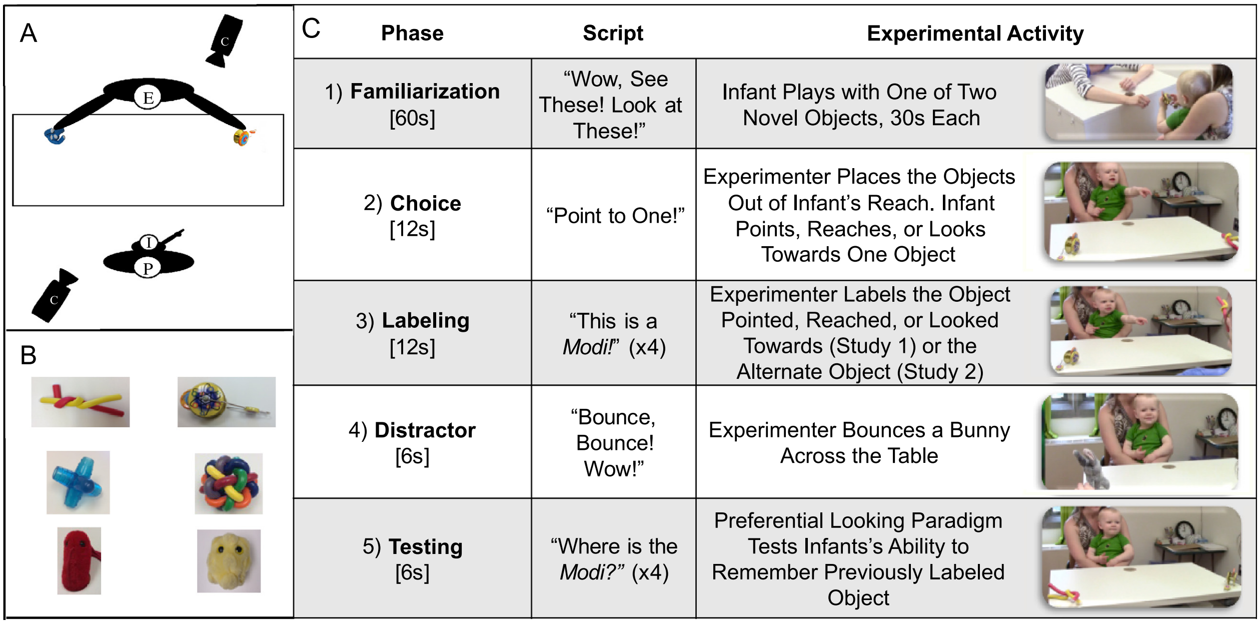

Figure 1. Design used in Studies 1 and 2. Experimental setup (A), pairs of stimuli (B), and procedure (C). [Color figure can be viewed at wileyonlinelibrary.com]

nontarget object remained on the table in the infants’ view. After this phase, the experimenter removed the toys and presented a 6-s distraction by bouncing a stuffed rabbit across the table.

Test phase. Following the rabbit distractor, the experimenter initiated the 6-s test phase by placing the target and nontarget object back on the table while prompting, *Where is the Modi? Find the Modi! See the Modi*? The label was presented 2,400 ms after the objects appeared on the table. The test phase was divided into two parts: a period of 2,400 ms before the onset of the target label (i.e., preword test phase) and a period of 3,600 ms following the onset of the target label (i.e., postword test phase). This allowed us to establish infants’ baseline preferences for the objects, when they could freely look at them without verbal instruction, in addition to infants’ fast mapping of labels, when they could look at the target and distractor objects immediately after hearing the target label. In doing so, we were able to quantify fast mapping success (i.e., looking toward the target object as a direct function of hearing the target’s label), as opposed to increased looking times due to initial salience of either object.

These phases were repeated with two additional sets of toys. In total, infants saw three sets of novel toys and labels. Thus, each infant had the potential to provide fast mapping data across three trials. The entire experiment lasted approximately 5 min per participant.

Coding

Infants’ behavior was coded based on (a) *choice phase communicative behavior*, the key independent variable, and (b) *test phase visual fixation*, the key dependent variable.

Choice phase: communicative behaviors. Criteria used to code infants’ communicative behaviors are presented in Table 1 (based on Matthews, Behne, Lieven, & Tomasello, 2012). Infants’ communicative behaviors during the choice phase (i.e., in response to, “Point to one of these!”) were categorized twice, along two different dimensions. First, behaviors were coded as an “expressions of preference” (i.e., point, reach, look). Infants’ behavior was then recoded as an “engagement in joint attention” (i.e., point, gaze alternation without any gesture, no joint attention). Although all videos were recoded offline to establish interrater reliability on infants’ choice of object (i.e., whether the experimenter chose the object the infant desired), only 20% of the videos were recoded to establish interrater reliability on the specific *type* of communicative behavior produced (Cohen’s kappas for expression of preference = .89; engagement in joint attention = .71; Fleiss, 1981).

Test phase: visual fixation to objects. To establish infants’ baseline preferences for the target objects and calculate fast mapping performance, infants’ visual fixation during the test phase was coded offline using DataVyu (www.datavyu.org). At

Table 1
Coding of Infants' Communicative Behavior During the Choice Phase

Expressions of preference		Engagement in joint attention	
Behavior	Description	Behavior	Description
Point	Infant extended their arm and finger toward an object of interest while maintaining an upright posture (i.e., the infant did not lean toward the object).	Point	Infant extended their arm and finger toward an object of interest while maintaining an upright posture (i.e., did not lean toward the object).
Reach	Infant 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.[a]	Gaze alternation without a gesture	Infant alternated their gaze between the target object and the experimenter, but did not produce a gesture.
Look	Infant did not produce a manual gesture toward an object of interest. Infants' interest in an object was defined as the object they looked at longer during the preference phase. If the infant did not clearly fixate their attention on one of the two objects, the experimenter labeled the object that the infant looked at first.	No joint attention	Infant did not engage in one of the above behaviors: infant either fixated their attention solely on an object or did not point.

Note. Infants' behavior was observed and then categorized twice, along two different dimensions: Expressions of preference or engagement in joint attention. A "point" was always considered a "point" in both categories.
[a]The key distinction made between a "point" and "reach" was based on the posture of the infant: Infants' attempts to act on the object (by reaching forward to obtain the object) were classified as a reach, whereas infants' clear, intentional communication about the object (by manually indicating what they were interested in) was classified as a point.

each 33-ms block of time, coders identified whether infants were fixated on the target object, nontarget object, experimenter, or away. Interrater reliability was excellent (intraclass correlation; ICC = .98). Any block of time in which infants were not attending one of the two novel objects was excluded from the analyses.

Baseline preferences. We operationalized infants' baseline looking preferences as the proportion of time infants looked toward the target object compared to the nontarget, during the preword test phase. This ensured that infants' looking toward the target during the postword test phase was not a result of selective interest in the target object, but due to true fast mapping (Reznick & Goldfield, 1992). These analyses are reported in Data S1, Supplemental Results.

Fast mapping. Consistent with prior research (e.g., Bergelson & Swingley, 2012) fast mapping was operationalized as the proportion of time infants spent looking toward the target object compared to the nontarget, during the postword test phase. If infants successfully fast mapped, they should look at the target object at rates significantly above chance during the postword test phase but not during the preword test phase.

Results

We tested whether infants' communicative behavior during the choice phase varied across the three trials of the experiment and predicted subsequent fast mapping success in the corresponding test phase of that trial. For 18-month-olds, productive vocabulary size on the MCDI was included as a covariate because it was more strongly correlated with overall fast mapping success (12-month-olds: $r = -.19$, $p = .26$; 18-month-olds: $r = .20$, $p = .29$) than infants' receptive vocabulary size on the MCDI (12-month-olds: $r = .16$, $p = .35$; 18-month-olds: $r = -.06$, $p = .74$). Receptive vocabulary sizes were included as covariates for 12-month-olds. Analyses were performed in R using the function glmer of the package lme4, cor.test, and wilcox.test (Bates & Maechler, 2010).

Communicative Behaviors Across Trials

The number of choice phases in which infants produced each expression of preference (i.e., points, reaches, or looks) and engagement in joint attention (i.e., points, gaze alternation without a gesture, or no joint attention) was calculated, in addition to the frequency with which infants varied their use of communicative behaviors across choice phases (Table 2). Forty-seven percent of 12-month-olds and 55% of 18-month-olds varied how they expressed their preference across the three trials (e.g., switched from reaching to pointing). Fifty-five percent of 12-month-olds and 75% of 18-month-olds varied how they engaged in joint attention across the three trials. Infants who pointed during the choice phases did not always point across all three trials. Only 29% of pointing 12-month-olds pointed across all three trials and 28% of pointing 18-month-olds pointed across all three trials—suggesting that any "pointing advantage" is due to the *act* of pointing itself and not a result of infants who point more generating higher fast mapping success, as only very few infants always pointed.

Communicative Behaviors and Fast Mapping Success Within Trials

Generalized linear mixed models (GLMM; Baayen, Davidson, & Bates, 2008) were used to test the influence of infants' pointing gestures in the choice phase against that of other communicative behaviors on their subsequent fast mapping performance in the test phase of that trial. Consistent with prior research, the dependent variable in this logistic regression was whether infants looked at the target compared to the nontarget object (i.e., yes or no) at each 200-ms block of time in the postword test phase (i.e., Bergelson & Swingley, 2012). Fixed effect predictors included infants' communicative behavior during the choice phase (point vs. reach vs. look), toy type (Set 1 vs. 2 vs. 3; Figure 1B), age (12- vs. 18-month-olds), and sex. The interaction of communicative behavior and age was included to determine whether infants' communicative behavior differentially impacted fast mapping as a function of age. MCDI and trial number were set as covariates to control for infants' preexisting vocabulary levels and fatigue in later trials. Three repeated observations per infant were taken into consideration by including the infants' ID in the model as a random effect. Likelihood ratio tests were used (Dobson, 2002) to compare the fit of the full model (TARGET_LOOK ~ TOY_TYPE + MCDI + TRIAL_NUMBER + SEX + COMMUNICATIVE_BEHAVIOR + AGE_GROUP + AGE_GROUP × COMMUNICATIVE_BEHAVIOR + random effect [INFANT_ID]) to the null model (TARGET_LOOK ~ random effect [INFANT_ID]).

No main effects of toy type, sex, or age emerged (all *p*s > .05). There was a main effect of pointing: Infants were significantly more likely to look at the target object during test phase if they had first pointed toward it during the choice phase (mean proportion of looking time to target = .63, *SE* = .06) compared to if they had first looked at it (*M* = .54, *SE* = .05; look vs. point: *Z* = 2.55, *p* = .01). There was a marginal difference between pointing and reaching, such that infants were more likely to look at the target object during test phase if they had first pointed toward it during the choice phase compared to if they had first reached toward it (*M* = .50, *SE* = .06; point vs. reach: *Z* = −1.71, *p* = .08). However, a significant Age × Communicative Behavior interaction (*Z* = −2.10, *p* = .03) subsumed this main effect. The model including the interaction of age and communicative behavior as a predictor fit substantially better than the model without the interaction term (likelihood ratio tests, $\chi^2 = 20.84$, *df* = 7, *p* = .004). The model did not improve in fit when sex and toy type were included (likelihood ratio tests, $\chi^2 = 4.91$, *df* = 3, *p* = .17). As a result, these predictors were removed from subsequent analyses.

To determine how the influence of communicative behaviors on subsequent fast mapping success varied as a function of age, the following two GLMMs were conducted within each age group (for a total of four models): (a) "expression of preference model"—which tested the influence of infants' pointing gestures on subsequent fast mapping success compared to other expressions of preference (i.e., reaching, looking), and (b) "engagement in joint attention model"—which tested the influence of infants' pointing gestures on subsequent fast mapping success compared to other ways of engaging in joint attention (i.e., gaze alternations without a gesture, no joint attention). We ruled out the possibility that infants' looking time during the test phase was a result of initial preference for the

Table 2
Proportion of Communicative Behaviors Used in Choice Phases in Study 1

Choice phase behavior	% Trials 12-month-olds/18-month-olds
Expression of preference	
Point	24/32
Reach	37/20
Look	39/48
Engagement in joint attention	
Point	24/32
Gaze alternation without a gesture	23/31
No joint attention	53/37

target or nontarget objects, as opposed to true fast mapping success, by modeling infants' looking time during the preword test phase. During the preword test phase, infants' looking time toward the target never significantly differed from chance (all *p*s > .05), suggesting that any increase in looking time during the postword test phase is a result of true fast mapping success, as opposed to initial preference for the target object (see Supporting Information).

12-month-olds.

Expressions of preference model. Infants' vocabulary size was not a significant predictor of fast mapping success ($Z = -0.02$, $p = .98$; Table 3). Infants were not more likely to look at the target object during the test phase when they had first pointed toward the target object during the choice phase ($M = .55$, $SE = .10$, 95% CI [.34, .74]) compared to when they had first reached ($M = .47$, $SE = .08$, 95% CI [.31, .64], point vs. reach: $Z = -1.83$, $p = .07$) or looked ($M = .57$, $SE = .08$, 95% CI [.41, .72], look vs. point: $Z = -0.54$, $p = .59$) toward the target object (Table 3, Figure 2A). Infants had a greater proportion of looking time toward the target object during test phase if they had first looked toward the target during the choice phase compared to if they had first reached toward it (look vs. reach: $Z = -2.70$, $p = .007$). However, none of these behaviors led to looking times significantly different from chance (i.e., 50% looking time to target; point: $Z = 0.51$, $p = .61$; reach: $Z = 0.38$, $p = .71$; look: $Z = 0.91$, $p = .36$).

Engagement in joint attention model. Infants' vocabulary size was not a significant predictor of fast mapping success ($Z = -0.37$, $p = .71$; Table 3). Infants were not more likely to map a label onto an object when they first pointed toward that object ($M = .55$, $SE = .10$, 95% CI [.34, .74]) compared to when they had gaze alternated without gesturing ($M = .57$, $SE = .10$, 95% CI [.35, .77]; gaze alternation without a gesture vs. point: $Z = -0.18$, $p = .86$), or did not engage in joint attention ($M = .50$, $SE = .07$; point vs. no joint attention: $Z = -1.25$, $p = .21$; Table 3; Figure 2B). Infants were also not more likely to map a label onto the target object when they had first gaze alternated without gesturing compared to when they did not engage in joint attention (gaze alternation without a gesture vs. no joint attention: $Z = -1.49$, $p = .14$). None of these behaviors led to looking times significantly different from chance (point: $Z = 0.51$, $p = .61$; gaze alternate without a gesture: $Z = 0.69$, $p = .49$; no joint attention: $Z = 0.00$, $p = 1.00$).

Table 3
Study 1: Results of the Best-Fit Generalized Linear Mixed Models Describing Relations Among Communicative Behavior During Choice Phases, MacArthur Communicative Development Inventory (MCDI) scores, and Fast Mapping Within Trials

	12-month-olds		18-month-olds	
	Z	*p* value	*Z*	*p* value
Expression of interest model				
Fixed effects				
Point versus reach	−1.83	.07	−2.63	.008
Point versus look	−.54	.59	−2.51	.01
Look versus reach	−2.70	.007	−.45	.65
MCDI score	−.02	.98	−.17	.86
Engagement in joint attention model				
Fixed effects				
Point versus gaze alternation without a gesture	−.18	.86	−2.08	.03
Point versus no joint attention	−1.25	.21	−2.10	.002
Gaze alternation without a gesture versus no joint attention	−1.49	.14	−.80	.42
MCDI score	−.37	.71	−.16	.88

18-month-olds.

Expressions of preference model. Infants' vocabulary size was not a significant predictor of fast mapping success ($Z = -0.17$, $p = .86$; Table 3). Infants' expression of preference during the choice phase was a significant predictor of fast mapping success. Infants were significantly more likely to look at the target object during the test phase when they had first pointed toward it ($M = .70$, $SE = .08$, 95% CI [.52, .84]) compared to when they had first reached ($M = .57$, $SE = .11$, 95% CI [.34, .78], point vs. reach: $Z = -2.63$, $p = .008$) or looked ($M = .52$, $SE = .07$, 95% CI [.38, .66], point vs. look: $Z = -2.51$, $p = .01$) toward it during the choice phase (Table 3; Figure 2C). Infants looking toward the target object did not vary as a function of whether infants had first reached or looked toward it (reach vs. look: $Z = -0.45$, $p = .65$). Infants' looking time toward the target object during test only differed from chance when infants had first pointed toward the target object but not when they first reached or looked toward it (point: $Z = 2.33$, $p = .01$; reach: $Z = 0.66$, $p = .51$; look: $Z = 0.29$, $p = .78$).

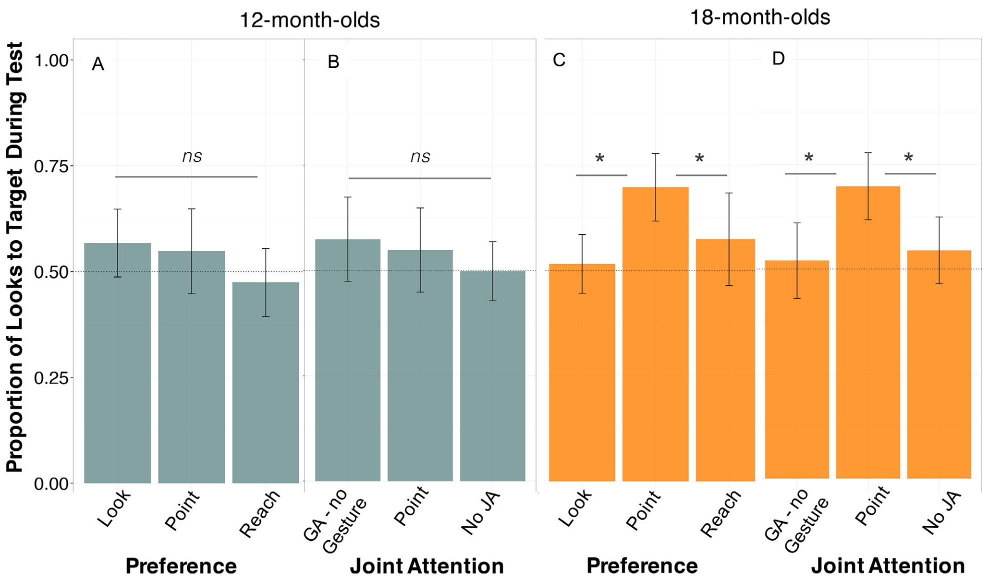

Figure 2. Proportion of looks to the target object during the test phase based on communicative behavior (expression of preference *or* joint attention) during the choice phase in Study 1. Infants' point data are represented twice for each Study (as an expression of preference and joint attention). $*p < .05$.

Engagement in joint attention model. Infants' fast mapping success was not predicted by infants' preexisting vocabulary size ($Z = -0.16$, $p = .88$; Table 3). Infants looked significantly longer at the target object during test when they had first pointed toward it during the choice phase ($M = .70$, $SE = .08$, 95% CI [.52, .84]) compared to when they had gaze alternated without gesturing ($M = .52$, $SE = .09$, 95% CI [.34, .70]; point vs. gaze alternation without a gesture: $Z = -2.08$, $p = .03$), or did not engage in joint attention at all ($M = .54$, $SE = .08$, 95% CI [.38, .70]; point vs. no joint attention: $Z = -2.10$, $p = .002$; Table 3; Figure 2D). Infants did not differ in their likelihood of looking toward the target object during the test phase if they had first gaze alternated without gesturing compared to if they did not engage in joint attention (no joint attention vs. gaze alternation without a gesture: $Z = -0.80$, $p = .42$). Infants' looking times toward the target object during test only differed from chance when infants had first pointed toward the target object during the choice phase but not when they had gaze alternated without gesturing or did not engage in joint attention (point: $Z = 2.33$, $p = .01$; gaze alternate without a gesture: $Z = 0.23$, $p = .82$; no joint attention: $Z = 0.51$, $p = .61$).

Pointing Versus Nonpointing Infants

One possible explanation for these findings is that infants who pointed at least once during our task (i.e., "pointing infants," $n = 18$) were more linguistically advanced, and therefore better fast mappers than infants who did not point during our task (i.e., "nonpointing infants," $n = 18$). If this were the case, then we would predict that the average fast mapping success of pointing infants, even on trials in which they did *not* produce a pointing gesture (number of trials = 20), would be higher than the average fast mapping success of nonpointing infants (number of trials = 53). This was not the case. The average fast mapping success of pointing infants in trials in which they did not produce a pointing gesture during the choice phase ($M = .58$, $SE = .08$) was not significantly different from the average fast mapping success of nonpointing infants ($M = .49$, $SE = .08$; pointing infants vs. nonpointing infants: Wilcoxon $W = 434.5$, $p = .32$). Wilcoxon tests, as opposed to GLMMs, were used for this analysis so that we could compare fast mapping success *across* infants, as opposed to fast mapping success *within* infants. The average fast mapping success of these groups did not differ from chance (pointing infants in no-point trials: $Z = 0.72$, $p = .47$; nonpointing infants: $Z = 0.15$, $p = .88$), indicating that the communicative behavior produced *within* each trial (as opposed to across trials) is the strongest predictor fast mapping success.

Discussion

Study 1 assessed 12- and 18-month-olds' ability to map labels onto objects in response to various communicative behaviors (i.e., expressions of preference or engagement in joint attention) toward desired objects. Eighteen-month-olds, but not 12-month-olds, were significantly more likely to map a label to an object if they had first pointed to that object than if they had not pointed. More specifically, 18-month-olds' pointing toward an object was related to enhanced learning about that object relative to all other expressions of preference (i.e., reaching or looking) and other ways of engaging in joint attention (i.e., gaze alternating without gesturing) around that object. Although previous research has demonstrated that infants who point more often have larger vocabulary sizes than infants who do not point as often (Colonnesi et al., 2010), the current findings are the first we know of to demonstrate that *in the moment* infants produce a pointing gesture, they are in an optimal state to fast map labels onto objects—a skill that represents a critical step in early word learning (Carey & Bartlett, 1978).

A Pointing Advantage?

The current findings demonstrate that despite *always* receiving labels in the same way, and despite being equally attentive while the target object was labeled, fast mapping was only facilitated when infants pointed toward an object but not when they reached, looked, or gaze alternated toward an object. Importantly, this was true *within* the same infant. Thus, it is possible that infants' differential learning was the result of what drove them to use different communicative behaviors in the first place.

If infants' sole motive for pointing was to express their preference for an object, and this heightened state of attention translates into enhanced learning, then infants should have been equally adept at mapping labels onto objects when this heightened attention was expressed by reaching or looking, two behaviors known to be driven by infants' preferences for objects (Fantz & Nevis, 1967; Thelen et al., 1993). However, in the current study, this was not the case. Eighteen-month-olds were more likely to map labels onto objects when they had first pointed toward them than when they had first reached or looked toward them, suggesting that infants' pointing gestures may do more than just serve as a means for expressing preference for objects.

Likewise, if infants' sole purpose for pointing was to engage in joint attention with the experimenter, and this type of infant-initiated joint attention translates into enhanced learning, then infants should have been equally adept at mapping labels onto objects when they engaged in joint attention via gaze alternation, either with or without producing a pointing gesture. However, this was not the case. Eighteen-month-olds were more likely to map labels onto objects when they had first pointed toward those objects compared to when they had first gaze alternated between the object and the experimenter without pointing. Thus, infants' pointing gestures may do more than just serve as a means for engaging in joint attention with others around objects.

Taken together, the current findings build on prior research and suggest that an alternate function may contribute to infants' use of pointing (Southgate et al., 2007). In addition to reflecting infants' preference for objects, and desire to engage in joint attention around objects, it is possible that pointing gestures may also reflect infants' desire to *learn* about objects. If infants point because they *want* and *expect* to receive information in response, it follows that they would be in an optimal state to *learn* that new information when it is provided. Although our findings provide preliminary support this theory, the design of the current could not directly measure infants' motives in the moment they produced a pointing gesture. Thus, we propose other potential explanations for the relation between pointing and learning in the general discussion.

Developmental Differences in the Relation Between Pointing and Learning

Why might pointing have reflected an optimal state for learning in 18-month-olds but not in 12-month-olds? Research has shown that parents consistently respond to infants' pointing toward objects by providing information about those objects (Kishimoto et al., 2007; Wu & Gros-Louis, 2014a). However, infants only begin producing pointing gestures around 12 months (Bates et al., 1975). Thus, it is not surprising that by 18 months, infants have accumulated enough communicative experiences (e.g., pointing and receiving information in response) that they now come to *expect* information to be provided in response to their pointing. Although 12-month-olds seem to prefer producing pointing gestures for recipients that respond with informing behavior compared to other behaviors (e.g., sharing attention; Kovács et al., 2014), there is currently no empirical evidence demonstrating that 12-month-olds have formed *an expectation* that their pointing gestures will elicit information from others. As 12-month-olds have just begun to produce pointing gestures, it might be the case that, at this early age, infants have not had sufficient experience pointing and receiving information in response to acquire the expectation that their pointing gestures *reliably* elicit information from others (Bates et al., 1975). Again, the current findings can only provide preliminary support for this proposal, as the design could not directly measure the infants' motives or goals in the moment they produced a pointing gesture. Additional explanations for the observed developmental difference in the relation between pointing and learning are considered in the general discussion.

Study 2

The findings from Study 1 suggest that the ideal time to teach infants new information is in the moment they produce a pointing gesture. However, an open question remains as to how these findings might be used in real-life learning contexts. Namely, when a caregiver notices their infant producing a pointing gesture, will they be successful in teaching their infant *any* information, or is learning only facilitated when information is tailored to the *specific* object infants to which point? In other words, do infants' pointing gestures reflect a broad, heightened state of attention for learning, or is the relation between pointing and learning specifically tailored to the pointed-to-object? Study 1 was unable to disentangle these hypotheses because labels were *always* provided for the object that infants pointed toward. Thus, Study 2 tests this question.

Although research has shown that infants have difficulty learning when their attention is redirected (i.e., when they are taught about an object they are *not* engaged with; Baldwin, 1991), it remains to be seen whether the act of pointing can aid in overriding the effect of having their attention redirected, enabling them to learn any new information when they produce a pointing gesture —even if it was not the focus of their point. If infants' pointing gestures simply reflect a general heightened state of attention for learning more broadly, then infants should be in an optimal state to learn *any* information presented when they produce a pointing gesture, regardless of whether it is related to the specific object pointed toward, so long as this information was provided when an infant pointed. Alternatively, if infants' pointing gestures reflect a readiness to learn about pointed-to-objects, then infants' pointing gestures should only reflect an optimal state for learning when information is tied to the specific objects pointed to (Begus et al., 2014).

Based on the findings from Study 1 demonstrating that pointing reflects a readiness to learn in 18-month-olds, but not 12-month-olds, we focused exclusively on 18-month-olds. In Study 2, we tested 18-month-olds in the same paradigm from Study 1, except that in response to infants' communicative behavior toward a desired object, the experimenter instead labeled an alternate, undesired object (i.e., one that infants did *not* point, reach, or look toward; Begus et al., 2014).

Method

Participants

Participants were recruited in an identical manner to Study 1. The final sample included 36 full-term, healthy 18-month-old infants (16 females, M = 17.85 months, SD = .82, range = 16.50–18.91 months). Data were collected between April 2014 and November 2015. The sample comprised monolingual, English-speaking infants from predominantly middle-class households (74% Caucasian, 14% African American, 3% Asian, 3% American Indian, 3% did not report). Data from three additional infants were excluded from the final analyses due to fussiness (n = 2) or experimenter error (n = 1).

Stimuli, Apparatus, and Procedure

The stimuli, apparatus, procedure, and coding were the same as those used in Study 1, except that the experimenter labeled the object that infants did *not* point, reach, or look toward during the choice phase. Thus, in Study 2, the "target object" (i.e., the labeled object) is the object that the infant did *not* point, reach, or look toward. Any trial in which an offline coder disagreed with the experimenter's choice of object (n = 3) or in which the infant was inattentive during the labeling phase (n = 2) was excluded from all analyses. Interrater reliability was calculated for expressions of preference during the choice phase (Cohen's κ = .77), engagement in joint attention during the choice phase (Cohen's κ = .89) and looking time during the test phase (ICC = .96).

Results

Communicative Behaviors Across Trials

Infants varied how they expressed their preference and engaged in joint attention around objects during the choice phases (Table 4). Infants did not

Table 4
Proportion of Communicative Behaviors Used in Choice Phases in Study 2

Choice phase behavior	% Trials
Expression of preference	
Point	39
Reach	23
Look	38
Engagement in joint attention	
Point	39
Gaze alternation without a gesture	32
No joint attention	29

always express their preference or engage in joint attention in the same way across the three choice phases. Fifty-three percent of infants varied how they expressed their preference across the three trials. Fifty-six percent of infants varied how they engaged in joint attention across the three trials. Infants who pointed in at least one choice phase (i.e., "pointing infants") did not *always* point across all choice phases. Only 26% of pointing infants pointed across all three trials.

Communicative Behaviors and Fast Mapping Success Within Trials

As in Study 1, a GLMM tested the influence of infants' communicative behavior during the choice phase on subsequent fast mapping performance during the corresponding test phase of that trial (Table 5). Infants' communicative behavior (expression of preference *or* engagement in joint attention) was set as a fixed effect; infants' ID was set as a random effect. Preexisting vocabulary size, as measured by productive vocabulary size on the MCDI, and trial number were set as covariates. Our dependent variable was whether infants looked at the target object (i.e., the object labeled during the labeling phase), compared to the nontarget, at each 200 ms block of time in the postword test phase. Analyses on infants' baseline looking preferences (i.e., looking time during the preword test phase) are reported in Data S1, Supplemental Results.

Expressions of preference model. Infants' vocabulary size was not a significant predictor of fast mapping success ($Z = 0.31$, $p = .76$). Infants did not display a greater proportion of looking time to the target object during test phase if they had first pointed ($M = .53$, $SE = .08$, 95% CI [.37, .69]) compared to if they had first reached ($M = .55$, $SE = .10$, 95% CI [.34, .75], reach vs. point: $Z = -0.44$, $p = .66$) or looked ($M = .58$, $SE = .08$, 95% CI [.41, .74], point vs. look: $Z = 0.70$, $p = .48$) toward a different (i.e., nontarget) object during the choice phase (Figure 3A). Infants were not more likely to look at the target object during test if they had first looked toward the nontarget object during the choice phase compared to if they had first reached for it during the choice phase (look vs. reach: $Z = -1.01$, $p = .31$). See Table 5. None of these behaviors led to looking times different from chance (point: $Z = 0.38$, $p = .70$; reach: $Z = 0.49$, $p = .62$; look: $Z = 0.99$, $p = .32$).

Table 5
Study 2: Results of the Best-Fit Generalized Linear Mixed Models Describing Relations Among Communicative Behavior During Choice Phases, MacArthur Communicative Development Inventory (MCDI) Scores, and Fast Mapping Within Trials

	Z	p value
Expression of interest model		
Fixed effects		
Point versus reach	−0.44	.66
Point versus look	0.70	.48
Look versus reach	−1.01	.31
MCDI score	0.31	.76
Expression of joint attention model		
Fixed effects		
Point versus gaze alternation without a gesture	−1.80	.07
Point versus no joint attention	2.00	.05
Gaze alternation without a gesture versus no joint attention	3.27	.001
MCDI score	0.35	.72

Engagement in joint attention model. Infants' vocabulary size was not a significant predictor of fast mapping success ($Z = 0.35$, $p = .72$). Infants were not more likely to map a label onto an object if they had first pointed ($M = .53$, $SE = .08$, 95% CI [.37, .69]) compared to if they had gaze alternated without gesturing ($M = .54$, $SE = .09$, 95% CI [.36, .71]; gaze alternation without a gesture vs. point: $Z = -1.80$, $p = .07$) or did not engage in joint attention ($M = .59$, $SE = .09$, 95% CI [.40, .77]; point vs. no joint attention: $Z = 2.00$, $p = .05$; Figure 3B) around the nontarget object during the choice phase. Infants were more likely to map a label onto the target object if they first did not engage in joint attention around the nontarget object compared to if they had first gaze alternated without gesturing around the nontarget object (gaze alternation without a gesture vs. no joint attention: $Z = 3.27$, $p = .001$). See Table 5. Importantly, however, none of these behaviors led to looking times different

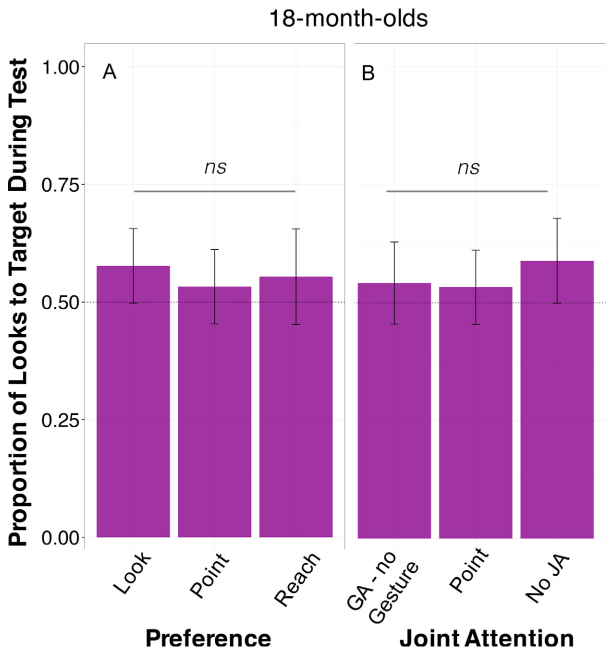

Figure 3. Proportion of looks to the target object during the test phase based on communicative behavior (expression of preference *or* joint attention) during the choice phase in Study 2.

from chance (point: $Z = 0.38$, $p = .70$; gaze alternation without a gesture: $Z = 0.46$, $p = .65$; no joint attention: $Z = 0.99$, $p = .32$).

Discussion

The purpose of Study 2 was to determine whether infants' pointing gestures reflect an optimal state for learning when information is provided about objects that are *not* pointed toward. Study 2 was identical to Study 1, with one key difference: labels were provided for objects the infant did *not* point, reach, or look toward. The results revealed that, in this context, infants did not successfully map labels onto objects, regardless of whether they first pointed, reached, gaze alternated without a gesture, or just looked at a different object before receiving a label. These findings suggest that infants' pointing gestures do not reflect a broad, heightened state of attention for learning. Rather the relation between pointing and learning is specifically tailored to the pointed-to object.

The findings from Study 2 have important practical implications for how to most effectively teach infants new information. If infants' pointing gestures signal that they are in a general, heightened state of attention for learning, then infants could be taught information about *any* object in the moment they produce a pointing gesture, and this would result in successful assimilation of that information. However, these findings suggest that pointing gestures do not signal that infants are in an optimal state to learn more generally. Rather, infants' pointing gestures signal that they are only in an optimal state to learn about specific, pointed-to objects. Thus, to transform moments in which infants produce a pointing gesture into learning opportunities, infants should be given information about the specific objects they point toward.

Why Is Learning Yoked to the Referent of a Pointing Gesture?

If infants point to obtain information about specific objects, and this desire to obtain information translates into a readiness to learn that information, then this may help explain why infants were able to learn information about pointed-to objects (Study 1) but not information about not pointed-to objects (Study 2). Alternatively, it may be the case that infants' pointing gestures do reflect a general heightened state for learning, but the design of the current study did not reveal this. Rather, in the current study it may have been too difficult for infants to switch their attention and learn about an object in which they were not interested. If the task had been easier (e.g., included a more extensive labeling phase), it is possible that a relation between pointing and learning of information about not pointed-to objects would have been detected. Future research is needed to disentangle these possibilities.

General Discussion

The current studies assessed 12- and 18-month-olds' ability to fast map labels onto objects when given labels in response to various types of communicative behaviors toward objects. In Study 1, 18-month-olds, but not 12-month-olds, were significantly more likely to map a label onto an object if they had first pointed toward that object, as opposed to if they had expressed their preference in other ways (i.e., reached or looked toward that object) or had engaged in another form of joint attention (i.e., alternated their gaze between that object and an experimenter). Conversely, in Study 2, when an experimenter provided a label for the object that infants did *not* point, reach, or look toward, 18-month-olds did not display successful label–object mapping, regardless of whether they had first pointed before receiving that label. These findings suggest that pointing does not reflect a general state of heightened preparedness to learn but that it is specific and limited to learning about the referent of the point.

By demonstrating that infants are in an optimal state to fast map a label to an object in the moment they produce a pointing gesture toward that object, the current findings build on decades of research demonstrating a link between early pointing and vocabulary development (Colonnesi et al., 2010). More specifically, the current findings demonstrate that infants' pointing gestures do not *only* influence their early vocabulary development by increasing their exposure to language (e.g., increased frequency), as previously proposed (Goldin-Meadow et al., 2007; Wu & Gros-Louis, 2014a, 2014b). Here, we ruled out the possibility that increased exposure is the *sole* mechanism driving the relation between pointing and vocabulary growth because respective labels were provided in response to *all* of the infants' behaviors. If exposure is sufficient to enhance learning, then infants in the current study should have been *equally* as likely to map labels onto objects regardless of which behavior they exhibited toward the objects or whether they pointed to the object being labeled or not (Study 2), because respective labels were always provided.

Possible Explanations for a Pointing Advantage

It is possible that infants' pointing reflected a readiness to learn because they were simply more attentive and engaged in the task when they pointed. In both studies, the experimenter did not begin labeling *until* infants had clearly established a selective preference for one of the two novel objects, by pointing, reaching, or looking. Furthermore, trials in which infants did not clearly indicate a preference for one of the two objects or were not attentive to the experimenter or object during were not included in the analyses. Thus, heightened preference for objects and general attentiveness alone cannot explain infants' enhanced fast mapping skills during trials in which they had pointed.

A second possible explanation for infants' enhanced fast mapping following their pointing gestures is that when infants pointed, they were initiating joint attention with the experimenter. During these point trials, infants may have been more socially engaged and thus more motivated to learn, as research has shown that infants learn words best in the context of joint attention (Tomasello, 1995). To test this possibility, we directly compared infants' fast mapping performance in trials in which they had first pointed toward objects to trials in which they did not gesture but simply gaze alternated—another behavior considered to be involved in infants' engagement in joint attention with others (Carpenter et al., 1998). However, infants were only more likely to map labels onto objects if they had first pointed toward those objects but not if they had alternated their gaze between that object and the experimenter without gesturing.

To interpret the above findings, it is important to consider the long-standing debate surrounding infants' use of gaze alternations (Akhtar & Gernsbacher, 2007). It has been argued that in addition to being a declarative act, gaze alternations can also be used by infants to seek out information (i.e., social referencing; Feinman, 1982). However, the evidence is mixed as to whether infants gaze alternate because they are seeking comfort or because they are seeking information (Striano, Vaish, & Benigno, 2006). Moreover, although there is direct evidence that infants' pointing gestures reliably elicit conceptual information (e.g., labels) from caregivers (Wu & Gros-Louis, 2014a), there is currently no evidence that infants' gaze alternating behavior also reliably elicits conceptual information about the object of shared attention from caregivers. Until research classifies caregivers' responses to infants' gaze alternating behavior, compared to infants' direct looks toward objects, it remains unclear as to whether infants would have the opportunity to acquire the expectation that their gaze alternations reliably elicit information in the same way that their pointing gestures do (Begus & Southgate, 2012).

Another potential explanation for the current findings has nothing to do with the *act* of pointing. Namely, it is possible that infants who pointed during our task were simply more linguistically advanced (i.e., had higher preexisting vocabulary sizes) or "smarter" than those who did not point. As a result, these infants were better "fast mappers" from the start. There are several reasons why this explanation falls short. First, the average fast mapping success of "pointing infants" (i.e., infants who pointed at least once during the study), in trials in which they did *not* point did not differ from chance and did not differ from the fast mapping success of "nonpointing infants" (i.e., infants who never pointed during the study). Additionally, only 5 of the 18-month-olds in Study 1 pointed across all three trials of the experiment, indicating that the current results were not driven by a subset of precocious, always-pointing infants. Second, pointing did not *always* result in superior learning. If infants who point are simply better learners, as opposed to the *act* of pointing itself reflecting a readiness to learn, then these more advanced "pointing infants" should have mapped labels onto objects in Study 2, regardless of whether the pointed-to objects were labeled or not. This was not the case. Finally, infants' vocabulary size alone did not predict fast mapping success—infants who came into the study with larger vocabulary sizes were not more likely to map labels onto objects than infants with smaller vocabulary sizes.

There are several reasons why we may not have found a relation between vocabulary size and fast mapping success. First, not all studies assessing the link between vocabulary size and fast mapping find a relation between the two abilities (e.g., Bergelson & Swingley, 2013; Swingley & Aslin, 2000; Wilbourn & Sims, 2013). Second, many of the studies that do find a relation between vocabulary size and fast mapping find that this relation only exists after children reach their second birthday but not earlier (Bion, Borovsky, & Fernald, 2013). Moreover, much of the work on the relation between vocabulary size and fast mapping has been conducted on infants from diverse socioeconomic backgrounds (i.e., infants with diverse vocabulary sizes; Fernald, Marchman, & Weisleder, 2013). Thus, it is possible with a sample of older infants, or infants from more diverse socioeconomic backgrounds, a significant relation between vocabulary size and fast mapping success would have been evident.

Ultimately, the current findings demonstrate that the communicative behavior produced *within* each trial (as opposed to behavior across trials, or preexisting linguistic abilities) is the strongest predictor infants' fast mapping success. Taken together, this suggests that the *act* of pointing, or what motivates infants *in the moment* they point toward an object, leads to enhanced fast mapping. One potential reason why infants may have pointed toward novel objects in the current task was to obtain information about that object. Indeed, experimental evidence strongly suggests that one of the primary motivations governing infants' pointing behavior is a desire to obtain information (Begus et al., 2014; Kovács et al., 2014). Moreover, research consistently demonstrates that an interest in obtaining information supports memory of that information (Adcock et al., 2006; Gruber & Otten, 2010; Kang et al., 2009; Loewenstein, 1994). These studies offer one potential explanation for the current findings: If infants produce pointing gestures to obtain information, and an interest in obtaining information supports memory of that information, then infants' pointing gestures should signal a readiness to learn.

Finally, it is important to consider that the act of pointing, in and of itself, could have facilitated infants' learning directly. Theories of embodied cognition suggest that the physical act of producing a pointing gesture might induce a heightened or increased preparedness to learn for children (Barsalou, 2008; Goldin-Meadow & Alibali, 2013). For instance, some have argued that infants' and young children's pointing gestures serve a cognitive regulatory function similar to Vygotsky's (1962) "private speech," in which children use egocentric language as a way to self-organize their behavior (Delgado, Gómez, & Sarriá, 2011). Observational research has shown that infants, as young as 12 months, engage in noncommunicative, private pointing (Bates et al., 1975; Delgado et al., 2011). Ultimately, this type of private pointing may assist preverbal infants in individuating objects from the visual field and regulating their own attention (Bates et al., 1975; Delgado et al., 2011). In verbal toddlers (i.e., 2- to 4-year-olds), this type of private pointing has been found to directly enhance performance on cognitive tasks (Delgado et al., 2011). Delgado et al. (2009) contend that children's private pointing enhanced their performance because it focused their attention on the relevant aspects of a problem, thereby modulating attention and action. Thus, a task for future research is to determine whether younger infants' private pointing serves a similar attentional regulatory function and enhances learning.

Importantly, the current study did not rule out the possibility that infants' pointing gestures serve a variety of functions, making it possible that the combination of these functions may have been what contributed to enhanced learning. For instance, infants may have pointed toward novel objects in the current task because they wanted to obtain that object, receive information about that object, *and* focus their attention on that task—all of which may have played an interactive role in helping infants learn about objects in the moment they pointed toward those objects. To pinpoint precisely *why* infants' pointing gestures reflected an optimal state for learning, future research is needed.

Future Directions

Regardless of *why* pointing and learning are related, the current findings confirm that a robust and direct relation exists. Although the null findings from the 12-month-olds in Study 1 suggest that pointing gestures are not related to learning for this age group, it does not necessarily rule out the possibility of a relation between pointing and learning at this age. Instead, this null result may be due to a variety of factors. For instance, the task may have simply been too difficult for 12-month-olds. Had the task been easier (e.g., included a more extensive labeling phase), a relation between pointing and learning may have been found in 12-month-olds as well. Importantly, however, a study conducted by Pruden, Hirsh-Pasek, Golinkoff, and Hennon (2006) found that infants as young as 10-months can successfully fast map under very similar, minimal learning conditions—even when given a more stringent test of word learning (i.e., a disambiguation task). Thus, it is unlikely that the 12-month-olds failure to fast map was solely due to the diffficult nature of the task, as learning in this context is possible. Alternatively, as 12-month-olds have just begun to produce pointing gestures, they may not have not had sufficient experience pointing and receiving information in response to have acquired the expectation that their pointing gestures will *reliably* elicit information from others (Bates et al., 1975). Thus, it may be the case that 12-month-olds' pointing gestures toward objects did not result in superior learning about those objects as they have not yet acquired an expectation that information is consistently provided about pointed-to objects. To directly test this hypothesis, future research must examine the relation between infants' experience pointing (e.g., age of pointing onset) and ability to learn in response to their pointing gestures.

Similarly, although the null findings from Study 2 suggest that the relation between pointing and fast mapping is tailored to the object that the infant pointed toward, as opposed to pointing reflecting a general, heightened state of preparedness to learn, there are other, alternative explanations. For instance, infants' failure to provide evidence of learning labels for not pointed-to objects could have been due to a lack of interest in those objects or a heightened focus on the preferred/not-labeled object. Future research should aim to disentangle these hypotheses.

Future research should also investigate the extent to which infants' pointing gestures reflect a readiness to learn and the depth of that learning. Although 18-month-olds' pointing gestures toward objects did signal that they were in an optimal state to fast map labels onto objects in a live setting, under minimal learning conditions, this finding does not prove that they *truly* learned that novel label, in the symbolic sense. Fast mapping represents an important first step in word learning, yet retention and extension after fast mapping is another vital step for vocabulary development (Carey & Bartlett, 1978).

Pointing as a Mechanism to Boost Early Vocabulary

In addition to the theoretical contributions to the literature, the current study also has potential implications for intervention research. To help boost children's early vocabulary, parents are currently being inundated with messages about talking more often, in more diverse ways, with their young children. However, the current findings demonstrate that there is even more that caregivers can do. By increasing caregivers' awareness about when their infants are seeking out information through pointing and encouraging them to provide labels in response to those points, caregivers will be better equipped to provide their infants with a more appropriate level of scaffolding for word learning. These moments, when infants seek out information with their pointing gestures, reflect specific windows of time when infants are both able and ready to fast map labels onto objects. If infants' attempts to request information lead to superior learning, the next task for researchers is to figure out *how* to encourage infants to request information more often, so that caregivers have even more opportunities to capitalize on these unique and powerful teaching moments. This is particularly important for lower income, at-risk groups (Hart & Risley, 1995; Rowe & Goldin-meadow, 2009).

One way to encourage infants to request information more often would be to train infants to point more frequently. However, to date, studies testing the effectiveness of a pointing–training intervention on infants' vocabulary development have yielded mixed results. For instance, Matthews et al. (2012) trained 14-month-old infants to point more and did not see gains in infants' subsequent vocabulary. More recently, Lebarton, Goldin-Meadow, and Raudenbush (2015) trained 18-month-old infants to point more and found the exact opposite result: Training infants to point more led to increases in their subsequent vocabulary size. The current findings suggest that rather than training infants to increase their use of pointing gestures, it may be more effective to train parents to increase their responsiveness to infants' pointing gestures. This may help infants more fully understand the information-eliciting function of pointing gestures, which may in turn help them use their points as word-learning tools. Although some research has focused on increasing parental responsiveness to infants' prelinguistic communicative acts, that responsiveness is undifferentiated in terms of *which* communicative acts (e.g., pointing, reaching, vocalizations) parents are responding to (Yoder & Warren, 2002). The findings of the current study suggest that an intervention focused on infants' pointing gestures specifically may be the most fruitful.

Conclusion

The current study represents an important step in determining *how* infants' early pointing gestures impact early vocabulary development. Importantly, these findings are the first to show that infants' overall use of pointing gestures is not only related to their overall vocabulary size but also that the actual act of producing a pointing gesture uniquely signals that infants are in an optimal state to map labels onto objects. This finding drives home the importance of these gestures in the key transition from nonverbal to verbal communication.

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Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's website:

Figure S1. Proportion of looks to the target object during test based on communicative behavior (i.e., a point produced with a gaze alternation [GA] vs. a point produced without a gaze alternation) during the choice phase.

Figure S2. Time course of infants' (18-month-olds, study 1) looking behavior during the pre- and posttest phase based on the communicative behavior (point vs. no point) produced during the choice phase.

Data S1. Supplemental results.