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The role of pointing gestures in facilitating word learning

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THE ROLE OF POINTING GESTURES IN FACILITATING WORD LEARNING

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CERTIFICATE OF APPROVAL

PH.D. THESIS

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To my family, who still might not know exactly what I do, but support me unconditionally nonetheless

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ABSTRACT

Previous natural observations have found a robust correlation between infants' spontaneous gesture production and vocabulary development: the onset and frequency of infants' pointing gestures are significantly correlated to their subsequent vocabulary size (Colonnesi, Stams, Koster, & Noom, 2010). The present study first examined the correlations between pointing and vocabulary size in an experimental setting, and then experimentally manipulated responses to pointing, to investigate the role of pointing in infants' forming word-object associations.

In the first experiment, we elicited 12- to 24-month old infants' pointing gestures to 8 familiar and 8 novel objects. Their vocabulary was assessed by the MacArthur Communicative Development Inventory (MCDI): Words and Gestures. Results showed that 12-16 month old infants' receptive vocabulary was positively correlated to infants' spontaneous pointing. This correlation, however, was not significant in 19-24 month old infants. This experiment thus generalizes the previous naturalistic observation findings to an experimental setting, and shows a developmental change in the relation between pointing and receptive vocabulary. Together with prior studies, it suggests a possible positive social feedback loop of pointing and language skills in infants younger than 18 months old: the bigger vocabulary size infants have, the more likely they point, the more words they hear, and then the faster they develop their vocabulary.

In the second experiment, we tested whether 16-month-old infants' pointing gestures facilitate infants' word learning in the moment. Infants were randomly assigned to one of three conditions: the experimenter labeled an unfamiliar object with a novel name 1) immediately after the infant pointed to it (the point contingent condition); 2) when the infant looked at it; or 3) at a schedule predetermined by a vocabulary-matched infant in the point contingent condition. After hearing the objects' names, infants were presented with a word learning test. Results showed that infants successfully selected the correct referent above chance level only in the point contingent condition, and their performance was significantly better in the point contingent condition than the other two conditions. Therefore, only words that were provided contingently after pointing were learned. Taken together, these two studies further our understanding of the correlation between early gesture and vocabulary development and suggest that pointing plays a role in early word learning.

PUBLIC ABSTRACT

This project aims to study how infants' pointing gestures help them learn words. It builds on prior naturalistic observations that there is a robust correlation between the use of pointing gestures and vocabulary growth. The first study elicited 12- to 24-month-old infants' spontaneous pointing in an experimental task, and measured their vocabulary with a language questionnaire. We found that for infants younger than 18 months old, the larger vocabulary size they had, the more pointing gestures they showed when communicating with an adult partner about things they saw. This suggested a possible positive feedback loop of pointing and language skills in young infants: the bigger vocabulary size infants have, the more likely they point, the more words they hear, and the faster they develop vocabulary. A second experiment investigated the role of pointing in word learning by labeling objects when infants point, when they just look, or at predetermined time schedule. Results showed that infants were most successful in mapping words to correct objects when the words were introduced after they pointed. Therefore, pointing not only correlates to vocabulary development, but also facilitates word learning in the moment. This project is significant for several reasons. First, it furthers our understanding of the observed correlation between pointing and language learning. Second, the research has wide applicability to education and societal benefits. Understanding the contribution of infant pointing gestures to language learning inform intervention programs for at-risk populations in addition to leading to recommendations for parenting to enable earlier language acquisition.

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CHAPTER I: INTRODUCTION

Before infants can talk, they can use gestures to interact with the environment. Naturalistic observations show that children's gesture relates to their language development through the first few years. However, what is still unclear is the nature of this observed correlation. For instance, does gesture play a causal role in fostering language development, or does it simply reflect children's general communicative ability during the first few years? In this research study, we first elicited infants' pointing gestures in an experimental setting to verify the correlation between pointing gestures and language skills in 1-2 year old infants. In a second experiment, we experimentally manipulated 16-month-old infants' production of pointing gestures, and responses to infants' pointing, to provide further understanding of the role that gesture plays in the word learning process. Does contingent labeling after children's pointing gestures help children learn word-object associations? We focused on 16-month old children who were beginning to speak words, and were at a transition period in language development.

The pointing gesture usually emerges in human infants at about 12 months of age (e.g., Carpenter, Nagell, & Tomasello, 1998; Leung & Rheingold, 1981). Observational studies have found a robust correlation between infants' pointing skills and subsequent vocabulary growth (Blake, Vitale, Osborne, & Olshansky, 2005; Brooks & Meltzoff, 2008; Butterworth & Morissette, 1996; Desrochers, Morissette, & Ricard, 1995; Rowe & Goldin-Meadow, 2009a, 2009b; Rowe, Özçalışkan, & Goldin-Meadow, 2008). These correlational studies are suggestive that pointing is associated with language skills. However, in addition to signaling children's emerging linguistic skills, pointing gestures may also play a causal role in the process of children's language learning.

To begin to investigate this possibility, we need to experimentally manipulate the production of pointing gestures, and responses to pointing gestures, to investigate how it influences infants' word learning. The present study thus aimed to directly test whether infants' pointing gestures could help them learn the association between a word and an object. Specifically, we asked (1) whether infants' elicited pointing gestures in an experimental setting were correlated to their concurrent language skills; (2) whether 16-month-old infants would show superior word learning when new labels of novel toys were provided after they pointed to the toys.

Background

Early Language Development

Young children's word learning process is gradual and slow. By 7 months, infants are able to relate vowel sounds with objects when the movement of objects is temporally coordinated with the spoken vowel sounds (Gogate & Bahrick, 1998). By 12 months, infants understand approximately 50 words (Fenson et al., 1994) and begin to produce vocalizations that link to objects around them (Bloom, 2000). Infants say very few words during the transition from prelinguistic to linguistic communication.

Learning the names for objects is among the first achievements in language learning. Most children begin learning object names at around 12 months. Object names are predominant in children's early vocabulary, especially the first 50 words, during the second year (e.g., Bates et al., 1994). About 61%-65% of children's first 50 words were nouns (e.g., Benedict, 1979; Nelson, 1973). By the time the child is about 2 years old, s/he can produce, on average, more than 300 object names. Moreover, the proportion of nouns in 13-month-old's spoken vocabulary is positively associated with their overall vocabulary size (Bates, Bretherton, & Snyder, 1991). These results suggest that a good target for studying infants' word learning is noun learning, because nouns largely make up infants' early vocabulary and also noun learning correlates to overall vocabulary development.

When children learn object names, they need to accurately and robustly associate words with respective referents when they encounter words and objects. How do children acquire these sound/object correspondences? This is not easy because the child has to solve the problem of referential ambiguity, as the exact referent is unclear in most cases (Quine, 1960). The majority of research on early word learning focuses on perceptual, cognitive and social processes that may account for the variability in young children's word learning (e.g., Hollich et al., 2000; Smith, 2000; but see McMurray, 2007). For example, the child can use external cues in the environment to help them identify the correct referent, such as object salience (Hollich et al., 2000), the social partner's pointing, hands, or eye gaze (Akhtar & Tomasello, 2000). In addition, they can use perceptual and cognitive constraints, such as the shape bias, mutual exclusivity, contrast, the whole object principle, to disambiguate the word-object associations (e.g., (Golinkoff, Mervis, & Hirsh-Pasek, 1994; Jones & Smith, 2002; Samuelson & Smith, 1999). As they get older, they can use linguistic information, such as syntax, to constrain possible mapping between words and objects (e.g., Bloom, 2000; Diesendruck & Shatz, 1997; Waxman & Senghas, 1992).

The literature has thus documented rich evidence on perceptual, cognitive and social processes underlying infants' word learning. Besides these processes, infants' own communicative ability also contributes to language learning (Paavola, Kemppinen, Kumpulainen, Moilanen, & Ebeling, 2006; Paavola, Kunnari, & Moilanen, 2005; Wu & Gros-Louis, 2014a). Prior to the development of language, infants develop a rich prelinguistic communication system. The transition from prelinguistic to linguistic communication is suggested to be a continuous process (Reddy, 1999). Gestures are infants' predominant communicative behavior before they can talk; they thus precede and predict language development. In the current research, we focus on how infants' gestures might influence their language learning.

Gestures Precede Speech Production

Before infants can talk, children communicate mainly through gesture during the *prelinguistic* period. For example, a series of gestures – giving, showing, pointing, and ritualized requests – emerge before first words (Bates, Camaioni, & Volterra, 1975). In addition, children use gestures before they use words to refer to external entities in the environment. Iverson, Capirci and Caselli (1994) explored the gestural and spoken lexicons in the early vocabularies of 12 typically developing Italian children at 16 and 20 months of age. At 16 months, eight of the 12 subjects preferred communication in the gestural modality. Up to 20 months-of-age, children gradually employed more word types and used words more frequently than gestures. That is, children gradually switched from conveying messages largely via gesture at 16 months of age, to communicating mostly through speech by 20 months of age. Furthermore, Iverson and Goldin-Meadow (2005) found that object names were likely to be produced first in gesture and, on average, there was a 3-month gap between when an object name was conveyed through a gesture and when it was conveyed through speech. Sauer, Levine and Goldin-Meadow (2010) tracked gesture use and productive and receptive vocabulary in 11 children with pre- or perinatal unilateral brain lesions from 18 to 30 months of age. They found that 75% of 18-month-olds' new lexical items initially appeared in gestures and only 46% of 22-month-olds' new lexical items appeared first in gestures. Children thus gradually increase communicating via speech while decreasing their overall gesturing.

Together these data suggest that, at 18 months old, children are on the cusp of a transition from communicating commonly in gesture to communicating largely in speech. Therefore, in Experiment 1, we measured 12- to 24-month-old infants, aiming to replicate the prior finding of a correlation between pointing and language learning in an experimental setting. We also tested potential developmental changes in these correlations. In Experiment 2, we examined whether infants' pointing promotes superior word learning. We thus targeted 15-17 month old children, who gesture frequently and are about to move to a stage that shows significant increases in vocabulary.

Gestures Predict Language Development

Gestures not only emerge before speech production, but may also play an important role during the transition from prelinguistic communication to linguistic communication (Gullberg, de Bot, & Volterra, 2008). The sum of infants' production of actions and gestures reported by parents predicted receptive scores on the Reynell Developmental Language Scale at 18 months and expressive language scores on the Bayley Scale at 24 months (Laakso, Poikkeus, Katajamäki, & Lyytinen, 1999). Infants' frequency of gestures at 14 months related to their vocabulary size measured by the Peabody Picture Vocabulary Test at 42 months (Rowe et al., 2008). Notably, children from high SES families gesture more than children from low SES families, and these differences in early gesture predict the vocabulary disparities observed when they enter school at 52 months (Rowe & Goldin-Meadow, 2009a). In addition, the age when children produce supplementary gesture-plus-word combinations, in which gesture and speech express different semantic meanings through one single communicative act, predicts the onset of two-word combinations (Iverson & Goldin-Meadow, 2005; Özçalışkan & Goldin-Meadow, 2005). Rowe & Goldin-Meadow (2009b) further showed that the number of different meanings conveyed in gesture at 18 months predicted vocabulary size at 42 months, while the number of supplementary gesture-word combinations produced at 18 months predicted sentence complexity at 42 months, thus gesture selectively predicts vocabulary and syntactic skills. This correlation exists not only in typically developing children, but also in several atypically developing populations (Capone & McGregor, 2004; Sauer et al., 2010).

Development and Categorization of Gestures

There are mainly two kinds of gestures that children use to communicate during the prelinguistic stage: *deictic* gestures, which are gestures toward objects, events or people in the environment (e.g., *pointing* to an object, holding it up to *show* it or *give* it to another person, or *reach* toward an object), and *representational* gestures (sometimes called "recognitory" or "iconic", or "gestural names", such as flapping arms to symbolize "bird"). The key distinction between these two kinds of gestures is that the form of a representational gesture carries meaning. For deictic gestures, however, the form of the gesture does not, on its own, convey meaning; instead, the meaning comes from the object that is referred to by the gesture (e.g., Iverson & Goldin-Meadow, 2005). In addition, deictic gestures occur much more frequently than representational gestures and typically emerge earlier in development (Crais, Douglas, & Campbell, 2004; Thal &

Tobias, 1988).

Among all gestures, one deictic gesture, *pointing*, has received particular attention from developmental psychologists since the 1960s. For example, Werner and Kaplan (1963) described the pointing gesture as the first clear-cut expression of gestural reference to objects, thus it is of particular importance in the communicative interactions of the young child. A pointing gesture is usually defined as the extension of arm and hand (either whole-hand with palm down, or with an extension of an index finger) toward something (e.g., Liszkowski, Carpenter, Henning, Striano, & Tomasello, 2004). Although pointing usually emerges in human development at an average age of 12 months, wide variability in the age of onset has been reported; children are observed to produce pointing gestures between 8-15 months of age (Butterworth & Morissette, 1996; Camaioni, Perucchini, Bellagamba, & Colonnesi, 2004; Carpenter et al., 1998; Salomo & Liszkowski, 2013). As noted above, infants point before they are able to refer to objects, people, or places via speech. Their pointing skill improves during the second year of life, and continues developing with the onset of speech (Carpenter et al., 1998).

Infants appear to point for both non-communicative (point for themselves) and communicative (point for others) reasons. Bates and colleagues (1975, 1979) proposed that pointing develops from a non-communicative form (pointing without looking to the recipient) to a communicative form, when it is accompanied with gaze alternation to the social partner (Franco & Butterworth, 1996). Though communicative pointing gestures emerge later, they do not fully replace non-communicative gestures, because studies have shown that the existence of a solitary pointing gesture for self extends to the preschool years (Delgado et al., 2009, 2011). Delgado, Gómez and Sarriá (2009) observed 16 infants between 12 and 24 months of age in two non-communicative situations: when infants were alone and when a social partner was reading a book thus was inattentive. They found that 11 infants produced pointing gestures to conspicuous events (e.g., a radio-controlled car) in these two conditions; in particular, they did not orient looks to the partner in the second condition, showing no apparent intention to engage the attention of the inattentive partner. Delgado et al. (2011) further showed that this private gesture may focus infants' attention and keep a target in his or her mind. They tested 39 children between 2 and 4 years of age on a task, which was to discover a hidden toy after a delay period ranging from 45 to 60 seconds during which the child was left alone. Private pointing gestures were more likely to be found in children who were asked to remember where the toy was hidden (cognitive demand) than children who were simply waiting (no cognitive demand). Therefore, children point when they are alone, and these non-communicative pointing gestures may focus infants' attention.

Despite the importance of private pointing gestures, communicative pointing gestures have received much more attention from developmental psychologists because of their socio-cognitive function and their relationship with language and theory of mind. Bates and colleagues (1975, 1979) argued that only communicative pointing gestures represent infants' ability to influence a social partner's attentional states to jointly attend to a third object in a triadic interaction. Bates and colleagues proposed that pointing gestures were initially produced as an expression of self-interest in something (imperative point) and only later served as a socio-communicative tool to jointly engage others (declarative point). Imperative pointing is a way to control the other's behavior: the pointer wants the recipient to *do* something that will help in some way (e.g., by providing needed information or objects). For example, the child points to a cookie in order to request the partner to obtain that cookie for him. Declarative pointing is a way to express feelings or thoughts about something: the pointer wants the recipient to *feel* what the pointer already feels – the pointer wants to share his or her own emotion and attitude ("expressive" pointing, Tomasello et al., 2007) or information ("informative" pointing, Tomasello et al., 2007) with the recipient. In a word, while imperative pointing aims to use the partner as a tool to obtain desired things, declarative pointing aims to achieve a common ground between the pointer and the recipient so that both are attending to, or knowing, the same thing.

These communicative pointing gestures have been considered as one of the key joint-attention behaviors in order to focus *others*' attention on something that the pointer is interested in, or to disambiguate the referent during social communication (Brooks & Meltzoff, 2005; Camaioni et al., 2004; Mundy et al., 2007). Tomasello and colleagues (2007) proposed an even stronger social cognitive view of infants' communicative pointing gestures. This rich interpretation of the pointing function argues that at the very beginning of the development of pointing gestures, around 12 months old, the pointing gesture already serves the function of sharing intentionality and influencing others' mental states. For example, an infant points because s/he sees something, s/he knows that the partner does not see that thing, and s/he points to direct the partner's attention to the thing s/he sees, so that they establish a joint attention moment: they now know that they both are attending to the same target. In this way, the infant shares his or her own attention and interest, and also influences the partner's mental states from ignorant to knowledgeable of the targets. Pointing thus serves as a basis for the development of theory of mind understanding because of its representation of sharing and influencing mental states (Tomasello et al., 2007).

One communicative pointing gesture, declarative pointing, has been considered as unique in that it shows different ontogenetic and phylogenetic pattern than imperative pointing, and it has a stronger relation to language development (Colonnesi et al., 2010). Declarative pointing emerges later in development than imperative pointing does (Carpenter et al., 1998). In addition, children with Autism do not point declaratively for others, even though they point imperatively; therefore, declarative pointing has become one important diagnostic criterion for Autism (e.g., Baron-Cohen, 1991). In addition, human raised chimpanzees were reported to point imperatively, but not declaratively (e.g., Call & Tomasello, 1996).

In sum, the use of pointing gestures enables infants to focus their own attention on something (as shown in research on non-communicative pointing), to declare his or her interest in the environment, to request something, and to provide information. The clear and conventional nature of this type of gestures makes it easily understood by other people. Below we will review evidence that although generally speaking pointing predicts language development, declarative pointing shows a stronger correlation with language learning.

Pointing Gesture Precedes and Predicts Language Development

In addition to preceding language, pointing is considered to be associated with, and facilitative of, language acquisition. Communicative pointing at 12 months, before the onset of speech, correlates with the size of the lexicon at 20 months (Camaioni, Castelli, Longobardi, & Volterra, 1991). The onset of pointing around 10 months of age (median age = 10.7 months) is correlated to comprehension of object names (Harris, Yeeles, Chasin, & Oakley, 1995) and animal sounds at 14 months (Butterworth & Morissette, 1996), and is related to both expressive and receptive language at 24 months (Desrochers et al., 1995). Furthermore, unlike other gestures, pointing predicts subsequent vocabulary growth, which is suggestive of the special role of pointing gestures in language development. For example, observational studies have found that the number of different objects to which infants pointed at 14 months predicts the size of their vocabulary at 42 months (Rowe & Goldin-Meadow, 2009b; Rowe et al., 2008). In contrast to pointing, infants' reach-request and protest gestures (e.g., pushing things away) at 15 months are negatively related to language at 3 years (Blake et al., 2005).

In fact, these prior studies on pointing and language comprehension and production showed that there was a stronger correlation between pointing and language comprehension than to language production in infants younger than 2 years old (e.g., Bates, Thal, Whitesell, Fenson, & Oakes, 1989; Blake, Vitale, Osborne, & Olshansky, 2005; see also a meta-analysis by Colonnesi et al., 2010). Most of the above findings were obtained by naturally observing caregiver-infant interactions, thus it is possible that, in different instances, pointing gestures may represent different motives that associate with language development to different degrees. In fact, a meta-analysis shows that the effect size of the relationship between imperative pointing gestures and language outcomes is smaller than the relationship between declarative pointing gestures and language outcomes (Colonnesi et al., 2010). Bates et al. (1979) suggest that declarative pointing, not imperative pointing, is a first form of declaration, thus a first form of referring, and a first way to use an external object/event in order to get another person's attention. In addition, declarative pointing is likely to elicit caregivers' labeling responses (e.g., "that's a cup!"), which are closely related to infants' ongoing attention and interest; in contrast, imperative pointing usually receives caregivers' action responses (e.g., push the cup toward the infant) (Olson & Masur, 2013, 2015). These labeling responses to declarative pointing gesture may be one possible explanation for why declarative pointing bears a stronger correlation to language development than imperative pointing.

Although correlational studies have documented a significant relationship between pointing and subsequent language development, more direct evidence of the role of pointing in language learning comes from experimental studies that manipulate infants' production of pointing gestures and the responses infants receive to their points (LeBarton, Goldin-Meadow, & Raudenbush, in press). LeBarton et al. (in press) found that experimentally increasing children's declarative pointing led to an increase in children's overall gesture production, which positively correlated to children's speech production during follow-up interactions with their parents (LeBarton, Goldin-Meadow, & Raudenbush, in press). In this study, fifteen 17-month-old children received training at home once a week for 6 weeks. Children were randomly assigned to one of the three training conditions: (1) in the *child and experimenter gesture* (C & EG) condition, the experimenter pointed to a target picture, labeled it, and asked the child to point to it (e.g., the experimenter pointed to a dress in a picture book and said, "look at the dress! Can you do it? That's a dress!"); (2) in the *experimenter gesture* condition, the experimenter pointed at and labeled the target picture, but did not ask the child to do so; (3) in the *no gesture* condition, the experimenter just labeled the target picture, but did not point to it or ask the child to point to it. In addition, children were observed in free-play caregiver-child interactions at home before each training session and 2 weeks after the training session to assess children's gesture production in naturalistic interactions as a function of training. Results showed that in the C & EG condition, in which children were trained to point, the number of distinct gesture meanings children produced (gesturing at different things, e.g., a point at a dog is assumed to mean *dog* and is thus counted as one gesture meaning, while a point to a *bird* is counted as another gesture meaning) increased significantly both during training and in follow-up interactions with caregivers. Furthermore, gestures correlated to larger spoken vocabulary in follow-up interactions in the group whose gestures were experimentally increased. These experimental studies, in combination with prior observational studies, suggest a robust correlation between pointing gestures, especially declarative pointing gestures, and language learning.

Based on the above theoretical and empirical evidence, the current study focuses on infants' declarative pointing gestures and noun learning in infants 1- to 2 years of age, an age when children mostly use gestures to communicate with others, and are at the cusp of transitioning to linguistic communication. The reason for studying declarative pointing gestures is that pointing is the gesture children most commonly use during the second year, and, more importantly, declarative pointing has been suggested to play a special role in infants' language development. Given the naturalistic evidence that infants' production of pointing gestures relates to subsequent vocabulary growth over development, the goal of the present study was to investigate whether pointing gestures correlate to their concurrent language scores (Experiment 1), and further, whether pointing gestures could help word learning in the moment (Experiment 2).

Why Pointing Relates to Child Language Development

Even though many correlational studies have confirmed the robust association between infants' pointing gestures and language development, it is still unclear what mechanisms might underlie the observed relations. Below I will review several hypotheses that aim to explain the correlations.

First, some researchers argue that infants' early gestures continue to relate to speech because there is a unified "gesture-speech system". This hypothesis suggests that a change in one part of the system would influence the entire system. This hypothesis is based on the observation that the average age of motor milestones parallels that of language milestones (for a review, see Iverson, 2010). For example, at twenty weeks, infants begin to sit with support and also start vocalizing with consonant-like sounds. At 6 months, infants begin to sit independently and reach unilaterally while sitting; meanwhile, they start babbling with single-syllable utterances. Later around 12 months, infants start walking; at the same time, the first words emerge. Among those motor movements, gestures seem to be especially important in associating with language skills. Gesture and speech form a unified system as early as in infancy (Bates & Dick, 2002). Starting at 6 months, infants' manual arm movements begin coupling with vocalizations (Iverson & Thelen, 1999). By 2 years old, gestures and words are tightly coordinated both temporally and semantically (Butcher & Goldin-Meadow, 2000). That is, infants' babbling is accompanied with gesturing, and the meaning conveyed via gestures equals (e.g., points to a bird while saying "bird"), or supplements (e.g., points to a bird while saying "eat" to mean "the bird is eating"), the meaning conveyed via speech. Moreover, the age of the emergence of supplementary gesture-word (e.g., points to a bird while saying “eat”) correlates to the onset of two-word sentences (e.g., “bird eat”), which suggests the importance of gestures (Iverson & Goldin-Meadow, 2005).

The argument for a “gesture-speech” system is further supported by evidence from studies on atypically developing populations. For instance, Sauer et al. (2010) found that children who suffered pre- and perinatal brain lesions showed early vocabulary delays. Furthermore, they observed that naturally occurring perturbations that affect speech development also affect gesture, which is in support of the united system of gesture and speech.

In sum, this hypothesis suggests that a correlation between gestures and speech development exists because they are both components of one “gesture-speech” system. This hypothesis thus predicts that changes in one part of this system would impact the whole system over development. However, it does not have a clear prediction about whether pointing gestures would influence language learning in the moment.

A second hypothesis for how pointing supports language learning, which is not mutually exclusive to the first one, is that pointing gestures serve to elicit verbal responses from social partners, which facilitate language development (Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007; Kishimoto, Shizawa, Yasuda, Hinobayashi, & Minami, 2007; Wu & Gros-Louis, 2014b). Empirical studies have provided support for this hypothesis. Caregivers have been shown to provide more verbal comments after children produce pointing gestures compared to when they do not produce pointing gestures (Kishimoto et al., 2007; Wu & Gros-Louis, 2014b). Olson and Masur (2013) compared mothers’ responses to children’s gestural and non-gestural bids in three communicative contexts: proto-declarative, proto-imperative, and ambiguous. Gestural bids referred to bids that contained gestures, such as pointing, reaching, object extension, and showing, while non-gestural bids included vocalizations, looks toward objects, and gaze to the mother. Mothers were more likely to provide verbal responses to infants' gestures as compared to non-gestural communication, even when comparing gestural and non-gestural bids that were accompanied by vocalizations. This suggests that it is the gestural component of the bid that elicits more verbal responses. Furthermore, mothers responded with object labels to gestural bids more than non-gestural bids in proto-declarative and ambiguous communicative contexts, but not the proto-imperative context. Thus, results showed that both infants' communicative modality and communicative intent influenced maternal responsiveness; however, because vocalizations often co-occurred with gestural bids in the contexts in which mothers provided more label responses, and gestural bids included a range of gestures, it was difficult to determine exactly which behavior elicited the responses.

Wu and Gros-Louis (2014b) directly compared parents' label responses to infants' pointing gestures and object-directed vocalizations. The results again confirmed that infants received object labels more reliably after pointing than after babbling. This is significant given the finding that rates of mothers' object labeling responses after infants points has been shown to predict infants' cumulative object-labeling vocabularies (Masur, 1982). In addition, words produced by mothers in response to infants' points (i.e. translations of infants' points) are more likely to enter children's vocabulary than words referred to by gestures that are not translated by mothers (Goldin-Meadow et al., 2007).

In sum, these studies suggest that infants' pointing gestures may create more word learning opportunities by eliciting linguistic input from social partners (Brooks &

Meltzoff, 2008). They also imply that it is actually the verbal reaction elicited from social partners that helps with word learning, but not the gesture itself. This is consistent with substantial findings that the amount of mothers' prompt, contingent and sensitive responses to infant behavior is positively correlated to larger receptive and productive vocabulary size (e.g., Gros-Louis, West, & King, 2014; Rollins, 2003; Tamis-LeMonda, Bornstein, & Baumwell, 2001). Note that gestures are not the only way children elicit contingent responses from social partners. For example, a social partner may follow infants' gaze direction and provide comments related to infants' attentional focus. Previous studies have shown that infants as young as 16 months can also learn in this situation (Baldwin, 1991; Tomasello & Farrar, 1986). From this perspective, one would expect to find that, given the same linguistic input provided contingently after infants' pointing behavior and after just looking, infants would learn the information equally well.

A third hypothesis for how pointing may contribute to language development is that, in addition to eliciting label responses, infants' pointing gestures may organize the timing of social feedback so that it occurs when the infant is in a state conducive to learning. For example, pointing gestures may serve as a signal of focused infant arousal and attention to an object in a similar way as object-directed vocalizations (Goldstein, Schwade, Briesch, & Syal, 2010). Goldstein et al. (2010) found that the more 12-month-old infants vocalized to an object, the more likely it was that they would distinguish the shape of that object; moreover, words provided after infants vocalize to the objects were more likely to be learned than the words provided after looking. They thus argued that infants' vocalizations may help them encode information about the objects they vocalize to, as well as the sound corresponding to the objects. Infants' pointing gestures also have been shown to be indicative of infants' attention and interest (e.g., Tomasello et al., 2007). Therefore, it might be possible that infants' pointing gestures help them focus on the thing to which they have pointed, which facilitates learning.

In addition to the focused attention, pointing gestures may show what infants *want to learn*, and this interest expressed via pointing leads to superior learning (Begus, Gliga, & Southgate, 2014). Begus and Southgate (2012) demonstrated that 16-month-old infants pointed more frequently to novel objects when confronted with a knowledgeable partner than with an ignorant partner. The knowledge state of the partner was established by having the partner label familiar objects correctly or incorrectly. They suggested that if infants are requesting information, infants expected their pointing behavior to be responded to with reliable information; if they perceived the partner to be unreliable, they would not point much when seeing novel objects. A further study showed that infants replicated an action on an object more successfully when the action was demonstrated on an object to which they had pointed than on an object they saw, but did not point to (Begus et al., 2014). This suggests that pointing gesture may reflect a state when infants are highly motivated to learn the information about the referent they point to.

Lastly, the pointing gesture may lessen cognitive loads for learning as shown in older children and adults (Cook & Goldin-Meadow, 2006; Cook, Mitchell, & Goldin-Meadow, 2008; Cook, Yip, & Goldin-Meadow, 2010; Delgado, Gómez, & Sarriá, 2011; Goldin-Meadow, Cook, & Mitchell, 2009). For example, Cook et al. (2008) investigated whether gestures play a causal role in learning how to solve mathematical equivalence problems (e.g., children were asked to fill in the blank in the equivalence: 3+2+5 = __+5). In the experiment condition, the experimenter demonstrated gestures that highlighted a correct way to solve this problem, and then asked 3rd and 4th grade students to reproduce the gestures. After training, students were tested on their ability to solve similar mathematical problems. Cook et al. (2008) found that this experimental manipulation increased students' gesture production, and the increased gestures further increased students' retention of knowledge gained during the training phase. By contrast, if children were just asked to speak about the methods but were not allowed to gesture, they were not likely to retain the methods learned from the instruction phase at a 4-week follow-up test session (Cook et al., 2008). Children who were not allowed to gesture learned more poorly than children required to produce partially correct gestures, who were worse than children who were asked to produce correct gestures (Goldin-Meadow et al., 2009).

Other research suggests that gestures not only make mathematical learning last, but also make memories of describing video vignettes last (Cook et al., 2010). In this study, college students viewed short vignettes, and then described what they had seen to the experimenter in one of the three ways: they could describe the video vignettes freely as what they normally do, or they were instructed to gesture when describing, or they were not allowed to gesture at all when describing. Participants were then asked to recall the video clips immediately after a short distractor task, or after 3 weeks. Spontaneous gesturing and instructed gesturing seemed to facilitate free recall of information, especially after 3 weeks.

These studies show that gestures play a causal role in encoding and recalling information, suggesting that gestures may lessen cognitive demands to promote learning. In terms of pointing, a particular kind of gesture, there is also evidence that young children may use it as a cognitive tool. For example, Delgado et al. (2011) showed that preschoolers may also use pointing as a cognitive tool; children perform better on tasks of memorizing the location of hidden objects when allowed to point freely than being constrained from pointing. Though Delgado et al. (2011)'s study investigated private pointing gestures, it might be possible that the interpersonal communicative pointing gestures also focus infants' attention on the target, help them process the information associated with it, and make memories of such information last.

In summary, several lines of evidence suggest a robust correlation between pointing gestures and language development, and several possible explanations exist for the observed correlation: a unified system of gesture-speech, a social-mediating function of eliciting verbal reactions, and a "readiness" to learn reflecting focused attention or increased arousal, motivation to learn, and/or saving cognitive resources.

Specific Aims and Predictions

Though a number of studies have reported correlational findings, to our knowledge, no studies have so far investigated the on-line effect of pointing gestures on word learning. Do pointing gestures merely correlate to language acquisition milestones because pointing gestures simply reflect a general communicative ability, or do gestures actually have an impact on word learning in real-time contexts? Because the previous findings that pointing gestures correlate to language development were obtained from natural observation of parent-child free play interactions, we first aimed to replicate the correlational findings in an experimental setting. As aforementioned, the motives underlying pointing gestures during free-play interactions may be multiple and mixed. But declarative pointing gestures have been suggested to bear a stronger correlation to language development than pointing gestures with other motives (e.g., Colonnesi et al., 2010). Thus, in the first experiment, we aimed to elicit infants' declarative pointing gestures to investigate the correlation between these declarative pointing gestures and infants' language outcomes measured by MacArthur Communicative Development Inventory (MCDI). Moreover, we examined the developmental changes in these correlations. In the second experiment, we focused on children who are transition to the one-word stage to examine whether pointing gestures play a role in word learning.

More specifically, in the first experiment, we elicited infants' pointing using previously established experimental methods. We presented infants with familiar objects and novel objects that popped out of window openings on a curtain, which was in view of infants but behind the experimenter (e.g., Liszkowski et al., 2004). Infants' language skills were measured by the MacArthur Communicative Development Inventory: Words and Gestures (Fenson et al., 1993). The first aim of this experiment was to examine concurrent correlations between infants' production of points and their language skills. Prior studies mainly found that early pointing gestures predicted subsequent vocabulary growth (e.g., Bates et al., 1979; Brooks and Meltzoff, 2008; Camaioni et al., 1991; Carpenter et al., 1998; Desrochers et al., 1995; Harris et al., 1995). Does infants' existing vocabulary size correlate to their production of spontaneous pointing gestures concurrently? The second aim of this experiment was to examine developmental changes in the correlations between pointing and vocabulary in children at different ages. We expected to find a high correlation between infants' pointing gestures and their MCDI scores, but this correlation may be different for children at different ages. As infants gradually use more words than gestures toward the end of their second year (Capirci, Iverson, Pizzuto, & Volterra, 1996), the correlation between their pointing and language may be weaker than that in infants who are younger, and are at the cusp of transitioning to linguistic communication (younger than 18 months old).

The second study aimed to directly test whether infants' pointing gestures could help them learn the association between words and objects in moment-to-moment interactions, rather than examining associations over time as prior studies have done. Specifically, we asked whether 16-month-old infants would show superior learning when they received labels about referents to which they pointed. We experimentally elicited infants' points and provided labels at different times. Infants were assigned to one of three conditions: the experimenter labeled an unfamiliar object with a novel name (a nonsense word created by researchers, e.g., "stad") 1) immediately after the infant pointed to it (the point contingent condition); 2) when the infant looked at it (the look contingent condition); or 3) at a schedule predetermined by a vocabulary-matched infant in the pointing condition (the yoked control condition). In the third condition, therefore, infants heard labels at the same times in the trial as the matched infant, but the label was unrelated to their own behavior. After hearing the objects' names, infants were presented with a word learning test: on each testing trial, two previously seen objects were shown to the infant side by side and the experimenter asked the infant to choose an object by requesting it by its name (e.g., "can you get the stad?").

As aforementioned, one hypothesis posits that infants' pointing gestures just serve a social mediating function, that is, they create more word learning opportunities by eliciting linguistic input from the environment. This viewpoint implies that it is the prompt, contingent responses that actually facilitate learning. Given the same linguistic feedback provided when infants point and just look, it is predicted that no significant differences would be found between the point contingent condition and the look contingent condition. The yoked control condition is tricky, because labels were provided at a predetermined time schedule, thus the labeling response was not contingent on infants' own behavior. However, previous studies have shown that a social partner's labeling an object increases infants' attention to that object, and this effect is sustained even beyond when the labeling occurs (Baldwin & Markman, 1989). Therefore, it is possible that when the experimenter starts labeling, the child will increase his or her attention to the target object and the word corresponding to it (Baldwin, 1991), which would make infants' performance in the yoked control condition no different from the look contingent condition.

Another possibility is that pointing gestures may reflect, or even create a state that is conducive for word learning. No matter whether it is because pointing focuses infants' attention on the target object, or motivates infants to learn or via other mechanisms, it would predict that infants form word-object associations better when the word is provided after they have pointed to the referent. Therefore, this perspective predicts that infants learn object labels better in the point contingent condition than in the other two conditions.

CHAPTER II: CORRELATIONS BETWEEN POINTING AND LANGUAGE

Previous studies that reported correlations between pointing gestures and language development observed pointing gestures during free-play interactions. These natural observations provide rich data on infants' spontaneous pointing behavior during social interactions, and correspondences to language measures; however, very few studies have investigated whether infants' language abilities also influence their pointing behavior in experimental tasks that are used to elicit infants' pointing gestures. If infants' pointing gestures reflect their preverbal communicative ability, one would expect that the better language skills a child has, the more often a child would point during an experimental setting.

A commonly used paradigm to elicit infants' declarative pointing gesture is showing infants interesting events from afar (i.e., out of the infants' reach), while experimentally manipulating the social partner's attention and responses (e.g., Liszkowski et al., 2004). In this way, one can investigate how young infants communicate with others about what they see. Experimenters usually measures infants' behavior in terms of the number of events to which infants pointed, across the entire session, whether infants pointed repeatedly within an event, the duration of the point(s), and whether infants looked to the partner's face. For example, Liszkowski et al. (2004) instructed an adult partner to react to 12-month-old infants' pointing behavior by sharing the infants' attention and interest (the joint attention condition), only looking at the infants' face (the face condition), only looking at the event but not looking back to infants' face (the event condition), or ignoring infants by looking at their own hands (the ignore condition). Liszkowski et al. (2004) found that in the joint attention condition, infants pointed the most often across the entire session. Similar results were found in additional studies, suggesting that infants as young as 12 months old point less if the adult already notices the event, but more if not. Gradually however, if the adult partner continued ignoring or not sharing the infants' emotion, infants decrease pointing over time (Liszkowski, Albrecht, Carpenter, & Tomasello, 2008; Liszkowski, Carpenter, Striano, & Tomasello, 2006; Liszkowski, Carpenter, & Tomasello, 2007).

These studies thus provide a way for us to elicit infants' production of pointing gestures. In the current study, we elicited infants' pointing by protruding familiar and novel objects out of window openings on a curtain, which was in front of the infant but behind an experimenter. As a response to infants' pointing, the experimenter followed the infant's pointing, looked back and forth between the infant and the object, and labeled the object (a typical response to pointing, see Masur, 1997; Wu & Gros-Louis, 2014b). We then coded infant's pointing behavior; meanwhile, we measured their language skills by requesting parents to fill out MCDI forms.

Two age groups of infants were tested. One group of infants was younger than 18 months old (12- to 16-month-olds). These infants' communicative modality was primarily gestures. The other group of infants was older than 18 months old (19- to 24-month-olds). These infants were transitioning to communicating primarily with words. We thus examined the potential developmental changes in the correlations between pointing and language skills in children at different ages.

Method

Participants

Forty-four 12- to 24-month-old infants (20 females; mean age = 17 months 14 days, *SD* = 108 days, range 12 months 29 days – 23 months 22 days) participated in this study. These infants were further categorized into two age groups: *younger* group (9 females; mean age = 14 months 3 days, *SD* = 26 days, range 12 months 29 days – 16 months 3 days) and *older* group (11 females; mean age = 20 months 27 days, *SD* = 27 days, range 19 months 18 days – 23 months 22 days).

An additional 5 infants were tested but excluded from analysis due to fussiness. The criterion for exclusion was: If infants failed to notice the toy due to looking at something else or becoming upset on more than half of the test trials (i.e., more than 8 trials). If infants completed more than 8 test trials, then only the trials on which the infants were fussy out were excluded from the analysis (1 infant completed 10 test trials and 2 infants completed 9 test trials).

Materials

The experiment set-up (see Figure 1) was adapted from previous studies on infants' pointing behavior to assess infants' gesture production as a function of the experimenter's attention and responses (Liszkowski, Albrecht, et al., 2008; Liszkowski et al., 2004). Testing took place in a 2.79 m $\times$ 4.17 m testing room. The infant was seated in an infant booster seat 1.27 m in front of a large off-white curtain, which blocked the entire back of the testing room. Experimenter 1 was seated facing the infant from a distance of about 40 cm, with her back to the curtain from a distance of about 20 cm. The curtain had eight openings through which stimuli were protruded one at a time by

Experimenter 2, who was out of view behind the curtain. Four openings were on the left and four were on the right side of the infant. The openings (six of them 1.02 m and two of them 1.47 m from the floor) were symmetrically positioned at about 60, 45, 30 and 15 degrees left and right from the infant's midline. The mother was seated in the corner of the room, and was asked not to interfere with the study. She was asked to fill out a language measurement and a demographic questionnaire throughout the experiment.

A total of 20 stimuli were used: 4 animal hand puppets with distinctive colors and features were used in the warm-up trials. They were a black and white spotted cow, a gray elephant, a giraffe, and a brown and black striped tiger. If an infant was scared of a certain puppet(s) as reported by his or her parent before the experiment started, then that puppet(s) would be replaced with another puppet from a selection of four additional puppets: a brown bear, a black cat, a pink pig, and a zebra. None of the puppets produced sound.

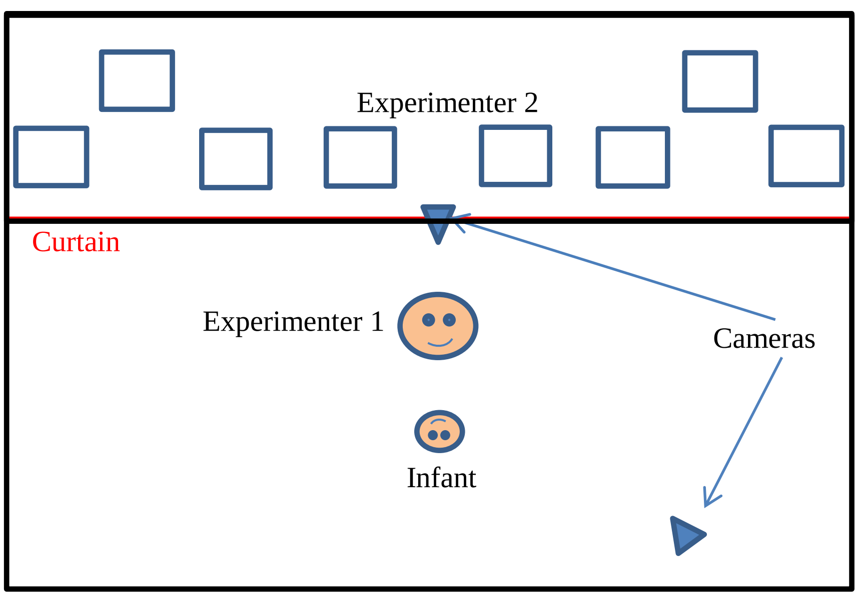


Figure 1. Schematic representation of the set-up of Experiment 1.

Eight familiar objects and 8 novel objects were used as testing stimuli. The familiar objects had typical shapes that are common in infants' daily life. They are known by roughly 66% of all 18-month-old children, according to the MacArthur-Bates Communicative Developmental Inventory Lex2005 database. These 8 familiar objects were drawn from the pool: a ball, a book, a car, a cup, a cat, a dog, a duck, a hat and a shoe (see Figure 2). The 8 novel objects were also drawn from a pool of items created in the laboratory (see Figure 3). Prior to the start of the experiment, parents were given pictures of the familiar and novel items and asked to check how familiar the child was with each item based on a 5 point scale (1-not familiar, 5-very familiar). Parents reported that infants were very familiar with the known items (mean rating = 4.49, *SD* = 0.58), and unfamiliar with the novel items (mean rating = 1.18, *SD* = 0.37).

Words that conformed to the phonological rules of English but had no known referent (*zorch*, *geep*, *dax*, *wug*, *youk*, *foom*, *tife*, *biss*) were used as novel names. The words were drawn from a database of words used in previous word learning studies (Horst, NOUN database, 2009).

Figure 2. Familiar items used in Experiment 1.

Figure 3. Novel items used in Experiment 1.

Experimenter 1 wore a pair of blue-tooth earphones, which were connected to the blue-tooth system on Experimenter 2's cellphone that played the reminder ringtone for interacting during the experiment (details below). A squeaky toy, which produced a squeak when squeezed, was used by Experimenter 2 to get the infant's attention to the curtain. Two cameras (Sony EVI-D100) recorded the interaction. One camera, positioned at the infant's midline and above the head of Experimenter 1, recorded the infant. A second camera was positioned in a corner opposite the curtain, and recorded Experimenter 1 and the curtain. Both cameras were routed through an audio-video mixer (Datavideo SE-800AVK) to allow for picture-in-picture recording. Infants wore overalls containing wireless microphones (Sennheiser ew 300 IEM G2) to obtain recordings of vocalizations. If the infant refused to wear the overalls, the experimenter placed the overalls underneath the infant's seat to record the sound.

Procedure and Design

Infants were exposed to 20 trials in total, including 4 warm-up trials, 8 familiar object trials, and 8 novel object trials. Before the experiment started, Experimenter 1 played with the child for 30-40 seconds. She smiled at the infant, touched the infant gently, and sang a song if the infant liked. She then demonstrated pointing gestures by calling out the infant's name, pointing to the decorations on the wall, looking back and forth between the infant and the items she pointed to while labeling (e.g., "*look, that's a tiger*!"). These items were stickers of a tiger, a zebra and an elephant that were already in the room. This was done with two aims: to calm down infants by getting them familiar with the room, and to demonstrate pointing gestures.

When Experimenter 1 judged the child was ready, she said "we are ready to play!" to signal Experimenter 2 to display the object from behind the curtain. Experimenter 1 stopped talking, refrained from interaction with the infant to avoid distraction, and looked at the child with a smiling face. At the same time, Experimenter 2 squeezed the noise maker to get the child's attention, protruded one object out of one window opening, and started two timers on her cellphone. One timer is 30 seconds, which signals the end of each stimulus presentation; the other timer is 15 seconds, which is to remind Experimenter 1 to provide a prompt if the infant does not point. The object was displayed in the visual field of the infant right behind Experimenter 1 and bounced rhythmically for 30 seconds, during which period the child could point to it. We used the squeaky toy to make sure that the infant noticed the objects shown on the curtain in all trials.

During the first 15 seconds, Experimenter 1 ignored the object until the child pointed to it. We defined pointing following the criteria of Liszkowski et al. (2004), that is, the infant extending the arm and index finger or open hand, palm down, in the direction of the stimulus. If the child pointed during the first 15 seconds, Experimenter 1 reacted immediately by following the child's points, sharing attention with the infant, acknowledging that she saw what the child pointed to, and labeling the object 4 times. For example, she looked back and forth between the child and the object, while saying, "Oh wow! Look, [child's name], it is a [label]! Look at the [label]! That is a [label]! It is a [label]". For the familiar object, the label is the object's name, such as a book, a car, etc. for the novel object, the label is a nonsense word preassigned to each novel object. Experimenter 1 did not use adjectives such as 'interesting', 'cool', 'yellow', etc., because young children may not know those words and might think they are novel names similar to novel labels such as ‘modi’, which may be a confound. After labeling, Experimenter 1 remained looking at the infant. If the child pointed to the target object again, she reacted in the same manner. This continued until the trial ended.

If the child did not point during the first 15 seconds, Experimenter 1 waited and smiled encouragingly until she heard the “beep” sound over her Bluetooth earphones, which were connected to Experimenter 2’s cellphone. This reminder ringtone was set by Experimenter 2 to count down 15 seconds from the beginning of the presentation. At the time when Experimenter 1 heard the sound, she prompted the child by saying, “What are you looking at? Can you show me?” She then waited for the child to point. If the child pointed, she reacted in the same manner as described above. Note that Experimenter 1 only prompted if the child did not point at all during the first 15 seconds; if the child already pointed spontaneously, no prompts were provided.

If the child did not point even after the prompt, that is, the child did not point at all during the whole trial, the trial ended and they moved to the next trial. Experimenter 1 would hear another reminder ringtone at 30 seconds (a different ringtone than the 15 second reminder), which signaled the end of the trial. If the child pointed close to the end of the trial, Experimenter 2 waited a little for Experimenter 1 to finish labeling the object 4 times before withdrawing the objects.

If the child pointed a second time while the object was displayed during the 30-second trial, Experimenter 1 repeated the same response as described above. If the child pointed when the object was not displayed, or the child pointed to something else in the room but not to the target object shown on the curtain, Experimenter 1 did not follow their point and briefly commented on their behavior (e.g., "Aha, that was a nice point," following Liszkowski et al., 2004). If the child pointed at the end of the trial after the object was withdrawn from displaying, Experimenter 1 reacted by saying, "Oh, it is gone!"

The same procedure was used for the 4 warm-up trials, 8 familiar object trials and 8 novel object trials. The 16 test trials were organized in 2 blocks, with 4 familiar object trials and 4 novel object trials in each block. The order of presenting familiar and novel objects was counterbalanced both within infants and across infants: half of the infants with order A were first exposed to a familiar object, followed with a novel object in the first block; in the second block, they were first exposed to a novel object, followed with a familiar object. In contrast, the other half of infants with order B were first exposed to a novel object, followed with a familiar object in the first block; in the second block, they were first exposed to a familiar object, followed with a novel object trial, or vice versa. The left and right position on the curtain was counterbalanced. The order of different familiar and novel objects and different window openings was randomly assigned.

Coding and Reliability

MCDI scores were calculated according to the MCDI manual, and comprehension, production and gesture scores were calculated separately. All video coding was done using ELAN (EUDICO Linguistic Annotator: Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands <http://www.lat-mpi.eu/tools/elan/>; Lausberg & Sloetjes, 2009), a free software program that allows for coding that is timelocked with the video data. We were primarily interested in infants' points during the 30-sec test trials. Only pointing to the test objects was included in analyses. Points were defined following the criteria of Iverson and Goldin-Meadow (2005). That is, the infant extending the arm (either fully or slightly bent) and index finger (*index point*) or open hand (*palm point*), palm down, in the direction of the stimulus. We first coded whether a pointing gesture occurred during each trial when an object was protruded, and how many points occurred if the child produced more than one within a trial. If the child pointed spontaneously, without any prompt from Experimenter 1, the trial was coded as "*spontaneous point*"; if the child pointed after Experimenter 1 prompted them at the 15 second time point (Experimenter 1 heard the reminder ringtone and prompted the child at 15 seconds if the child did not point spontaneously during the first 15 seconds), then the trial was coded as "*prompted point*"; if the child did not point at all during the 30 seconds, the trial was coded as "*no point*".

Three main measures were derived from the points coded across trials:

Proportion of trials with a point: number of trials in which the infant pointed at least once spontaneously divided by the total number of trials (proportion of trials with a spontaneous point), or number of trials in which the infant pointed after prompts divided by the total number of trials (proportion of trials with a prompted point).

Proportion of trials with repeated points: number of trials in which the infant pointed more than once divided by the number of trials in which the infant pointed. Because it is hard to tell whether a second point within each trial was produced spontaneously or prompted by the experimenter (e.g., the experimenter's labeling response to the first point or the questioning occurred at the 15^{th} second), we did not distinguish repeated spontaneous points and repeated prompted points. Therefore, any trial that had more than one point to the target object was counted as a trial with repeated points.

Proportion of infants who pointed spontaneously: Number of infants who pointed spontaneously divided by total number of infants who participated in each trial.

Latency to point: Mean time interval between stimulus onset and point onset.

Videos were coded by three trained assistants, who had to reach 95% accuracy on practice videos before coding independently. Inter-observer reliability was assessed by a second coder, who coded 20% of the videos. All coders were blinded to the hypotheses of the study. Reliability was excellent: Cohen's Kappas on a 1-sec time-base were .99 for proportion of trials with points, .90 for repeated point, and .96 for latency of point onset. These were similar to the coding reliability reported by Liszkowski et al. (2004).

Results

We first present descriptive data of measures of infants' pointing gestures and communicative skills. Results of Shapiro-Wilk tests showed that the data of older infants' pointing measures and comprehension scores were not drawn from a normal distribution, $ps < .01$. The data remained non-normal even after using commonly used transformations, such as transformation of arcsin, natural log, and square root. Therefore, non-parametric tests were used to examine age and gender differences in pointing and language skills. In addition, we used R (R Core Team, 2012) and lme4 (Bates, Maechler & Bolker, 2012) to perform a logistic linear mixed effects analysis, aiming to examine how infants' age, gender, language comprehension and production, gesture scores, and the trial type (familiar vs. novel object), trial number and order of presentation influenced the production of pointing.

Age and Gender Differences

Proportion of trials with point(s). Because a few infants (3) were shown less than 16 stimuli (because of fussiness), the pointing gesture analysis was carried out on mean proportions. The descriptive data of the proportion of trials on which infants pointed to familiar and novel items, split by age, is presented in Table 1.

Table 1. Descriptive data of proportion of trials with a point to familiar and novel objects.

	Familiar object			Novel object		
	NP	PP	SP	NP	PP	SP
Younger age group						
Mean	.47	.05	.48	.47	.08	.44
SD	.35	.09	.36	.34	.12	.36
SE	.08	.02	.08	.07	.03	.08
Median	.45	.08	.55	.44	.00	.44
Range	0-1	0-.25	0-1	0-1	0-.38	0-1
Older age group						
Mean	.15	.05	.80	.16	.07	.77
SD	.21	.08	.25	.24	.12	.30
SE	.04	.02	.05	.05	.03	.06
Median	.00	.00	.88	.06	0	.88
Range	0-.63	0-.25	.25-1	0-.75	0-.38	.13-1
All infants						
Mean	.31	.05	.64	.32	.08	.60
SD	.33	.09	.35	.33	.12	.37
SE	.05	.01	.05	.05	.02	.06
Median	.19	.00	.75	.16	.00	.63
Range	0-1	0-.25	0-1	0-1	0-.38	0-1

Note: NP = no point; PP = prompted point; SP = spontaneous point; SD = standard deviation; SE = standard error of mean.

As shown in Table 1, the most frequent behavior is spontaneous point; infants overall pointed spontaneously to familiar objects in 64.15% of trials and to novel objects in 60.47% of trials. Related-samples Wilcoxon signed rank test showed no significant difference between spontaneous pointing in the familiar and novel object trials, standardized test statistic = 1.28, p = .20. The next most frequent category was no point, even after prompted by the experimenter (32.96% to familiar objects and 32.93% to novel objects, no significant difference between familiar and novel trials, related-samples Wilcoxon signed rank test = .12, p = .91). Infants overall pointed very little after being prompted; they only pointed after prompts in 5.23% of familiar object trials and 7.73% of novel object trials (no significant difference between familiar and novel trials, related-samples Wilcoxon signed rank test = -1.43, p = .15). Even excluding the trials with spontaneous points (infants did not have a chance to hear the prompts if they pointed spontaneously already), they pointed in 18.85% of familiar object trials and in 23.32% of novel object trials.

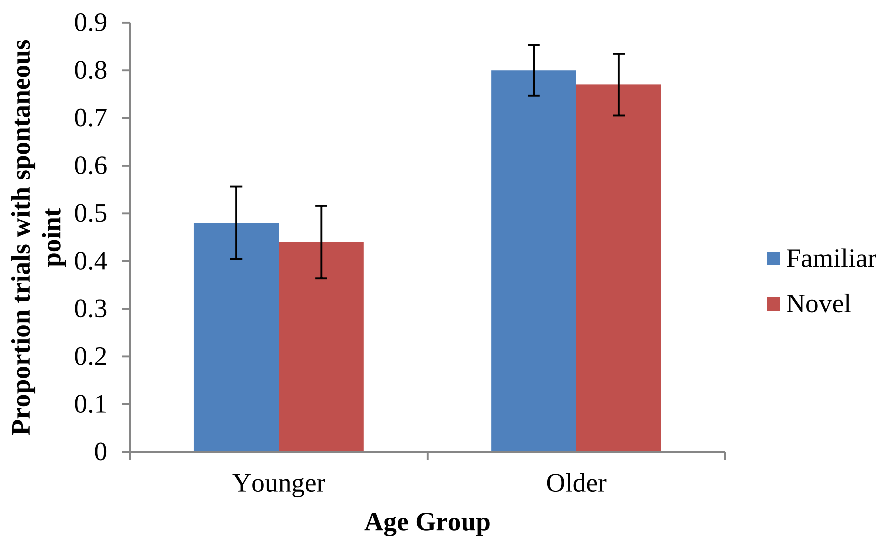


Figure 4. Proportion of trials with spontaneous points in the younger and older age group. The error bars represent the standard error of the means.

Figure 4 depicts the mean proportion of trials with spontaneous pointing as a function of age and trial type (novel and familiar object trial). No significant differences between novel and familiar trial types were found in either age group, related-samples

Wilcoxon signed rank test = 1.25, -.26, *p*=.21, .79, respectively for younger and older age group. Regarding the familiar object trials, the proportion of trials in which infants had pointed spontaneously was higher in the older age group (*M* = .80, *SD* = .25) than the younger age group (*M* = .48, *SD* = .36), Mann – Whitney test *z* = 3.17, *p* = .002; whereas, the proportion of trials with no pointing was lower in the older age group (*M* = .15, *SD* = .21) than the younger age group (*M* = .47, *SD* = .35), Mann – Whitney test *z* = 3.27, *p* = .001. No age difference was found in the proportion of trials with prompted points. Regarding the novel object trials, similar findings were found: proportion of trials in which infants had pointed spontaneously was higher in the older age group (*M* = .77, *SD* = .30) than the younger age group (*M* = .44, *SD* = .36), Mann – Whitney test *z* = 2.77, *p* = .006; whereas, proportion of trials with no pointing was lower in the older age group (*M* = .16, *SD* = .24) than the younger age group (*M* = .47, *SD* = .34), Mann – Whitney test *z* = 3.17, *p* = .002. No age difference was found in the trials of prompted points.

Regarding gender differences, males (*M* = .43, *SD* = .36) had more trials with no pointing to novel objects than females (*M* = .18, *SD* = .23), Mann – Whitney test *z* = 2.26, *p* = .02. In addition, males (*M* = .04, *SD* = .10) had a lower portion of trials with prompted pointing to novel objects than females (*M* = .12, *SD* = .13), Mann – Whitney test *z* = 2.33, *p* = .02. Males and females did not differ significantly in spontaneous pointing to novel objects, or any pointing to familiar objects, *p*s > .10.

Proportion of trials with repeated points. We calculated the proportion of trials with repeated pointing (number of trials with repeated pointing divided by the number of trials in which infants pointed). The results are reported in Figure 5.

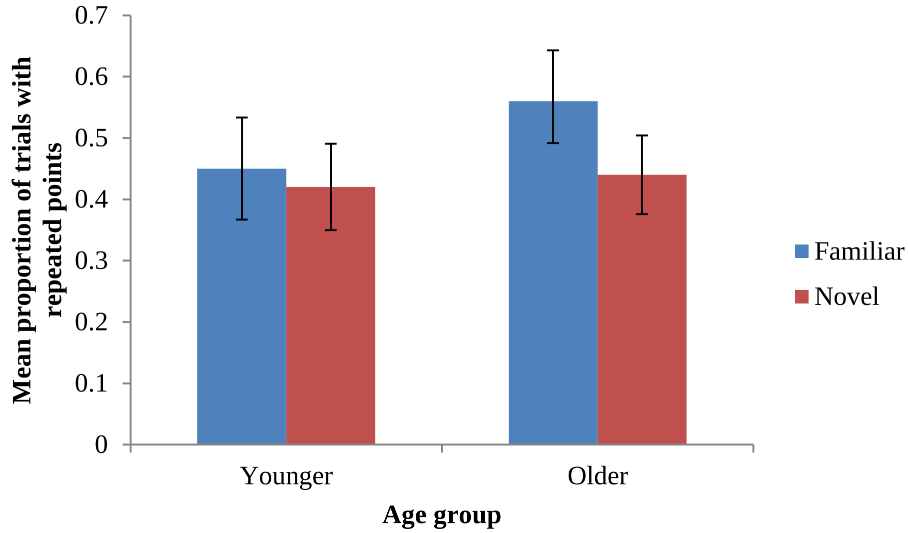


Figure 5. Proportion of trials with repeated points in the younger and older age group. The error bars represent the standard error of the means.

Overall, infants pointed repeatedly on 51% (*SD* = .35) of the familiar object trials in which they pointed, and on 47% (*SD* = .31) of the novel object trials in which they pointed. The difference was marginally significant, related-samples Wilcoxon signed rank test = 1.75, $p = .079$. The proportion of trials with repeated points was not significantly different between the younger age group and the older age group, Mann – Whitney test $z = 1.01, .18$, $p = .31, .85$, respectively for familiar and novel object trials.

More specifically, infants in the older age group showed more repeated pointing to familiar objects ($M_{familiar} = .56$, $SD_{familiar} = .32$) than to novel objects ($M_{novel} = .44$, $SD_{novel} = .30$), related-samples Wilcoxon signed rank test = 2.14, $p = .03$; by contrast, no significant difference was found in younger infants ($M_{familiar} = .45$, $SD_{familiar} = .39$; $M_{novel} = .42$, $SD_{novel} = .33$), related-samples Wilcoxon signed rank test = .32, $p = .75$.

There were no significant differences in repeated pointing between females ($M_{familiar} = .56$, $SD_{familiar} = .32$; $M_{novel} = .44$, $SD_{novel} = .24$) and males ($M_{familiar} = .52$,

SD_{familiar} = .38; M_{novel} = .42, SD_{novel} = .37) either, Mann – Whitney test z = .18, .32, p = .85, .75, respectively for familiar and novel object trials.

Proportion of infants who pointed spontaneously. Overall, there were only 2 infants (both were from the younger age group) who never pointed spontaneously in the test. We examined infants' pointing to familiar and novel objects separately, and found that 18 (out of 22) younger infants pointed in familiar object trials, and all (22 out of 22) older infants pointed in familiar object trials. The difference was significant, $\chi^2 = 4.40$, $p = .04$. The same results were found in novel object trials; more infants in the older age group (22 out of 22) pointed than infants in the younger age group (18 out of 22), $\chi^2 = 4.40$, $p = .04$. In contrast, no significant gender difference was found in proportions of infants who pointed spontaneously to familiar objects (20 out of 24 males pointed, and 20 out of 20 females pointed), $\chi^2 = 3.67$, $p = .06$; or to novel objects (22 out of 24 males pointed, and 18 out of 20 females pointed), $\chi^2 = .04$, $p = .85$.

Latency to point. Mean latency to point as a function of age and trial type is depicted in Figure 6. Older infants pointed more quickly to both familiar and novel object trials than younger infants did. Specifically, for familiar objects, on average, younger infants did not point until 9.73 seconds (SD = 6.41) had elapsed after the object appeared, but older infants pointed after 5.53 seconds (SD = 3.92), Mann – Whitney test z = 2.37, p = .02. The difference was also significant in latency to point to novel objects (M_{young} = 11.56, SD_{young} = 8.44; M_{old} = 6.10, SD_{old} = 4.97), Mann – Whitney test z = 2.35, p = .02. There was no significant difference between pointing to familiar and novel objects, related-samples Wilcoxon signed rank test statistic = 1.30, p = .20.

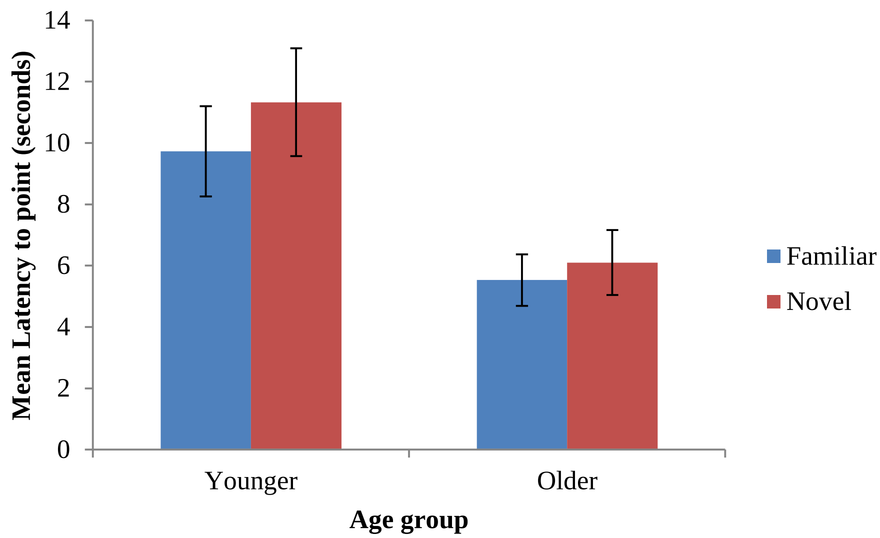


Figure 6. Mean latency to point to familiar and novel objects in younger and older infants. The error bars represent the standard error of the means.

There were no significant differences in latency to point between females ($M_{familiar}$ = 7.67, $SD_{familiar}$ = 6.06; M_{novel} = 9.88, SD_{novel} = 8.46) and males (M_{novel} = 7.30, SD_{novel} = 5.18; M_{novel} = 7.74, SD_{novel} = 6.06) either, Mann – Whitney test z = .43, .64, p = .67, .52, respectively, for familiar and novel object trials.

Language measures. Preliminary examination showed that one child in the younger age group (male, age = 400 days) had comprehension (score = 393), production (score = 364) and gesture scores (score = 61) beyond 3 standard deviations of mean scores of the younger age group. His data was thus treated as an outlier and was excluded from the data analysis. Another child in the older age group (female, age = 598 days) had missing language scores due to incomplete MCDI, thus was excluded from data analysis too. The descriptive data of infants' language measures split by age is presented in Table 2. Because these infants were 12 months to 24 months old, the range of their language measures was quite large. Their comprehension score ranged from 15 to 396, with a mean score of 192.76 (*SD* = 118.92), the production score ranged from 1-378, with a mean score of 84.67 (*SD* = 107.95), the gesture score ranged from 17-63, with a mean score of 40.65 (*SD* = 12.31). The comprehension of nouns made up, on average, 53.11% of the total comprehension scores, and the production of nouns made up, on average, 39.49% of the total production scores.

As shown in Table 2, there were significant age differences in infants' comprehension scores, Mann – Whitney test $z = 3.96$, $p < .001$, production scores, Mann – Whitney test $z = 5.19$, $p < .001$, and gesture scores, Mann – Whitney test $z = 3.59$, $p < .001$.

No significant gender differences were found in any language measure, *p*s > .10.

Table 2. Descriptive data of infants' language measures.

	Comprehension	Production	Gesture	Noun comprehension	Noun production
Younger age group					
Mean	112.00	11.00	33.70	58.81	3.86
SD	58.20	10.41	10.59	33.77	5.16
SE	12.70	2.27	2.37	7.37	1.13
Median	107.00	7.00	32.50	56.00	2.00
Range	15-232	1-38	17-59	7-152	0-17
Older age group					
Mean	273.52	155.00	47.60	151.19	90.62
SD	109.11	112.23	9.86	59.32	68.20
SE	23.81	23.93	2.21	12.94	14.88
Median	308.00	141.50	44.75	171.00	91.00
Range	47-396	13-378	30-63	18-209	0-205
All infants					
Mean	192.76	84.67	40.65	105.00	47.24
SD	118.92	107.95	12.31	66.77	64.88
SE	18.35	16.46	1.95	10.30	10.01
Median	168.00	25.00	39.00	86.00	9.00
Range	15-396	1-378	17-63	7-209	0-205

In sum, we found that, compared to younger infants, a higher proportion of older infants pointed in the test; older infants showed more spontaneous pointing, and pointed more quickly, to both familiar and novel objects. In addition, older infants repeated pointing more often to familiar objects than to novel objects, but there was no significant age difference in the proportion of trials with repeated points overall. A significant gender difference was only found in proportion of novel object trials with no point and proportion of novel object trials with prompted point, but not in other measures.

Correlations between Pointing and Language

Scatterplots indicate that there were linear relationships between comprehension scores and proportion of trials with spontaneous pointing to familiar objects (Figure 7) and novel objects (Figure 8) in younger infants, but not in older infants. There were no linear relationships between production scores and proportion of trials with spontaneous pointing to familiar objects (Figure 9) and novel objects (Figure 10). The linear relationships between gesture scores and proportion of trials with spontaneous pointing to familiar objects (Figure 11) and novel objects (Figure 12) seemed to be more apparent in older infants than younger infants.

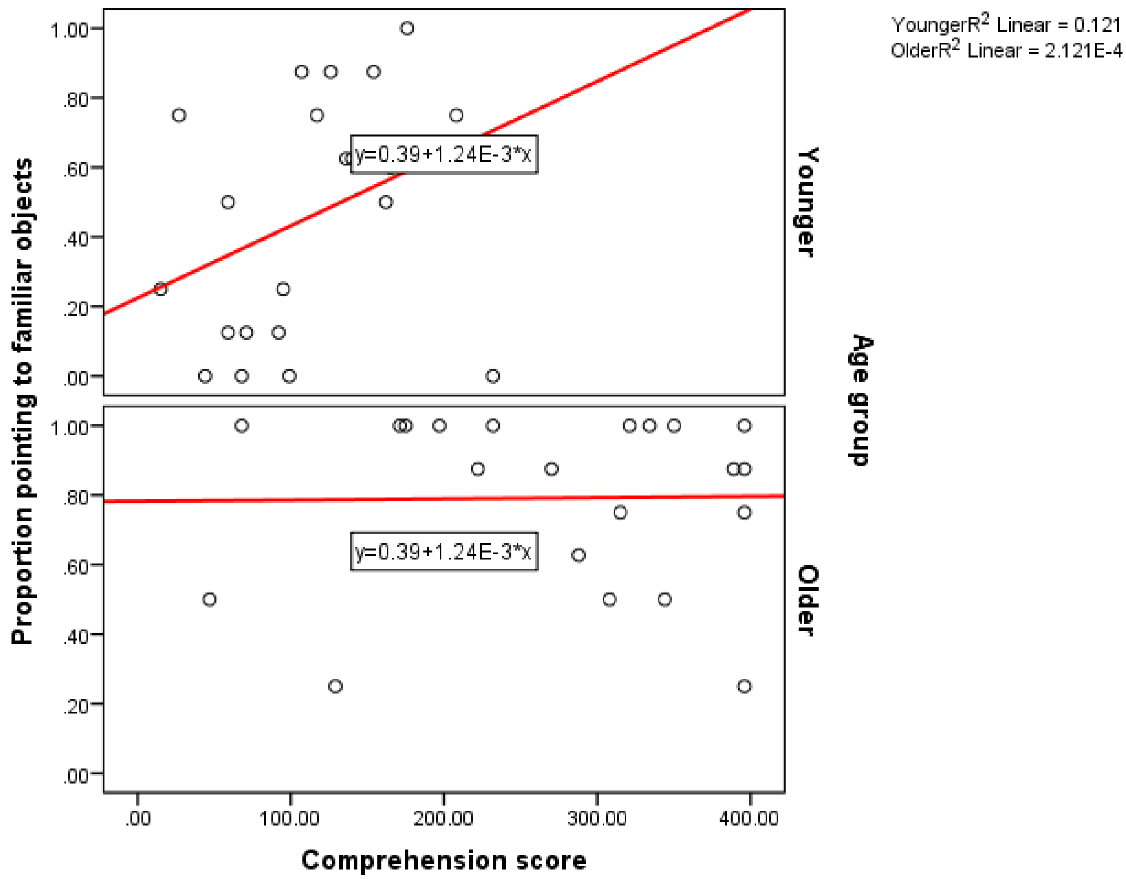


Figure 7. Scatterplots of relations between comprehension score and proportion of trials with spontaneous pointing to familiar objects as a function of age group.

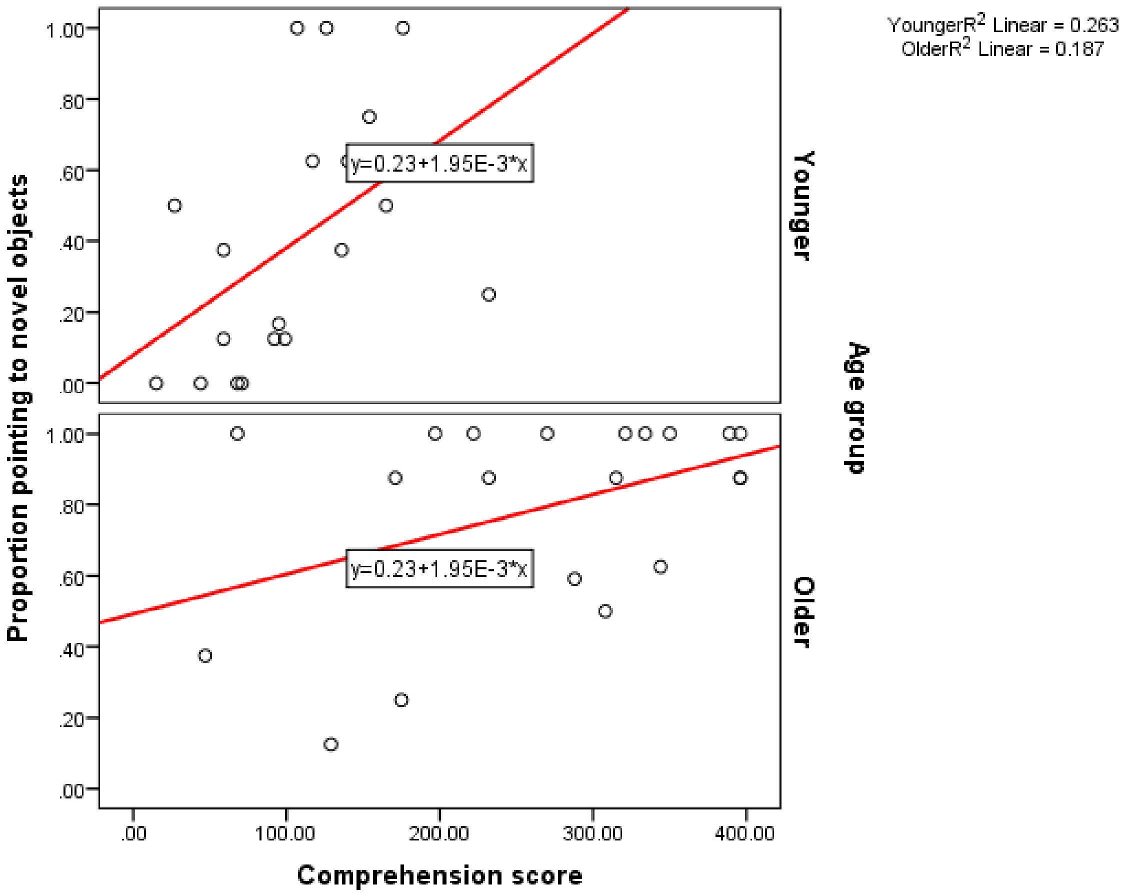


Figure 8. Scatterplots of relations between comprehension score and proportion of trials with spontaneous pointing to novel objects as a function of age group.

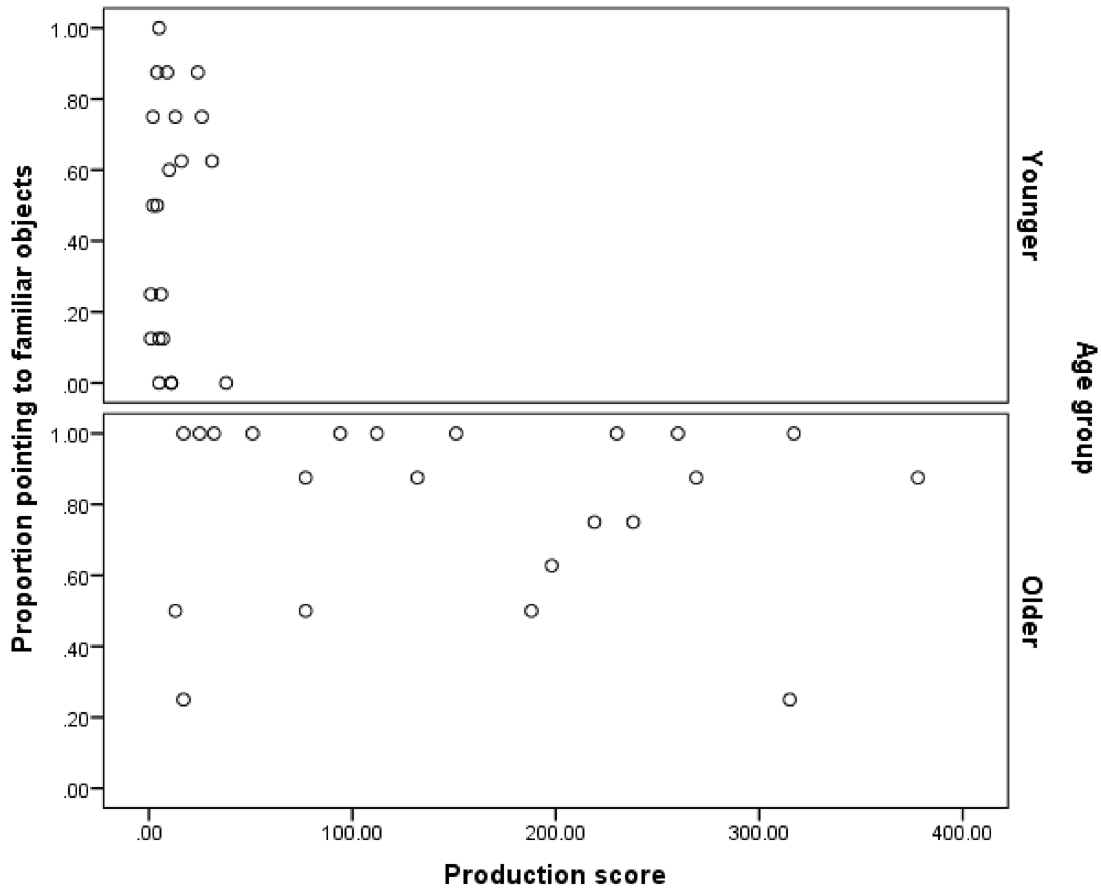


Figure 9. Scatterplots of relations between production score and proportion of trials with spontaneous pointing to familiar objects as a function of age group.

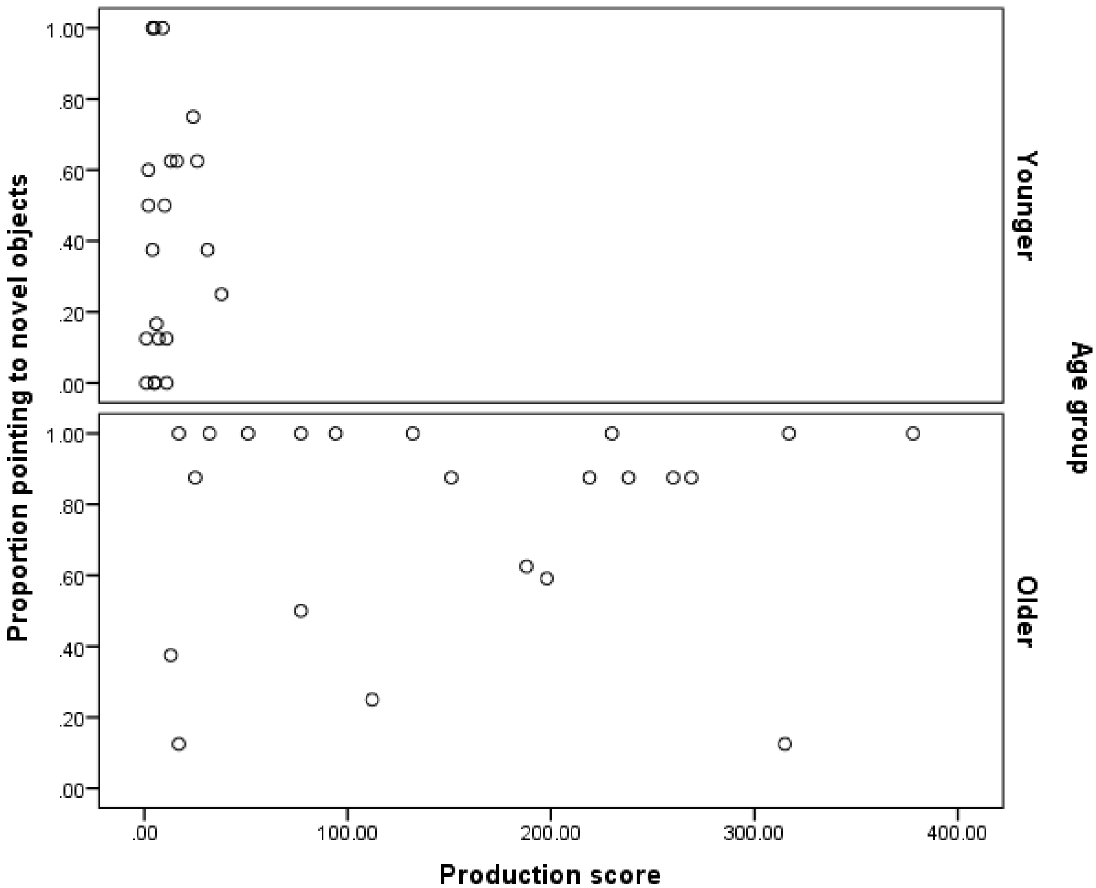


Figure 10. Scatterplots of relations between production score and proportion of trials with spontaneous pointing to novel objects as a function of age group.

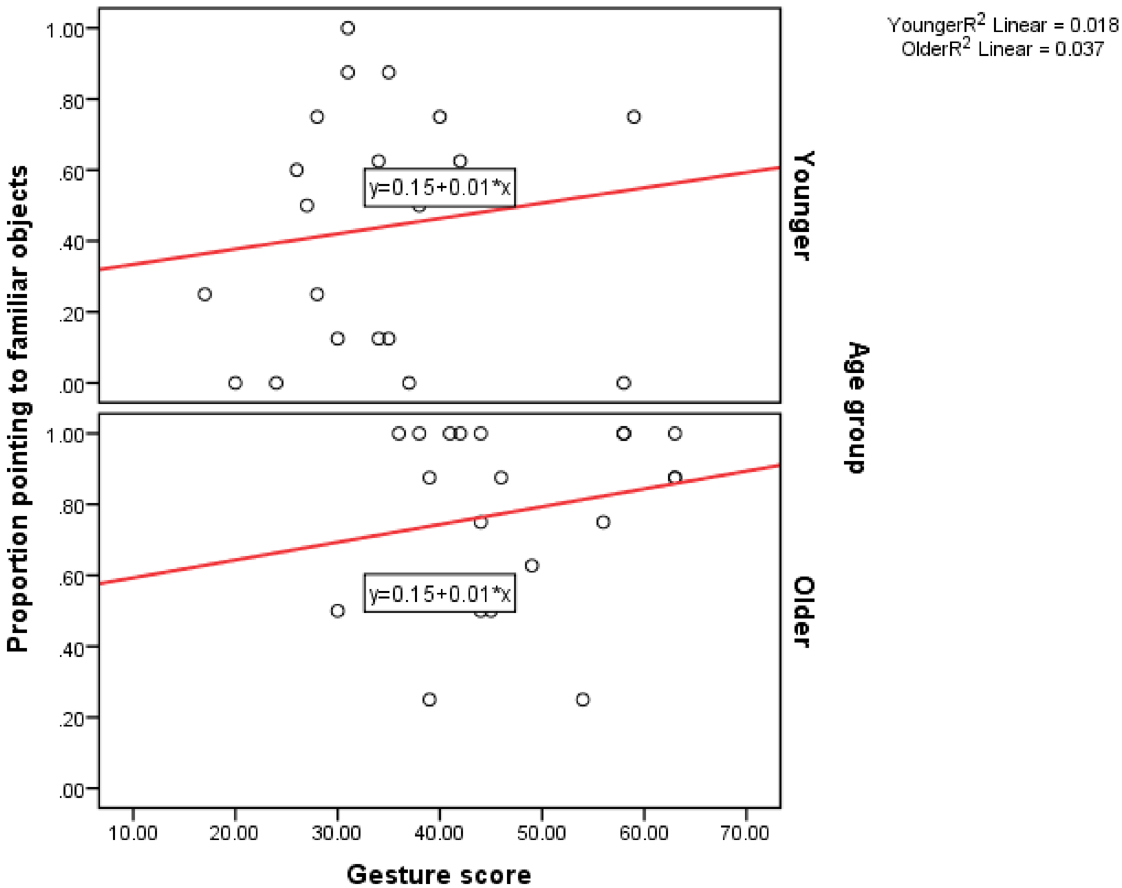


Figure 11. Scatterplots of relations between gesture score and proportion of trials with spontaneous pointing to familiar objects as a function of age group.

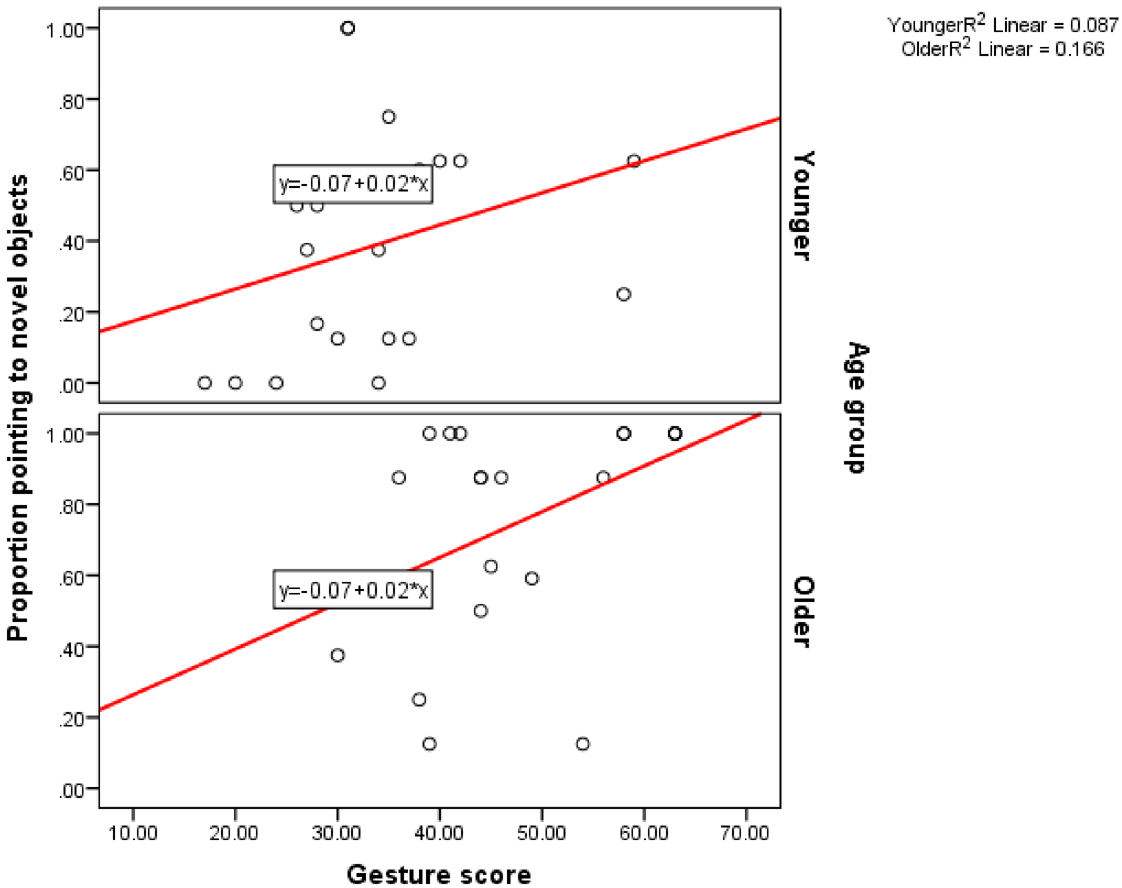


Figure 12. Scatterplots of relations between gesture score and proportion of trials with spontaneous pointing to novel objects as a function of age group.

Generalized Linear Mixed Models

In this section of data analyses, I focused on what factors influenced infant's spontaneous pointing (the dependent variable). I used mixed logistic regression models to analyze the data, because recent arguments suggest that ANOVAs on categorical outcome variables are inappropriate (see Jaeger, 2008). Additionally, these models enable control for any potential random effects due to individual differences between children or specific stimuli. In each trial, infants either pointed spontaneously or did not point spontaneously, thus the distribution of the dependent variable is binary (0 or 1). Factors included age (days), gender, comprehension, production and gesture, trial type (novel vs. familiar object trial), trial (numbered 1 to 16) and order of presentation (familiar object first or novel object first). Collinearity among variables was removed by sum-coding data and scaling continuous variables. To determine appropriate random effects, I began with completely specified random effects structures including random slopes for all within-subject variables included in a given model. Using model comparisons, I systematically removed uninformative random effects and fixed effects. These model comparisons showed that trial type, the order of presentation and gender did not significantly influence infants' pointing, thus these three factors were not included in the models.

Comprehension score and spontaneous pointing. To determine how comprehension scores contributed to infants' spontaneous pointing, I first conducted a model with age and trial number as the fixed effects, and random subject and stimulus effects. The model structure was this: Spontaneous point ~ scale (age) $\times$ trial number + (1|subject) + (1|stimulus). In the second step, I added comprehension score as a third factor to the model: Spontaneous point ~ scale (age) $\times$ trial number $\times$ scale (comprehension) + (1|subject) + (1|stimulus). Lastly, I compared the first and the second model using the ANOVA function in R, aiming to see whether adding comprehension scores to the model significantly changed the fit of the model. The results showed that adding comprehension scores significantly improved the fit of the model, χ^2 (4) = 28.31, p < .001. This suggests that infants' comprehension scores can account for variability in infants' spontaneous pointing gestures that could not be accounted for by age.

To be conservative in examining the effect of comprehension scores on infants' spontaneous pointing, I regressed age on comprehension, and used the residuals of this regression model to represent the effect of comprehension scores after partialling out the effect of age effect: comprehension residual <- resid (lm (comprehension ~ age, na.action = na.exclude)). I then used the residual as one fixed factor to predict infants' production of spontaneous pointing. If the effect of this fixed factor was significant, it suggested that comprehension scores influenced infants' production of spontaneous pointing independent of the age effect. The generalized linear mixed model structure was: Spontaneous point ~ scale (age) × trial number × scale (comprehension residual) + (1|subject) + (1|stimulus).

The results of this model are presented in Table 3. Results showed that: 1) a significant three-way interactive effect of trial number, age and comprehension, $z = 2.23$, $p = .03$; 2) a significant interaction between age and comprehension, $z = -2.53$, $p = .02$, suggesting that the effect of comprehension was weaker as age increased; 3) a significant interaction between age and trial number, $z = 4.01$, $p < .0001$, suggesting that older infants increased their pointing gestures across trials.

Table 3. Generalized linear mixed model with age, trial number and comprehension (after partialling out the age effect) as predictors of spontaneous pointing for all infants.

Dependent Variable	Estimate	Std. Error	*z*	*p*
Spontaneous pointing				
Intercept	.60	.40	1.50	.13
Trial number	.06	.03	1.84	.07
Age	.39	.38	1.02	.31
Comprehension residual	1.11	.48	2.29	.02
Trial number × age	.12	.03	4.01	< .001
Trial number × comprehension residual	.02	.03	.68	.50
Age × comprehension residual	-1.15	.46	-2.53	.02
Trial number × age × comprehension residual	.07	.03	2.23	.03

To further explore the significant three-way interactive effect of trial number, age, and comprehension, I split the data by age group, and conducted a similar data analysis as above in the two age groups separately: Spontaneous point ~ scale (age) × trial number × scale (comprehension residual) + (1|subject) + (1|stimulus). The results for infants in the younger age group are reported in Table 4, and for infants in the older age group are reported in Table 5.

Table 4. Generalized linear mixed model with age, trial number and comprehension (after partialling out the age effect) as predictors of spontaneous pointing for infants in the younger age group.

Dependent Variable	Estimate	Std. Error	*z*	*p*
Spontaneous pointing				
Intercept	-.03	.52	-.05	.96
Trial number	-.06	.04	-1.57	.12
Age	-.38	.53	-.72	.47
Comprehension residual	1.47	.55	2.69	.007
Trial number × age	.01	.04	.16	.88
Trial number × comprehension residual	-.04	.04	-1.06	.29
Age × comprehension residual	-.55	.52	-1.07	.28
Trial number × age × comprehension residual	.002	.04	.06	.95

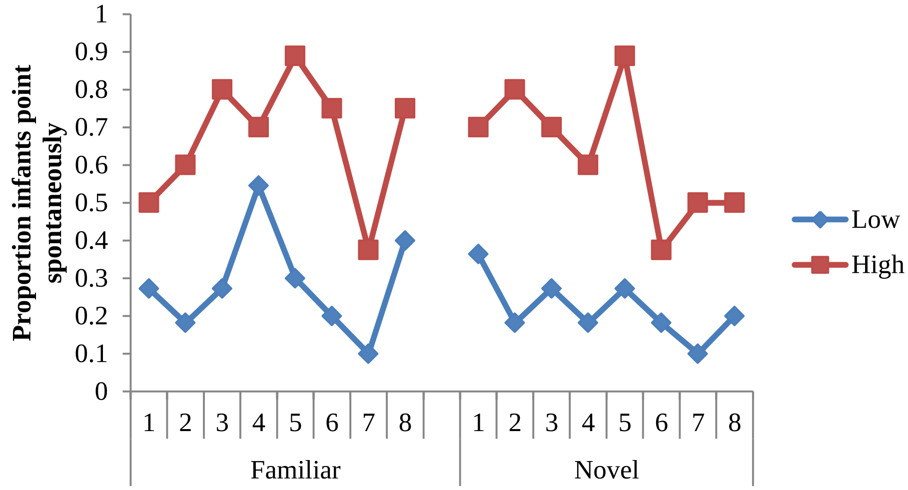
As shown in Table 4, after partialling out the age effect, 12-16 month old infants with higher comprehension scores showed more spontaneous pointing, as indicated by the significant main effect of comprehension residual, $z = 2.69$, $p = .007$. No other significant effects or interactive effects were found. These results are also indicated in Figure 13a, which shows the proportion of infants who pointed spontaneously on each familiar and novel object trial, split by the median of young infants' comprehension score.

Table 5. Generalized linear mixed model with age, trial number and comprehension (after partialling out the age effect) as predictors of spontaneous pointing for infants in the older age group.

Dependent Variable	Estimate	Std. Error	*z*	*p*
Spontaneous pointing				
Intercept	1.13	.56	2.02	.04
Trial number	.19	.05	3.53	.0004
Age	-.45	.50	-.91	.37
Comprehension residual	-.38	.55	-.69	.49
Trial number × age	-.004	.04	-.12	.91
Trial number × comprehension residual	.15	.05	2.93	.003
Age × comprehension residual	-.05	.46	-.10	.92
Trial number × age × comprehension residual	-.02	.03	-.64	.52

As shown in Table 5, in contrast to younger infants, for infants in the older age group, there was not a significant main effect of comprehension score, $z = -.69$, $p = .49$. Instead, there was a significant main effect of trial number, $z = 3.53$, $p < .0001$, and a significant interaction between trial number and comprehension, $z = 2.93$, $p = .003$. As depicted in Figure 13b, infants in the older age group increased their pointing as the trial number increased, and the increase was larger in infants with higher comprehension scores.

a)



b)

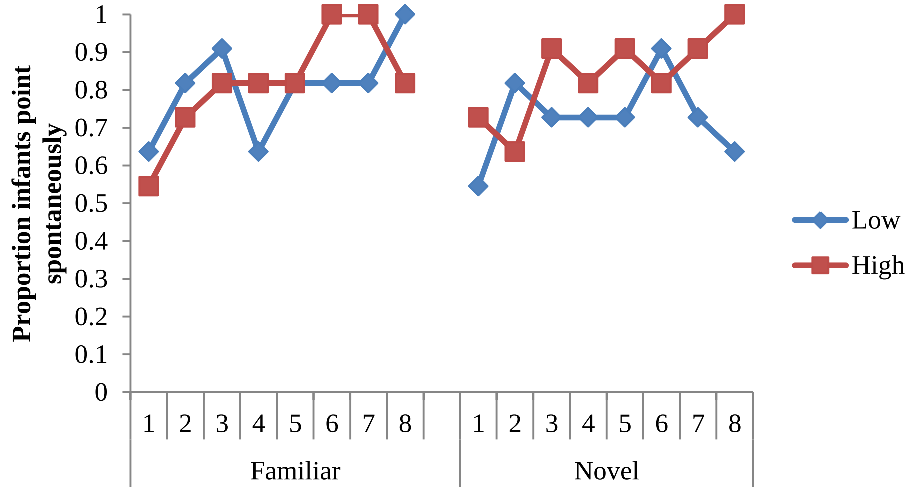


Figure 13. Proportion of infants who pointed spontaneously in each trial as a function of comprehension group (Low vs. High, split by median) for infants in the younger age group (a) and older age group (b). Note that the graph does not capture the fact that the analysis took into account random subject and stimuli effects.

Production score and spontaneous pointing. I used the same method to examine how infants' production score and other factors contributed to infants' production of spontaneous pointing behavior. I regressed age on production, and used the residuals of this regression model to represent the effect of production scores after partialling out age effect: production residual <- resid (lm (productiion ~ age, na.action = na.exclude)). The generalized linear mixed model structure was: Spontaneous point ~ scale (age) × trial number × scale (production residual) + (1|subject) + (1|stimulus). The results of this model are presented in Table 6. As shown in Table 6, there was a significant interaction between age and trial number, $z = 3.92$, $p < .0001$. This suggests that older infants increased pointing across trials. Importantly, there was no significant main effect of production (after partialling out the age effect), $z = .82$, $p = .41$, or any interactive effects involving production, *p*s > .10.

Table 6. Generalized linear mixed model with age, trial number and production (after partialling out the age effect) as predictors of spontaneous pointing for all infants.

Dependent Variable	Estimate	Std. Error	*z*	*p*
Spontaneous pointing				
Intercept	.68	.40	1.68	.09
Trial number	.06	.03	1.88	.06
Age	.40	.40	1.01	.31
Production residual	1.07	1.30	.82	.41
Trial number × age	.11	.03	3.92	< .001
Trial number × production residual	.08	.09	.90	.37
Age × production residual	-1.27	1.35	-.93	.35
Trial number × age × production residual	.02	.09	.18	.86

Gesture score and spontaneous pointing. Similar methods were used to explore gesture scores and spontaneous pointing. I regressed age on gesture, and used the residuals of this regression model to represent the effect of gesture scores after partialling out age effect: gesture residual <- resid (lm (gesture ~ age, na.action = na.exclude)). The generalized linear mixed model structure was: Spontaneous point ~ scale (age) × trial number × scale (gesture residual) + (1|subject) + (1|stimulus). The results of this model are presented in Table 7. Results showed that: 1) a significant three-way interactive effect of trial number, age and gesture, $z = 3.47$, $p = .0005$; 2) a significant interaction between age and trial number, $z = 4.47$, $p < .0001$, suggesting that older infants increased their pointing gestures across trials; 3) a significant main effect of trial number, $z = 2.59$, $p = .0009$.

Table 7. Generalized linear mixed model with age, trial number and gesture (after partialling out the age effect) as predictors of spontaneous pointing for all infants.

Dependent Variable	Estimate	Std. Error	*z*	*p*
Spontaneous pointing				
Intercept	.39	.41	.96	.34
Trial number	.09	.03	2.59	.009
Age	.32	.40	.79	.43
Gesture residual	.67	.41	1.60	.11
Trial number × age	.15	.03	4.47	< .001
Trial number × gesture residual	.05	.03	1.61	.11
Age × gesture residual	-.46	.42	-1.07	.28
Trial number × age × gesture residual	.12	.03	3.47	.0005

To further explore the three-way interactions, I conducted two more models separately for younger and older infants using the structure:

Spontaneous point ~ trial number × scale (age) × scale (gesture residual) + (1|subject) + (1|stimulus). Results for younger infants and older infants are reported respectively in Table 8 and Table 9.

As shown in Table 8, for 12-16 month old infants, their gesture scores significantly predicted their production of spontaneous pointing gestures, $z = 2.68$, $p = .007$; however, this effect decreased as age increased, as indicated by an interactive effect of age and gesture, $z = -2.20$, $p = .03$.

Table 8. Generalized linear mixed model with age, trial number and gesture (after partialling out the age effect) as predictors of spontaneous pointing for infants in the younger age group.

Dependent Variable	Estimate	Std. Error	*z*	*p*
Spontaneous pointing				
Intercept	-.21	.53	-.41	.68
Trial number	-.05	.04	-1.37	.17
Age	-.49	.53	-.92	.36
Gesture residual	1.58	.59	2.68	.007
Trial number × age	-.005	.04	-.15	.88
Trial number × gesture residual	-.07	.04	-1.74	.08
Age × gesture residual	-1.23	.56	-2.20	.03
Trial number × age × gesture residual	.07	.04	1.78	.08

As shown in Table 9, 19-24 month old infants who had higher gesture scores increased pointing across trials, as indicated by a significant interactive effect of trial number and gesture, $z = 3.49$, $p = .004$. The main effect of gesture was not significant, $z = -.62$, $p = .54$.

Table 9. Generalized linear mixed model with age, trial number and gesture (after partialling out the age effect) as predictors of spontaneous pointing for infants in the older age group.

Dependent Variable	Estimate	Std. Error	*z*	*p*
Spontaneous pointing				
Intercept	.52	.53	.98	.33
Trial number	.34	.09	3.82	.0001
Age	-.11	.47	-.24	.81
Gesture residual	-.32	.52	-.62	.54
Trial number × age	-.07	.04	-1.56	.12
Trial number × gesture residual	.29	.08	3.49	.004
Age × gesture residual	-.24	.47	-.51	.61
Trial number × age × gesture residual	-.04	.04	-1.12	.26

In sum, results from generalized linear mixed models showed that infants' language production scores did not predict infants' pointing gestures, but infants' language comprehension and gesture scores did. Infants who had higher comprehension scores pointed more, but this correlation became weaker in older infants. Infants who had higher gesture scores also pointed more. In addition, 19-24 month old infants who had higher comprehension and gesture scores pointed more as trials proceeded.

Discussion

The pointing gesture is an important communicative behavior before infants can talk. The question of why young children begin to point is important not only for understanding infants' readiness to initiate interactions, but because points offer a way to study infants' early intention understanding and sharing abilities (Tomasello et al., 2007). This study used an experimental task to study the nature of young infants' pointing behavior. There are four main findings: 1) older infants generally pointed more often and more quickly than younger infants did; older infants who had higher comprehension and gesture scores gradually increased their pointing behavior as the study went on; 2) The majority of infants pointed spontaneously or did not point, yet rarely pointed after being prompted by others; 3) there was no main effect of trial type (familiar and novel objects); that is, overall, infants, regardless of age, pointed equally often to familiar and novel objects; however, older infants repeated pointing more often to familiar objects than novel objects; 4) there was a change in correlations between infants' language skill (measured with MCDI comprehension) and their pointing behavior in children at different ages. For infants aged 12 to 16 months, their comprehension score significantly influenced their spontaneous pointing behavior, with age effect partialled out. That is, infants with higher comprehension scores pointed more often than infants with lower comprehension scores. This correlation between receptive language skills and pointing was not found in infants aged 19-24 months. For these older infants, the higher gesture scores these older infants had, the more likely they pointed as the experiment went on.

Features of Infants' Pointing

To our knowledge, this is the first study to use a progressive cue task to systematically elicit infants' pointing gesture: after presentation of an object in infants' view, the experimenter waited silently until infants pointed spontaneously in the first 15 seconds; if infants did not point, at the 15 second mark, the experimenter provided a cue to prompt infants to point by asking, "what are you looking at? Can you show me?" and then waited for infants to respond. This prompt was not provided if the child already pointed spontaneously during the first 15 seconds. When responding to infants' pointing gestures, the experimenter provided both positive emotion and positive attitude toward the target object ("Wow!"), and the label of the target object, which is a typical response to infants' pointing behavior as shown in previous studies (e.g., Masur, 1997; Wu & Gros-Louis, 2014b). Using this paradigm, I found that overall infants spontaneously pointed in about 62% of the trials. In addition, adult prompts were helpful in eliciting infants' pointing gestures, but did not improve infants' pointing behavior dramatically; in the trials that infants did not point spontaneously and they thus heard the prompts, infants pointed only about 20% of time. That is, the majority of infants who did not point spontaneously during the first 15 seconds still did not point even after being prompted.

This interesting result may suggest that at this age, infants are not capable of using pointing gestures to answer adult's questions such as "What are you looking at? Can you show me?" In everyday life, a parent may follow infants' gaze and communicate with the infant about things they see together; therefore, it may not be typical for the adult partner to simply ask questions without turning around to see what the infant is looking at. This may explain why infants did not use pointing gestures to answer questions in the current study.

Motivation to Point

In addition to the lack of experience, another possibility is related to the motivation underlying infants' pointing gestures. If infants do not point to answer questions, why do they point spontaneously? Researchers have been arguing that, as young as 12 months old, infants may point to request certain objects (imperative function, means "give me that", Bates et al., 1975), share attention and interest with others (declarative function, means "look at that", Liszkowski, Albrecht, et al., 2008; Liszkowski et al., 2004, 2007), to provide information for others who are ignorant of something (informing function, Liszkowski et al., 2006), and to solicit information from others (interrogative function, Begus & Southgate, 2012; Kovács, Tauzin, Téglás, Gergely, & Csibra, 2014; Southgate, van Maanen, & Csibra, 2007).

In a very recent study, Kovács et al. (2014) directly compared the declarative and interrogative accounts of infant pointing. They presented 32 12-month-olds with atypical members of a known kind (e.g., a cat in boots) out of window openings of a curtain (a similar experimental set-up as in the current study). In response to infants' pointing gestures, the experimenter either labeled the object with a familiar word ("a kitty") in the Sharing condition, or with a novel word ("a dax") in the Informing condition. They then measured infants' pointing gestures. Their logic was that if infants pointed to share attention and interest, then infants should prefer the adult's response that came from shared semantic knowledge ("a kitty"); however, if infants pointed to request information, then infants should prefer the adult's response of providing new information about the referent ("a dax"). The results showed that infants were more likely to point in the Informing condition than the Sharing condition, which they believe fit the "epistemic request hypothesis", that is, infants point to solicit information.

However, it is also possible that infants pointed more frequently because it was more interesting to hear weird sounds referring to something not totally strange to them. In Kovács et al. (2014)'s study, the stimuli they used were: a teddy bear with a hat, a ball with spines, a cat in boots, a racing car, a doll puppet with a hat, a bunch of plastic keys, a dog puppet, and a green telephone. These are not very novel toys, and infants may already have names for them (e.g., "ball" for the ball with spines). Therefore, they might find it interesting to hear a funny name referring to it (e.g., dax), and thus point to it to *share* this interesting event.

In the current study, I used a different way to test the declarative and interrogative functions of infants' pointing gesture. I presented infants with familiar and novel objects. If infants point to request information, they would point more often to the novel objects; in contrast, if they point to share attention and interest with others, they would point equally to familiar and novel objects because both familiar and novel objects were protruded unexpectedly.

Our results did not provide clear evidence to support the hypothesis that infants use pointing gestures to request information. Infants pointed to the familiar and novel objects equally often, as suggested by a non-significant main effect of trial type. The only difference we found in this study was that 19-24 month old infants were more likely to repeat pointing to familiar objects than novel objects. One possibility is that these older infants were not satisfied with the experimenter's labeling response in the familiar object trials, because they already knew the name of the novel object. It is likely that these infants wanted more information about the familiar objects. By contrast, this difference was not found in 12-16 month old infants. These results suggest that using pointing gestures to request information may be an ability that emerges later in development, when infants' communicative skills are developed to a certain level. It might be that they learn from their experience that pointing results in receiving information, thus they gradually learn to do so. More studies are needed to test this hypothesis.

Note that underlying motivations are very hard to measure and to distinguish. It is not necessarily purely declarative or interrogative motives that drive infants' gesturing. Though this experimental setting is widely used as a "referential-declarative" context, it is possible that infants may just want to have the toys (i.e., imperative motive) rather than declare their interest. Infants' non-verbal communication may be rooted in various motives, including epistemic and affiliative motives. Therefore, motives of pointing gestures may be varied toward familiar and novel objects, in younger and older infants, or even within one child across different trials.

Among these motives, however, if infants do use the pointing gesture as an epistemic request, they can play an active role in the process of information gathering and assimilating it because they can designate the referent they want to learn about. Furthermore, this interest can lead to superior learning, as studies have shown that infants replicate actions on novel objects more successfully if the objects were the ones they pointed to, as opposed to objects to which they did not point (Begus et al., 2014).

Therefore, if infants master the skills of requesting information by pointing, they may be in a better position for learning.

Correlations between Pointing and Vocabulary

This study found support for a strong concurrent relation between the pointing gesture emerging during infancy, and language development (for a review, see Colonnesi et al., 2010). It is not surprising that infants' pointing gestures correlated to their gesture scores measured by MCDI because pointing is one type of gesture. However, it is noteworthy that infants' pointing behavior had a robust correlation to the *receptive*, but not expressive vocabulary size, of infants younger than 18 months of age. It is unlikely that this result is an artefact of the age effect, because adding comprehension scores to regression models significantly improved the fit of models, showing that comprehension scores account for variability that could not be explained by age in infants' production of spontaneous pointing. More importantly, I regressed age on comprehension scores, and used residuals of this regression model as a fixed factor when examining the factors that contributed to infants' production of spontaneous pointing. The effect of these residuals was significant, which suggested that after partialling out the age effect, language comprehension significantly predicted infants' spontaneous pointing. In particular, there was a significant interactive effect of age and comprehension. Further analyses showed that the correlation between spontaneous pointing and receptive vocabulary size was significant in younger infants but not in older infants.

In our study, the novel objects were ones that children never saw before they came to the lab, and the familiar toys were ones that were commonly seen in daily life (also confirmed by parents). The experimenter labeled each object after infants had pointed. Infants heard a familiar word that they knew after they pointed to a familiar object, and heard a novel word after they pointed to a novel toy. Prior studies have argued that pointing increases word learning opportunities, such that more gestures were related to higher subsequent vocabulary size (e.g., Brooks & Meltzoff, 2008). The current finding may add another piece to this picture: infants with higher vocabulary size also point more frequently than infants with lower vocabulary size. The current study and previous studies together suggest a possible positive feedback loop in infants' language learning: infants with higher receptive vocabulary size are more likely to point, and elicit linguistic input from the environment (e.g., Wu & Gros-Louis, 2014b), which, in turn, can improve infants' vocabulary learning.

What are other possible explanations for the correlations between infants' receptive vocabulary and pointing skills for infants younger than 18 months of age? A *parallelism* approach proposes that speech and gesture schemes for objects are related in early development because they both depend on a common underlying symbolic function (Piaget, 1962; Werner & Kaplan, 1963) or referential understanding (Tomasello et al., 2007). By contrast, a *comprehension mediation* hypothesis suggests that language/gesture correlations reflect the fact that children use adult speech as a guide during their social interactions (Bates et al., 1989). Understanding the adult labeling may thus guide infants to point more frequently, maybe due to the typically contingent relation between pointing and hearing words (e.g., Wu & Gros-Louis, 2014b). Thirdly, as discussed above, infants with better understanding may expect to gather information about things based on their prior experience. These three lines of hypotheses could help interpret the results.

The differences in the correlations between MCDI scores and pointing for children at different ages are important findings. It is interesting to ask why receptive vocabulary size positively predicts infants' spontaneous pointing in infants younger than 18 months old, but not in older infants. One possibility is that infants with high vocabulary might have learned the contingency between pointing and hearing words. Infants with high vocabulary size are thus more likely to point to elicit verbal feedback from the social partner. These verbal responses may be particularly important for infants younger than 18 months old, who are frequent gesturers and are at the cusp of the transition to linguistic communication. Therefore, these young infants receive information at a time when they are ready to learn (Goldin-Meadow, 2007).

Infants aged 19 to 24 months in our study, however, pointed spontaneously on approximately 80% of the trials, and 64% of them pointed to every single object. Thus, a possible ceiling effect in older infants' pointing might have caused a non-significant correlation between pointing and receptive vocabulary. It is possible that there is a range within which word comprehension might be related to the production of spontaneous pointing (the scatterplots suggest up to 100 words that the child could comprehend). Beyond that range, however, other factors such as motives may play a larger role than word comprehension in infants' production of spontaneous pointing. In addition, infant pointing is certainly not the only factor that influences language development. Numerous perceptual, cognitive and social factors have been shown to influence language learning (e.g., Golinkoff et al., 2000). For these older infants who are farther along in the gradual shift toward using speech as a primary communicative modality instead of gesturing, it is likely that the correlation between pointing gestures and vocabulary is weaker.

Interestingly, there were no significant correlations between infants' production scores and pointing behavior in either age group. This is consistent with some previous findings that tracked infants from 8-9 months of age to 14-15 months of age (Butterworth & Morissette, 1996; Carpenter et al., 1998) or even to 3 years old (Blake et al., 2005), and found no significant longitudinal correlations between pointing and production scores measured by MCDI. On one hand, if production scores measured by MCDI indicated infants' verbal communicative skills, and pointing gestures represent infants' non-verbal communicative skills, one may expect a positive significant correlation due to an integrated verbal and gestural communicative system. However, an integrated verbal and gestural communicative system may just suggest a combination of gestures and speech during communication, but not necessarily a correlation between pointing and word production measured with parent report as in the current study. For example, Murphy (1978) studied infants' pointing behavior in the context of reading books with their mother, and found that 20- and 24-month-old infants were significantly more likely to name the pictures in the book when they were pointing than at any other time. Murphy (1978) suggested that gestural and linguistic deixis were well integrated by the age of 20 months. Rowe (2000) also found that 14-month-old children who pointed more talked more during free-play interactions with their mother. A later review of the video recordings of the present study suggested that infants in the older age group frequently named the familiar objects while pointing. It would be interesting to code the current study videos in more detail, and investigate how infants combine their vocalizations and gestures differently as they see familiar and novel objects, and how these combinations change with infants' age.

On the other hand, one may expect a negative correlation between pointing and production scores. Lock (1978) posits that gestures are supplanted by language once verbal communication becomes proficient. Goldin-Meadow (2007) also suggests that gesturing is a way for infants to express things that they are not yet able to convey via speech. Accordingly, verbally advanced children should use fewer communicative gestures than peers who are less proficient in language, and infants should point less if they are able to communicate with words. However, the present study showed that older infants who had better language comprehension and production also pointed more often, and more quickly than younger infants, which was not consistent with this viewpoint. Dobrich and Scarborough (1984) also found contradictory evidence to this viewpoint; they showed that 2-year-old children who had higher language skills (measured by mean length of utterance, MLU) did not use fewer gestures than low-MLU children. One possibility is that the function of pointing at this age range (1-2 years old), when language skills are still quite limited, is to accompany and add emphasis to language rather than to replace it. This may explain why we did not find a negative correlation between pointing and production scores. The high proportion of synchronous pointing and vocalizing observed in 1- and 2-year-old children (e.g., Gros-Louis & Wu, 2012; Iverson & Goldin-Meadow, 2005; Wu & Gros-Louis, 2014a) provides support for this possibility. Coding combinations of pointing and vocalizing that occurred in the present study, as mentioned above, will be informative on this idea. In addition, we can code whether infants communicate with vocalizations first, or gestures first when they see something they have words for and something they do not have words for. If infants talk first when they see something they have words for (e.g., according to parental report, the child could produce “dog!”) and only point after seeing the experimenter not sharing attention, but they point first when they see something they do not have words for, it may provide suggestive evidence that speech is used first to communicate while gestures augment the communication.

One may argue that another possible explanation for the non-significant correlations between pointing and production scores is related to the experimental setting. In the current study, the experimenter did not share infants’ attention until infants pointed, which might have “forced” infants to point to achieve a goal of “shared attention”, whether they can produce the appropriate words or not. If this is the case, no significant correlations would be expected between comprehension scores and pointing; however, the fact that we did observe a significant concurrent correlation between comprehension scores and pointing suggests that this experimental setting does not account for the differential correlations between production, comprehension and pointing.

In conclusion, this study found that there was a close correlation between infants’ pointing behavior and receptive vocabulary size in infants younger than 18 months old. Receptive vocabulary was more strongly correlated to pointing than expressive vocabulary was. A longitudinal study tracking infants’ use of gestures and language will clarify and extend the independence and interactions among modes of communication (gesture and speech) as children develop. There might be a positive feedback loop: infants point and hear words, they learn the words, and then this larger vocabulary size drives them to point more, and learn more, etc. Second, the study verified the validity of this experimental setting and found that the correlations between pointing and word comprehension were significant in infants younger than 18 months old. In the second study, I thus used this experimental setting to directly test whether pointing gestures facilitate word learning in 16-month-old children in moment-to-moment interactions.

CHAPTER III: POINTING FACILITATES WORD LEARNING

As shown in the last experiment, 12-16 month old infants with high receptive vocabulary pointed more often in an experimental setting, where a social partner could not see toys that appeared out of window openings in a curtain. These pointing gestures usually elicit verbal feedback from adults (Kishimoto et al., 2007; Masur, 1982; Olson & Masur, 2011, 2013; Wu & Gros-Louis, 2014b), which further help infants develop language (Masur, 1997; Masur, Flynn, & Eichorst, 2005; Olson & Masur, 2015). Therefore, these gestures appear to be an important component of a positive social feedback loop in infants' language learning.

However, pointing is not the only way to elicit linguistic input. For example, an adult can also follow infants' looking and comment on what they look at. Do infants learn better when the words are provided after infants' pointing gestures? This experiment aims to directly test whether infants' pointing gestures could help them learn the word-object associations. Novel words were provided following one of three different timing schedules: immediately in response to infants' pointing gestures (point contingent condition), in response to infants' looking (look contingent condition), and at predetermined time schedule (yoked control condition). Note that both the point contingent and look contingent condition are similar to follow-in labeling conditions used in previous studies of word learning (Baldwin, 1991; Tomasello & Farrar, 1986). In the follow-in case, the child and the social partner can establish a joint reference situation, in which the adult looks at the object that the child is also focused on. The child can thus use the adult's line of visual regard, voice direction and body posture, to learn words. If infants' pointing gestures just function as establishing a joint reference situation, then I expect to find similar word learning performance in the point contingent and look contingent conditions. In contrast, if infants' pointing gestures prepare infants for word learning, then the words provided in response to the pointing gestures should be better learned than in the other two conditions.

A typical word comprehension test is to present infants with a pair of objects that they have seen previously, one of which is the target, and the other does not have a name; the child is then asked to get the target object by its name (e.g., Baldwin, 1991; Tomasello & Farrar, 1986). In the current study, it is possible that in such a test infants might point to or look at the object that they prefer within each pair, regardless of whether it was the one previously labeled by the experimenter. That is, it is possible that infants' choices during the word learning test could reflect object preferences rather than their knowledge of the mapping between words and objects. To decrease this risk, during the word learning phase of the experiment, I presented infants with two pairs of objects (Target 1 and Distractor 1, Target 2 and Distractor 2) and labeled one object in each pair (Target 1, Target 2) when the infant pointed to it, looked at it, or at a predetermined time schedule. During the word testing phase, then, each target was presented with the distractor from the other pair (Target 1 and Distractor 2, Target 2 and Distractor 1). This thus decreased the risk that infants simply picked the one they liked better within each pair, because infants did not see Target 1 and Distractor 2 or Target 2 and Distractor 1 together during the learning phase.

Moreover, as an additional control, I included preference questions (e.g., "Which one do you like? Can you pick one") at the end of the task to determine which objects infants liked better in each pair infants had seen during test. Infants' selections in response to the preference questions should simply reflect their toy preference. If infants' selections for the preference questions are not the same as for the comprehension test questions, then infants' comprehension performance is not merely guided by their toy preference.

Thirdly, the study included a more stringent test to determine whether infants indeed established word-object mappings. In the above example of a typical word comprehension test, it is possible that the adult's labeling increases infants' attention to the object (e.g., Baldwin & Markman, 1989), leading them to choose that toy on the comprehension test, without any word mapping having occurred at all. To test this possibility, in addition to including the regular word comprehension test in which only one object had been previously labeled, the study also included a more stringent word learning test: both objects had labels, and the child had to figure out which was which. With both objects having been previously labeled by the experimenter, infants need to map the word to the correct referent to be successful on this task.

Fourthly, the present study included an assessment of infants' comprehension of well-known, familiar labels, such as *dog*, *cup*, *shoe*, and *book*. Infants' ability to select the correct object in the familiar object label comprehension trials provides a baseline estimate of infants' performance on the word comprehension test. These familiar object trials are informative about whether infants stay on task; furthermore, they give us an idea of infants' highest level of word comprehension performance that can be reasonably expected from the sample used in the current study.

Method

Participants

Thirty-six 16-month-olds (18 females; mean age = 16 months 14 days, *SD* = 30.66 days, range 15 months 0 days – 18 months 14 days) participated in the study. An additional 5 infants were tested but excluded from analysis due to fussiness (4) and absence of pointing (1). According to a demographic questionnaire filled out by the caregiver who brought the infant to visit the lab, all infants were full term at birth, developing normally, and came from monolingual, native-English speaking families. The highest level of education of the infants' caregivers was a bachelor's degree for 58.33% of participants, a master's degree for 27.78% of participants, and a doctoral degree for 13.89% of participants. None of them were receiving government assistantship.

Infants were randomly assigned to either the *point contingent* (PC) condition or the *look contingent* (LC) condition. In order to control for the potential effect of general communicative ability on word learning, infants assigned to the *yoked control* (YC) condition were matched to infants in the PC condition based on their language comprehension scores (as measured by a Macarthur Communicative Development Inventory, MCDI).

Materials

Setting. The experimental set-up is illustrated in the Figure 14. A curtain with two window openings stood blocking the back of the testing room. Experimenter 2 protruded objects through the openings, one for each opening (unexpected toys popping out has been successful in eliciting infants' pointing behaviors in previous studies, such as Liszkowski et al., 2004). Infants sat in a booster seat at a table (or on the caregiver's lap if preferred) facing the curtain. Experimenter 1 sat across the table from the infant and in front of the curtain. One camera recorded infants from the midline of the curtain (above the head of Experimenter 1), and one camera recorded Experimenter 1 and the stimuli from the side; both cameras were fed into a quad-splitter. Experimenter 1 wore a pair of Bluetooth earphones, which were connected to Experimenter 2's cellphone.

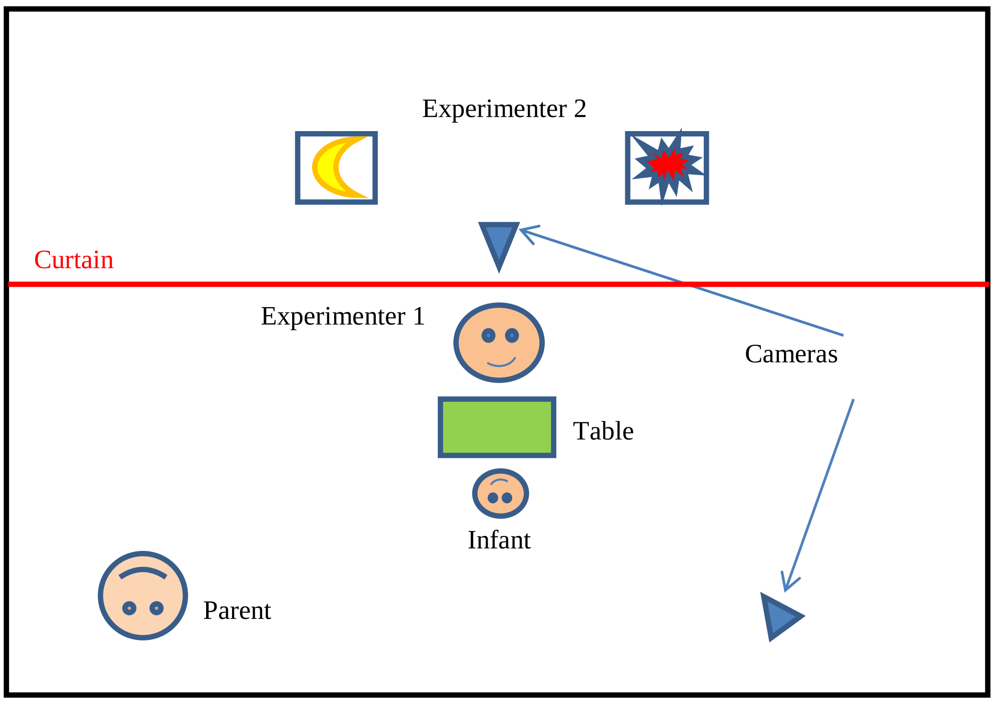


Figure 14. Schematic representation of the set-up of Experiment 2.

Before the experiment started, Experimenter 2 set the timer and ringtones on her phone. At the beginning of each trial, before protruding objects out of the window openings, she started the timer on her phone, which sent the reminder ringtone for Experimenter 1 to mark the end of each trial (30 seconds for each presentation), and the reminder ringtone at a predetermined time schedule in the yoked control condition (based on the timing of labeling in the point-contingent condition of a vocabulary-matched child). The Bluetooth earphones ensured that only Experimenter 1 could hear the ringtone and the child would not be distracted during the task. A noise maker was used by Experimenter 2 to direct the infant's attention toward the curtain at the beginning of each trial.

A Macarthur Communicative Development Inventory (MCDI) and a demographic questionnaire were filled out by caregivers sitting next to the infant. This is to examine whether infants' performance in the experiment relates to general vocabulary acquisition. Caregivers were asked not to interfere with the study.

Stimuli. Each infant saw four pairs of toys, 2 pairs of novel objects (as shown in Figure 15) and 2 pairs of familiar objects.

Figure 15. Novel items used in Experiment 2

The familiar objects were a shoe, a dog, a book and a cup. A set of familiar substitute objects (a banana, a cat, a duck, a hat, and a car) was also on hand in case a child did not know the name of one of the familiar objects. Parents were asked to fill out an object checklist before they participated in the study. They were shown pictures of each item, and were asked to check whether their child knows the name of each familiar item, whether their child has a name for each novel item, and how familiar their child is with each item on a 5 point scale (1-not familiar, 5-very familiar). Familiar objects were used only if the parent reported that the child knew the item, and rated it 3 or higher on the familiarity scale. No parents reported that their child had a name for the novel items used in the current study, and they all rated "1" for the familiarity of each novel item. The same four novel objects were thus used for every infant. These novel toys were thus *novel*, at least as confirmed by parents, to the infant participants. They were demonstrated to be attractive, balanced in salience, and manipulable for infants in a pilot study.

During the word testing session, stimuli were presented on a white tray divided into 2 equal sections. We made sure that the items within each pair were visually distinctive from each other. An array of *two* objects present each time was decided upon to reduce the information-processing load of young infants (Baldwin, 1991).

Novel labels. Two novel labels were used in the study: *stad* and *jick*. These words were drawn from a database of words used in previous word learning studies (Horst, NOUN database, 2009). They were selected because they are: 1) novel for infants and, 2) distinctive from one another and from the familiar labels used in the study (e.g., *dog*, *cup*, *shoe* and *book*). Novel labels were used in the word learning task rather than Standard English labels because 1) it ensures that no child had ever heard the labels before they participated in the study, thus we can measure their word learning performance more accurately; 2) it allows for counterbalanced assignment of the labels to the four different novel objects.

Procedure and Design

Experimental design. The study included three conditions: point contingent, look contingent and yoked control condition. The three conditions each included three phases: 1) a warm-up phase, in which familiar items were used to get infants familiar with the procedure; 2) a word training phase, in which a new label was introduced to infants under controlled conditions, and 3) a test phase, in which infants were asked comprehension questions ("*Can you get the stad?*") on both an easier test (only the target "stad" was present, the other object did not have a name) and a harder test (both "stad" and "jick" were present); moreover, they were also asked preference questions regarding the novel toys involved in the test at the end (e.g., "*Which one do you like?*").

The three conditions differed in certain essential ways. First, the timing of labels provided was different. In the point contingent condition, Experimenter 1 waited until the child pointed; she then followed the child's pointing gesture toward the target object and, uttered the novel label while looking back and forth between the child and the target. In the look contingent condition, Experimenter 1 followed the child's attention when the child oriented his or her look (and also maintained his or her look to the target object for more than 2 seconds), alternated gaze between the child and the target, and uttered the novel label in the same manner as in the point contingent condition. In the yoked control condition, Experimenter 1 waited until she heard the reminder ringtone sent from the Experimenter 2's cellphone. The ringtone was preset by Experimenter 2 according to the time schedule of a vocabulary-matched infant in the point contingent condition. She then alternated her gaze between the child and the target object according to the vocabulary-matched infant in the point contingent condition, and labeled the target object in the same way as with the vocabulary-matched infant in the point contingent condition. Therefore, infants in the yoked control condition heard exactly the same labels toward the same target objects, after being exposed to the toys (starting from when the toys were protruded out of the window openings on the curtain) for the same amount of time as infants in the point contingent condition. However, in this condition, the labels were not provided contingently on infants' own behavior. Importantly, in all three conditions, the experimenter alternated her gaze between the child and the target object when uttering a label; therefore, infants knew clearly what was being labeled by the experimenter. The critical difference is thus the time when labels were provided: after infants pointed, looked, or at predetermined time schedule.

An additional difference among the three conditions is the way that objects were presented: objects were presented in the same way in the point contingent and the yoked control condition, but differently in the look contingent condition. Specifically, in order to investigate the role of pointing gesture in infants' word learning, we need to dissociate pointing and no pointing; that is, to compare infants' word learning performance when they point (while looking) versus when they do not point (just look). Previous studies have shown that when the adult partner has already noticed the existence of the interesting events, infants rarely point (Legerstee & Barillas, 2003; Liszkowski, Schäfer, Carpenter, & Tomasello, 2009; Moore & D'Entremont, 2001). Therefore, in the look contingent condition, instead of presenting objects out of the window openings on the curtain to elicit infants' pointing behavior as in the point contingent condition, Experimenter 1 held objects near the window openings. Because it was clear that Experimenter 1 presented the objects and thus was aware of the existence of these objects, we expected this manipulation would eliminate infants' pointing behavior. Note that the objects were presented at the same distance from each other and from the infant in the point contingent and look contingent condition.

Each infant participated in one of the three experimental conditions, and saw two pairs of familiar objects and two pairs of novel objects. Assignment of toy pairs and labels was counterbalanced with respect to gender in the point contingent and look contingent conditions. Assignment of novel toy pairs and labels for infants in the yoked control condition was exactly the same as the assignment for vocabulary-matched infants in the point contingent condition. Note that only which label was assigned to which pair was counterbalanced; the exact toy that was labeled within each pair depended on infants' own behavior (point or look orientation). Assignment of the familiar toys was also roughly counterbalanced, but the precise counterbalancing was not achieved because infants were not always exposed to the same 4 familiar toys (they were determined by parents' report; the most 4 familiar objects for each infant were used).

During test for any given infant, the target toys appeared equally often in the right- versus left-hand position. The order of which label was asked first was also counterbalanced. Each of the two novel label comprehension trials were intermixed with one familiar label comprehension trial. The three preference trials were presented at the end of the task.

Specific procedure. The infant was placed in an infant seat at a table facing a curtain, with the parent seated nearby, and Experimenter 1 seated across the table from the infant, with her back to the curtain. Parents filled out the language questionnaire and a demographic questionnaire during the session to minimize the parent-child interactions.

If infants insisted, they were allowed to sit on parents' lap to avoid fussiness and parents were instructed to not interact with their infant. The procedure was divided into warm-up, word training, and testing phase.

Warm-up Phase. Infants played with four familiar objects one by one for up to 60 seconds. Experimenter 1 then passed those objects underneath the curtain to Experimenter 2. Experimenter 2 squeezed the noise maker to get the child's attention, started the timer on her phone, and protruded two familiar objects simultaneously out of the window openings for 30 seconds (timed by her phone; if Experimenter 1 was still labeling at the 30th second, Experimenter 2 waited until Experimenter 1 finished labeling). Experimenter 1 labeled the protruded familiar object with its name (e.g., "that's a dog") either immediately after the infant pointed to it (the point contingent condition); or at a schedule predetermined by a vocabulary-matched infant in the pointing condition (the yoked control condition). In the second condition, therefore, infants heard labels at the same times in the trial as the matched infant in the PC condition, but the label was unrelated to their own behavior. In the look contingent (LC) condition, Experimenter 1 labeled an object while holding two objects at a distance near the window openings after infants oriented their first look to an object and maintained looking at it for about 2 seconds.

After labeling one object in the first pair four times, the procedure was repeated with a second pair of objects. Note that only one object within each pair (the first object they pointed to or looked at) was labeled. If infants pointed to the other object in each pair, Experimenter 1 followed infants' attention and said "I see".

After providing the 2 names, one name for each pair, Experimenter 2 then passed all four objects underneath the curtain to Experimenter 1, who gave them one by one to infants to examine up to 60 seconds again. This second examination allowed infants to attend to both target and distractor objects. After that, infants were presented with a *word comprehension test* to be sure that infants understood the task. Experimenter 1 presented two previously-seen familiar objects, side by side, on a tray. She set the tray on the table and silently counted for 3 seconds. This period gave the child an opportunity to look at the objects. Experimenter 1 then looked at the child and asked, “Can you get the XX (name of one familiar object, e.g., dog)? Where is the XX?” and slid the tray forward. Infants were prompted up to four additional times on each trial. On these familiar object trials, infants were praised heavily for correct responses (Experimenter 1 clapped and cheered) and corrected if necessary. After infants correctly identified objects on four trials, the experimenter moved on to the word-training phase. The warm-up stimuli were used as familiar objects during the testing phase.

Word training phase. The word training phase immediately followed the warm-up trials and proceeded in the same way except that infants saw two pairs of novel objects instead of two pairs of familiar objects. Therefore, infants heard two novel names (“stad” and “jick”) after they pointed, at a predetermined time schedule, or when they were just looking, in a similar way as in the warm-up phase.

Test phase. The test phase examines the consistency of infants’ selections in response to the experimenter’s questioning. It includes a word comprehension test and a preference test. The word comprehension test proceeded in the same manner as the word comprehension test in the warm-up phase except that infants were not praised or corrected on the word comprehension test. Instead, Experimenter 1 simply said “OK” or “thank you” when the infant made a selection, regardless of which toy the child picked; If the child showed or gave the toy to the parent sitting nearby, the parent was instructed to simply say “I see” and then returned the toy to the infant or to the experimenter if the infant refused to give the toy to the experimenter. If the infant failed to make a selection after an additional 4 prompts, Experimenter 1 retrieved the toys and moved to the next trial. There were two kinds of tests. On easy testing trials, only one of the two novel objects presented during the test had been labeled previously. The distractor had been seen previously, paired with another target, but it had not been labeled. On hard testing trials, both novel objects had been previously labeled. Infants thus saw three pairs of objects in total in the testing trials: (1) the target “stad” and a distractor that was not labeled, and infants were asked to get the “stad”; (2) the target “jick” and a distractor that was not labeled, and infants were asked to get the “jick”; (3) the target “stad” and “jick”, and infants were asked to get the “stad” or “jick”. Each testing trial was repeated twice, resulting in 8 testing trials in total. In order to maintain infants’ interest and decrease the fussiness rate, we presented the easy testing trials before the hard testing trials. Moreover, after every two novel label comprehension trials, there was one familiar label comprehension trial, in which infants were shown familiar objects seen in the warm-up session. These known objects trials were included as a control to check that the child stayed on task.

Following the novel word comprehension test, children were presented with three preference trials during which the same three pairs of objects from the word testing trials were present. Each pair of item was placed on the tray and children were asked “which one do you like? Can you get one?” before the tray was slid forward for the child to make a choice. These trials provided a measure of children's overall bias in the absence of any word or label. Infants' selections in response to the preference questions should simply reflect their toy preferences (Baldwin et al., 1991). If infants displayed a different pattern of selections for the preference trials than for the word testing trials, then their word learning performance could not be merely a function of their preference for one toy over the other.

If infants became fussy or failed to make four selections in succession, the comprehension test was discontinued and that infant's data was excluded from analyses. If infants answered more than half of the test questions, regardless of whether their answers were right or wrong, the trials that were answered were included and the trials in which infants failed to make any selection were excluded.

Coding and Reliability

Coding was done in two steps: 1) looks during training and 2) test phase coding. First, we coded infants' looking behavior and gesturing during the training phase. Using ELAN (EUDICO Linguistic Annotator: Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands <http://www.lat-mpi.eu/tools/elan/>; Lausberg & Sloetjes, 2009), coders who were blind to the study hypothesis coded the videos frame by frame and judged 1) where the child looked during each object presentation: at either of the two toys presented on each trial, the experimenter, the parent, or something else; 2) whether infants were looking at the target toy at the time of the experimenter's labeling utterance; 3) when infants gestured (pointed to objects with an index finger, or reached toward objects with one whole hand or both hands); and 4) the duration of infants' gesture. Two infants' looking behavior (1 in the point contingent condition and 1 in the yoked control condition) were unable to be coded, because they sat on the parent's lap, which was taller than the infant's seat, and the infants' eyes were thus above the region of video recording. Therefore, these two infants' object selection behavior was coded and analyzed, but their looking behavior data was missing. Another two videos (1 in the point contingent condition and 1 in the yoked control condition) did not have sound due to microphone error, thus we could code these two infants' looking behavior, but were unable to code whether infants were looking at the target at the time of experimenter's labeling. Another naïve coder coded 33% of the sessions, and the agreement was 91%.

Second, we coded infants' selections in response to the comprehension and preference questions from video recordings of each session, in terms of 1) which of the two toys infants first touched or gestured to in response to the question (basic choice) and 2) which of the two toys infants used as an answer to the question (final choice). Coders were blind to the training phase and the study hypothesis; therefore, they did not know which object was the correct referent to the label on the novel word comprehension test. A random selection of 33% of the sessions was coded by a second naïve coder. Inter coder agreement was 97%.

Results

Infants' mean age and language scores are presented in Table 10. Overall, infants' mean comprehension vocabulary was 137.19 (*SD* = 88.36, range = 33-336, object labels = 75.34, 51.35% of total), and production vocabulary was 27.39 (*SD* = 36.10, range = 0-159, object labels = 13.66, 36.38% of total). Preliminary data analyses showed no significant differences in infants' age and MCDI scores across the three conditions, *p*s > .10. In addition, regression analyses showed that infants' vocabulary size did not predict their comprehension performance, either on familiar label trials or novel label trials.

Preliminary analyses revealed no effects or interactions involving gender. Therefore, the following data analyses were conducted on data collapsed across gender.

Table 10. Characteristics of participants in Experiment 2 as a function of experimental condition.

	PC	LC	YC
n	12 (6F)	12 (6F)	12 (6F)
M_{age}	16;6	16;21	16;12
$M_{comprehension}$ (*SD*)	126 (84)	151 (94)	128 (96)
$Range_{comprehension}$	33-328	45-332	42-336
$M_{production}$ (*SD*)	20 (13)	30 (52)	34 (39)
$Range_{production}$	4-42	0-159	0-125
$M_{gesture}$ (*SD*)	33 (8)	38 (9)	41 (10)
$Range_{gesture}$	22-46	23-52	24-52

Note: PC = pointing contingent condition; LC = looking contingent condition; YC = yoked control condition.

Manipulation Check

The experimental design called for labels being presented after the infant pointed to it (pointing contingent condition), looked at it (look contingent condition), and at predetermined time schedule according to a vocabulary-matched point contingent infant (yoked control condition). We first did a manipulation check to investigate whether the experimental manipulation was successful. We thus examined the relation between infants' gestures during the training phase and the time when Experimenter 1 provided a label. Table 11 shows the number of infants who pointed in each condition and Table 12 shows the proportion of infants' pointing gestures toward the target object in each condition.

Table 11. Number of infants who pointed in each experimental condition.

	Index-finger point	Whole-hand point	Both	Total
Point contingent	7	4	1	12
Look contingent	2	5	0	7
Yoked control	2	4	4	10

Table 12. Proportion of infants' pointing gestures toward the target object in each experimental condition.

	Index-finger point	Whole-hand point	Both	Total
Point contingent	67%	93%	75%	75%
Look contingent	56%	56%	\	56%
Yoked control	33%	38%	55%	45%

All of the 12 infants in the point contingent condition pointed (7 pointed only with an index finger, 4 pointed only with whole hands, and 1 did both kinds of points across trials) in the training trials, and Experimenter 1 labeled the first object (thus the target) to which the infant had pointed immediately. Six infants also pointed to the other object (the distractor) after the experimenter labeled the target. Each infant pointed, on average, 3.25 times. Overall, among point contingent infants' pointing gestures, 75% of them were toward the target objects. More specifically, 67% of the index-finger pointing gestures were toward the target objects, and 93% of the whole-hand points were toward the target objects.

Seven infants in the look contingent condition pointed at least once, and 4 of them pointed at least once to the distractor. Overall, about 56% (12 out of 18 pointing gestures in total) of look contingent infants' pointing gestures were toward the target objects. Only 2 infants in the look contingent condition pointed with an index finger (1 infant pointed to a target object in 1 training trial, and another infant pointed to a distractor in 1 training trial). In addition, 5 infants in the look contingent condition pointed with whole hands toward the objects (56% of the whole-hand points were toward the target objects). Each infant pointed, on average, 2.57 times. Among the 96 naming events (8 naming events for each of the 12 infants) in the look contingent condition, only 8 naming events happened within 2 seconds of infants' pointing. This happened when the experimenter labeled the target object 4 times in a row and the child pointed at the same time, which was hard to avoid.

Ten infants in the yoked control condition pointed at least once, and 8 of them pointed at least once to the distractor. Overall, about 45% of yoked control infants' pointing gestures were toward the target objects. For the yoked control condition, 2 infants pointed with an index finger (1 infant pointed to a target object in 1 training trial, and another infant pointed to distractors in both training trials). Four infants pointed with whole hands (38% of the whole-hand pointing were toward the target objects) during training, 4 infants pointed with both (55% of the pointing were toward the target objects), and 2 infants did not point at all. Each infant pointed, on average, 3.70 times. Among the 96 naming events in the yoked control condition, only 6 naming events occurred within 2 second of infants' pointing to the target object.

Chi-square tests showed that the number of infants who pointed during the test was different across the conditions, $\chi^2(2) = 6.74$, $p = .03$. Specifically, fewer infants pointed in the look contingent condition (7 out of 12) than the point contingent condition (12 out of 12), $\chi^2(1) = 6.31$, $p = .01$. Comparisons between the other two pairs (look contingent and yoked control condition, point contingent and yoked control condition) showed no significant differences, *p*s > .10.

A one-way ANOVA test was conducted, with the proportion of pointing gestures to the target objects (arcsin transformed) as the dependent variable. Results showed that the proportion of pointing gestures to the target objects overall did not differ significantly across the three conditions, F (2, 25) = 2.30, p = .12, partial η^2 = .16. An independent-Samples Kruskal-Wallis Test showed similar results, test statistic = 3.78, p = .15. These results suggest that, if infants pointed during the phase when labels were introduced, the proportion of pointing toward the target objects were the same across three conditions.

These results suggest that the experimental manipulation was overall successful. Infants in the point contingent condition heard labels immediately (within 2 seconds) after they pointed to the target objects. In contrast, though some infants in the look contingent condition and the yoked control condition pointed, the naming events rarely occurred contingently on their pointing. Pointing rate was relatively lower in the look contingent condition, but once infants pointed, infants pointed to the target objects equally often.

Looking Behavior during Training

Each training trial lasted approximately 30 seconds, and there were 2 training trials for each infant, with one label being introduced in each trial. There were no significant differences in length of the training trial across the three conditions, M_{PC} = 35.07 seconds, SD_{PC} = 2.81; M_{LC} = 33.25 seconds, SD_{LC} = 2.99; M_{YC} = 34.41 seconds, SD_{YC} = 3.45), F (2, 31) = 1.02, p = .37, partial η^2 = .06. We calculated the amount of time looking at the target object, the distractor and the experimenter per trial, and also calculated the frequency of looking at the target object at the time of labeling.

The amount of time looking at the target object. The descriptive data is shown in Figure 16.

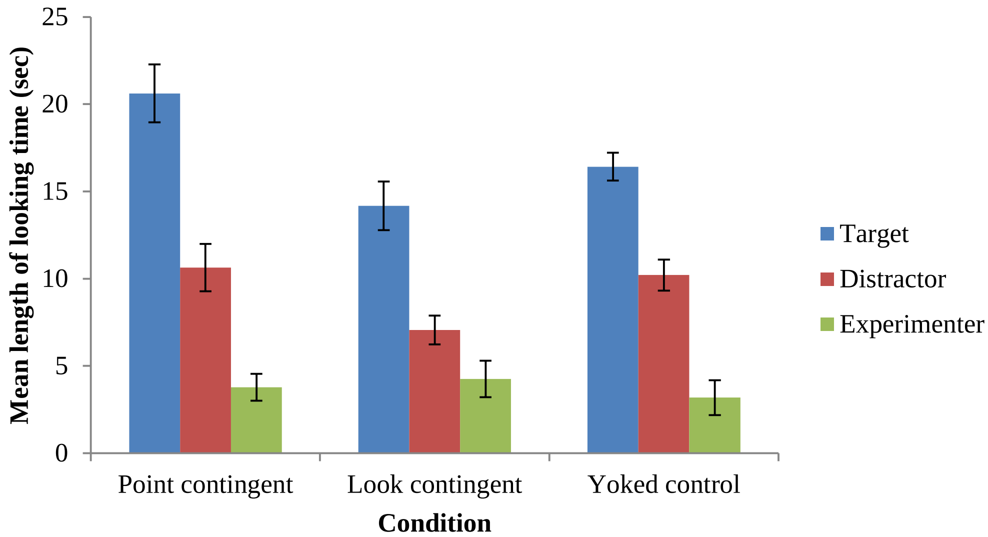


Figure 16. The mean length of looking time to the target, the distractor and the experimenter during training in the point contingent, look contingent and yoked control condition. The error bars represent the standard error of the means.

We conducted a 3 (within-subject factor, look: target, distractor, experimenter) × 3 (between-subject factor, condition: PC, LC, YC) mixed factor analysis, with the amount of time looking as the dependent variable. Overall there was a significant main effect of look, F (2, 30) = 69.21, $p < .001$, partial $\eta^2 = .82$. Infants overall looked longer to the target object (M = 16.99, SD = 5.14) than to the distractor (M = 9.24, SD = 3.77), which was significantly longer than to the experimenter (M = 3.75, SD = 3.16). Corrected Bonferroni pair-wise comparisons showed that each pair comparison was significant, $p < .001$. There was also a significant main effect of condition, F (2, 31) = 12.38, $p < .001$, partial $\eta^2 = .44$. Post-hoc Bonferroni tests showed that infants in the point contingent condition (M = 11.68, SD = 1.53) looked at the target, the distractor and the experimenter, on average, for a longer amount of time than infants in the look contingent condition (*M* = 8.50, *SD* = 1.53), $p < .001$, and also longer than infants in the yoked control condition (*M* = 9.93, *SD* = 1.53), $p = .04$. The difference in the looking time between the look contingent condition and the yoked control condition was not significant, $p = .10$. There is a marginally significant interactive effect of look and condition, F (4, 62) = 2.30, $p = .068$, partial $\eta^2 = .13$. Further analyses showed that the main effect of condition held up for looks to the distractor, F (2, 31) = 3.60, $p = .039$, partial $\eta^2 = .19$, and also for looks to the target, F (2, 31) = 6.00, $p = .006$, partial $\eta^2 = .28$, but not for looks to the experimenter, F (2, 31) = 0.32, $p = .73$, partial $\eta^2 = .02$. That is, infants in the point contingent condition looked longer to the target as well as to the distractor than infants in the look contingent and the yoked control condition, yet the latter two conditions did not differ significantly from each other.

We also asked whether infants' looking pattern was different before and after the experimenter uttered the label. We calculated infants' looking time to the target, the distractor, and the experimenter *before* the experimenter uttered the first label and *after* the experimenter uttered the first label in each trial (see Table 13).

Table 13. The mean length of looking time (standard deviation) to the distractor, the experimenter and the target before and after the experimenter uttered the first label in each condition.

	Before labeling			After labeling		
	Target	Distractor	Experimenter	Target	Distractor	Experimenter
PC	11.62(5.16)	5.47(3.97)	1.20 (1.43)	8.92(4.67)	4.82(3.23)	2.56(2.11)
LC	5.56(3.96)	2.15(2.10)	1.17 (1.45)	8.61(4.68)	4.89(3.51)	3.08(2.66)
YC	11.15(4.47)	7.69(2.73)	1.97(1.94)	5.35(3.56)	2.62(2.01)	1.46(2.30)

Note: PC = pointing contingent condition; LC = looking contingent condition; YC = yoked control condition.

We then conducted a 2 (within-subject factor, time: before and after) × 3 (within-subject factor, look: target, distractor, experimenter) × 3 (between-subject factor, condition: PC, LC, YC) mixed factor analysis, with the amount of time looking as the dependent variable. Results showed a three-way interaction between time, look and condition, F (4, 58) = 2.52, p = .05, partial η^2 = .15. We first analyzed this 3-way interaction by examining the looking behavior before and after the experimenter's labeling separately. Before the experimenter uttered the first label, infants' looking time to the distractor was significantly different in the 3 conditions, F (2, 29) = 9.68, p = .001, partial η^2 = .40. Infants in the look contingent condition looked at the distractor for a significantly shorter amount of time (*M* = 2.15, *SD* = 2.10) than infants in the point contingent condition (*M* = 5.47, *SD* = 3.97) and the yoked control condition (*M* = 7.69, *SD* = 2.73), p = .04, .00, respectively, yet the latter two conditions did not differ from each other, p = .32. In addition, infants' looking time to the target also differed significantly, F (2, 29) = 6.25, p = .006, partial η^2 = .06. Infants in the look contingent condition looked at the target for a shorter amount of time (*M* = 5.56, *SD* = 3.97) compared to the other two conditions (point contingent condition *M* = 11.62, *SD* = 5.16; yoked control condition *M* = 11.15, *SD* = 4.48), p = .01, .02, respectively for the point contingent and the yoked control condition, which did not differ significantly from each other, p = .10. Infants' looking time to the experimenter, however, was not significantly different in the 3 conditions, F (2, 29) = 0.82, p = .45, partial η^2 = .05.

The shorter time of looking at the target and distractor in the look contingent condition compared to the other conditions might be due to the fact that the experimenter labeled the object more quickly in the look contingent condition, which was designed to label things when the child oriented his or her first look and maintained his or her look at least 2 seconds on the object. To test this possibility, we coded the interval between the onset of the object presentation and the first label uttered by the experimenter in each trial. We conducted a Univariate test with the interval between the onset of the object presentation and the first label uttered by the experimenter as the dependent variable, and the condition as the independent variable. There was a significant main effect of condition, F (2, 29) = 12.59, $p < .01$, partial $\eta^2 = .47$. Bonferroni post-hoc tests showed that the interval was significantly shorter in the look contingent condition (M = 9.90, SD = 6.63) than the point contingent condition (M = 21.08, SD = 8.90) and the yoked control condition (M = 24.00, SD = 5.09), p = .003, .00, respectively. The difference between the latter two conditions was not significant, p = 1.000.

Importantly, we found that contrary to infants' look patterns before the experimenter's labeling, *after* the experimenter uttered the label, no significant condition effects were found in infants' looking time to the target, F (2, 29) = 2.11, p = .14, partial $\eta^2 = .13$, to the distractor, F (2, 29) = 1.88, p = .17, partial $\eta^2 = .12$, or to the experimenter, F (2, 29) = 1.29, p = .29, partial $\eta^2 = .08$.

Frequency of monitoring. The above analysis of looking time indicates that infants looked at the target, the distractor, and the experimenter for a similar amount of time *after* the experimenter uttered the first label regardless of which condition they were in. In addition to the amount of time looking, we also coded the frequency of infants' looking orientation toward the target, the distractor and the experimenter after hearing a label, which may reflect infants' monitoring during word learning (Baldwin, 1991). The descriptive data is shown in Table 14.

Table 14. The mean number of looks (standard deviation) to the distractor, the experimenter and the target after the experimenter uttered the first label in each condition.

	Target	Distractor	Experimenter
Point Contingent	5.20(2.20)	5.00(2.40)	2.30(1.89)
Look Contingent	4.92(2.27)	4.50(2.61)	4.08(2.27)
Yoked Control	3.40(1.58)	3.20(2.10)	1.70(2.16)

We conducted a 3 (within-subject factor, look: target, distractor, experimenter) × 3 (between-subject factor, condition: PC, LC, YC) mixed factor analysis, with the number of looks *after* hearing a label as the dependent variable. Results showed: (1) a significant main effect of look, F (2, 28) = 12.43, $p < .001$, partial $\eta^2 = .47$, with infants looking more often to the target (M = 4.53, SD = 2.14) and the distractor (M = 4.25, SD = 2.44) than to the experimenter (M = 2.78, SD = 2.31), p = .000, .027, respectively. The comparison between the number of looks to the target and to the distractor was not significant, p = 1.00. (2) There was a marginally significant main effect of condition, F (2, 29) = 3.15, p =.06, partial $\eta^2 = .18$. Further analysis showed that the marginally significant main effect of condition only held up for the number of looks to the experimenter, with infants in the look contingent condition tending to look more to the experimenter than in the yoked control condition. (3) There was no significant interaction between condition and look, F (4, 58) = 1.23, p =.31, partial $\eta^2 = .08$.

Frequency of looking at the target at the time of Experimenter 1's labeling. Experimenter 1 introduced two labels in total, and each label was uttered four times on each trial. We thus coded how many times each infant was looking at the target during these 8 word learning opportunities. We then conducted an ANOVA test with the frequency of looking at the target among the 8 word learning opportunities as the dependent variable, and the condition as the independent variable. Infants overall were quite focused on the target object at the time of experimenter's labeling, $M_{PC} = 7.30$, $SD_{PC} = .82$, $M_{LC} = 7.67$, $SD_{LC} = .65$, $M_{YC} = 7.30$, $SD_{YC} = .82$. There was no significant effect of condition, F (2, 29) = .87, $p = .43$, partial $\eta^2 = .06$.

The looks-during-training results are noteworthy on four counts. First, regardless of which condition the child was in, they looked at the target (i.e., the one that was labeled) overall longer than the distractor during training. Second, though infants in the look contingent condition looked at the target and the distractor for an overall shorter amount of time than infants in the point contingent and the yoked control condition, this difference only existed before the experimenter uttered a label; after a label was provided, no significant difference in the amount of time looking at the target, distractor and the experimenter was found. In addition, there was no significant difference in the number of infants' looks toward the target, the distractor and the experimenter after hearing a label. This suggests that the experimenter's labeling was quite successful in attracting infants' attention toward the presented objects. Third, we found that infants in the look contingent condition heard labels after being exposed to objects for a shorter time than infants in the other two conditions. This may explain why infants in the look contingent condition looked to the target and the distractor for a shorter amount of time than infants in the other two conditions before the experimenter produced a label. In the look contingent condition, the experimenter followed the first orientation of infants' look and provided a label (in case the infant glanced very quickly and it was hard to follow the infant's attention, we defined that the experimenter only followed and labeled if the child first maintained the look for 2 seconds). In the point contingent condition, the experimenter labeled after the child pointed, and in the yoked control condition, the experimenter labeled according to a time schedule determined by a vocabulary-matched infant in the point contingent condition. It usually takes longer for infants to point than to just look, which results in a shorter amount of time looking for infants in the look contingent condition.

The last way in which the looking behavior during training is notable is that, based on infants' looking behavior, they appeared to maximize word learning opportunities. On all 8 of the times when the experimenter uttered a label, infants in all three conditions were very focused on the target object. In sum, the looks-during-training results showed no significant differences in the amount of time looking at, or in the number of looks toward, the presented objects across the three experimental conditions; in addition, infants in all conditions were mostly looking at the target at the time of experimenter's labeling. This may exclude the possibility that the children's word learning performance was due to their looking behavior during training.

Object Choice Behavior

The proportion of infants' final choice was used as the dependent variable. Proportions in all analyses were submitted to the arcsin transformation ($X' = arcsin\sqrt{X}$), because the distribution of transformed variables is closer to normal than untransformed proportions. However, for the ease of comprehension, the mean scores (and standard deviations) are reported for the *untransformed* variables (see Figure 17).

Comprehension of familiar labels. Infants' object choice in the familiar label trials did not differ across conditions (M_{PC} = 81.65%, SD_{PC} = 22.55%; M_{LC} = 78.78%, SD_{LC} = 23.92%; M_{YC} = 75%, SD_{YC} = 21.32%), F (2, 33) = 1.45, p = .25, partial η^2 = .08.

Comprehension of novel labels. We first tested whether infants selected the correct toy more often than would be expected if they were merely making random selections. Because there were two toys present each time in each test trial, the chance level is 50%. Infants' word learning performance in novel label trials is shown in Figure 17. One-sample t test showed that infants chose the correct object significantly above chance level only in the point contingent condition, for the easy test, $t(11) = 2.57$, $p = .03$, $d = 0.74$; for the hard test, $t(11) = 2.76$, $p = .02$, $d = 0.78$. Their object choice did not differ significantly from chance level in the other two conditions, *p*s > .10.

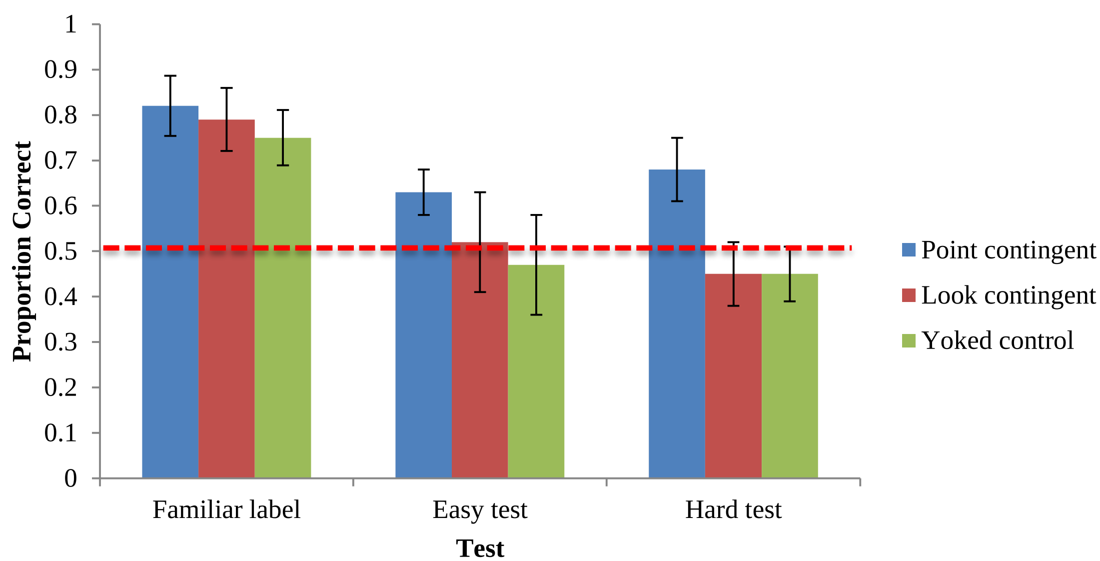


Figure 17. The mean proportion of correct object choice across the three conditions on the easy and hard test. The horizontal line represents the 50% chance level. The error bars represent the standard error of the means.

Of particular interest in the word comprehension test is the possibility of a condition effect in infants' correct object choice. A 2 (within-subject factor, test: easy vs. hard) × 3 (between-subject factor, condition: PC, LC, YC) mixed-design analysis showed that there was a significant main effect of condition, F (2, 33) = 4.15, $p = .025$, partial η^2

= .20. Post-hoc analyses showed that the word learning performance was significantly better in the PC condition than that in the LC condition, p = .048, and better than the YC condition, p = .036, but no difference was found between LC and YC, p = 1.00. The main effect of test, F (1, 33) = .09, p = .76, partial η^2 = .003, and the interactive effect of test and condition was not significant, F (2, 33) = .14, p = .87, partial η^2 = .008. Subsequent analyses showed that the main effect of condition held up for the hard test, F (2, 33) = 4.21, p = .02, partial η^2 = .20, but not for the easy test, F (2, 33) = .78, p = .47, partial η^2 = .05. That is, in the hard test, infants in the point contingent condition (M = .68, SD = .23) performed significantly better than infants in the look contingent (M = .45, SD = .23) and the yoked control condition (M = .45, SD = .18), p = .04, .04 respectively.

Comparing comprehension of familiar and novel labels. Infants' word learning performance on the easy and hard tests was averaged to represent their comprehension performance for novel labels, because we did not include two levels of test for the familiar objects. A 2 (within-subject factor, test: familiar vs. novel) $\times$ 3 (between-subject factor, condition: PC, LC, YC) mixed-design analysis showed that there was a significant effect of test, F (1, 33) = 18.62, p < .001, partial η^2 = .36. Infants' overall comprehension performance was better for familiar labels (M = .78, SD = .22) than novel labels (M = .52, SD = .20). The main effect of condition was marginally significant, F (2, 33) = 3.24, p = .052, partial η^2 = .16. The interactive effect of condition and test was not significant, F (2, 33) = .79, p = .46, partial η^2 = .05.

It is not surprising that infants performed better on the comprehension questions regarding familiar labels that they had known for some time than they did on the questions regarding the novel labels that they had heard only four times during the study.

The importance of this finding relates to the fact that the familiar label tests were intermixed with the novel label tests; therefore, the finding that infants' performance on the familiar label tests did not differ across conditions and was better than the performance on the novel label tests suggests that infants were staying on task.

Selection of the target toy in the preference trial. Recall that in the 3 preference trials, the same 3 pairs of objects that were presented in the word comprehension test were present. They were: a target object 1 (e.g., "stad") and a distractor 1 with no name, a target object 2 (e.g., "jick", the order of "stad" and "jick was counterbalanced) and a distractor 2 with no name, and both targets ("stad" and "jick"). The first two pairs were seen in the easy comprehension test, and the last pair was seen in the hard comprehension test. Note that in the point contingent condition, the target object was the object that the child pointed to, while the distractor was the one that the child did not point to; in the look contingent condition, the target object was the object to which the child oriented and maintained his or her look to for at least 2 seconds; in the yoked control condition, the target object was selected by the experimenter according to a vocabulary-matched infant in the point contingent condition, that is, the target object was unrelated to the infant's own behavior. Did infants prefer the objects that they pointed to? If so, infants in the point contingent condition would choose the target object in the preference trials, in which the target was contrasted with a distractor, more often than infants in the other two conditions.

To test this possibility, I combined the two preference trials in which one target (i.e., labeled) was paired with one distractor (i.e., not labeled), and counted the number of times they chose the target. The number of infants who chose the target object 0, 1, or 2 times in the two preference trials is presented in Table 15.

Table 15. Number of infants who chose the labeled object 0, 1 or 2 times in the preference trials in which the labeled object was paired with an unlabeled one.

		Point contingent	Look contingent	Yoked control
Chose the labeled object	none	2	4	4
	once	4	7	5
	twice	4	0	1

Note: only infants who answered both 2 preference questions were included, $N = 31$.

The selections obtained in the three conditions did not differ significantly from each other, $\chi^2(4) = 6.82$, $p = .15$. Of the 31 infants who answered both of the preference questions in which a target was paired with a distractor, 4 out of 10 infants in the point contingent condition chose the target on both preference trials. This frequency is not different from chance (the chance of choosing the target on both preference trials is .25), binomial test $p = .15$. Meanwhile, 0 children in the look contingent condition chose target objects in both preference trials and 1 child in the yoked control condition chose target objects in both preference trials, which did not differ significantly from chance levels either (binomial test $p = .15$, .33, respectively). These results suggest that infants in the point contingent condition did not select the toys that they pointed to in the preference trials more often than children in the other two conditions.

In the third preference trial, both objects that had been previously labeled were present, which were the same as those seen in the hard comprehension test. We thus coded which object the child preferred, and counted how many times the child selected the same toy in the hard comprehension test. There were 4 hard comprehension test trials in total. The results are presented in Table 16.

Table 16. Number of infants who chose the same object in the hard comprehension trials and the preference trial in which both labeled objects were present.

		Point contingent	Look contingent	Yoked control
Number of times choosing the same object	none	1	1	0
	once	0	2	0
	twice	2	2	4
	Three times	3	3	3
	Four times	3	3	3

Note: only infants who answered the preference question of comparing two labeled objects were included, $N = 30$.

The number of children who always chose the same object in the hard comprehension trial did not differ across the three conditions, $\chi^2(2) = .09$, $p = .96$. Of the 30 infants who answered the preference question in which both objects had been previously labeled, 3 infants in each condition chose the same object 4 times in the hard comprehension test trials and the preference trial. This frequency is not different from chance (binomial test $p = .27$, .25, .27 respectively for the point contingent, look contingent and yoked control condition). Note that the proportion of these 12 children's correct object choices was 0.5, because in the 4 hard comprehension trials, each object was requested twice; if the child chose the same object 4 times, then the proportion of successful mapping was 50%, which was chance level. Though these children picked the same object on the hard comprehension test trials as they did when they were asked to pick the one they liked, it is difficult to know whether these children were always picking the one they liked regardless of what question was asked, or they just picked randomly and happened to pick the same object. Importantly, there was no condition effect in the number of children picking the same object in the comprehension test and the preference trial. Therefore, we did not exclude these children's data from analyses.

In sum, the data from preference questions was noteworthy in two counts. First, it is possible that the object children pointed to was also the one that children liked. If this is the case, one might worry that on the easy comprehension test trials in which the labeled object was paired with a non-labeled object, children in the point contingent condition might be more likely to choose the one to which they had pointed, merely because they liked the one they pointed to better. The results from the two preference trials in which the same two pairs of objects were seen in the easy comprehension test trials did not support this possibility. We did not find that infants in the point contingent condition were more likely to choose the object to which they had pointed than children in the other two conditions. Second, there were a few children who always chose the same object on the hard comprehension test trials and on the preference trial when both labeled objects were present. The number of these children did not differ significantly from chance level, nor did they differ across the three conditions. In total, the results from the preference trials may exclude the possibility that the higher proportion of correct object choice in the point contingent condition was due to a preference for the object to which infants had pointed.

Ruling out alternative hypotheses. The results considered so far suggest that infants of 16 months are more successful at mapping novel words to the correct referents when the words are provided after they point to the objects. However, the looking behavior analysis showed that infants in the point contingent condition overall looked to the target and the distractor during the training phase longer than infants in the other two conditions. Though subsequent analysis showed that the difference in the looking time occurred only *before* the experimenter's labeling, not after the experimenter's labeling, one may argue that the decreased selection of the correct referents in the look contingent and yoked control conditions might have occurred simply because infants looked at the target less during training.

To test this possibility, I conducted a similar test as I did above, but entered the amount of time infants spent looking at the target objects during training as a covariate in a 2 (within-subject factor, test: easy vs. hard) $\times 3$ (between-subject factor, condition: PC, LC, YC) ANCOVA test. This analysis revealed the same pattern of effects as the original analysis: there was a significant main effect of condition, F (2, 30) = 4.45, p = .02, partial η^2 = .23. Post-hoc analyses showed that the word learning performance was significantly better in the PC condition than that in the LC condition, p = .04, and better than the YC condition, p = .02, but no difference was found between LC and YC, p = 1.00. The main effect of test, F (1, 30) = .41, p = .53, partial η^2 = .01, and the interactive effect of test and condition was not significant, F (2, 30) = 1.76, p = .19, partial η^2 = .11. The effect of covariate was not significant, F (1, 30) = 1.09, p = .31, partial η^2 = .04. Similarly, subsequent analyses showed that the main effect of condition held up for the hard test, F (2, 30) = 10.90, p < .001, partial η^2 = .42, but not for the easy test, F (2, 30) = .23, p = .80, partial η^2 = .02. That is, in the hard test, after controlling for the amount of time looking at the target object, infants in the point contingent condition (M = .68, SD = .23) performed significantly better than infants in the look contingent (M = .45, SD = .23) and the yoked control condition (M = .45, SD = .18), ps = .001, .001 respectively.

A second possibility is that infants in the look contingent and the yoked control condition were irritated by the experimenter's inattentive and relatively directive behavior. For example, in the yoked control condition, the experimenter labeled the objects at predetermined time schedule, which was unrelated to infants' own behavior; if infants pointed, the experimenter simply commented, "that's a nice point", but did not follow pointing or provide labels to respond to the point. If infants were irritated, they may have been less cooperative during the test, and less responsive to comprehension questions, which would have looked like worse word learning performance. If this is true, then infants should also be uncooperative in answering questions regarding the familiar label questions; therefore, infants' word learning performance in the familiar label comprehension trials could be used as an assessment of their "irritation". Note that infants' familiar label comprehension performance in the yoked control condition (75%) seemed to be lower than that in the point contingent condition (81.65%), but the difference was not statistically significant.

To test the validity of this possibility, we conducted a similar ANCOVA test as we did above, but entered infants' word learning performance in the familiar label comprehension trials as a covariate. This analysis again revealed a significant main effect of condition, F (2, 32) = 4.15, p = .03, partial η^2 = .21. The main effect of test, F (1, 32) = 1.15, p = .29, partial η^2 = .04, and the interactive effect of test and condition, F (2, 32) = .06, p = .94, partial η^2 = .004, were not significant. The effect of covariate was not significant, F (1, 32) = .22, p = .64, partial η^2 = .01. Similarly, subsequent analyses showed that the main effect of condition held up for the hard test, F (2, 32) = 3.51, p = .04, partial η^2 = .18, but not for the easy test, F (2, 32) = .1.07, p = .36, partial η^2 = .06. That is, in the hard test, after controlling for infants' performance in the familiar label comprehension test, infants in the point contingent condition (M = .68, SD = .23) performed significantly better than infants in the look contingent (M = .45, SD = .23) and the yoked control condition (M = .45, SD = .18), ps = .043, .053 respectively.

These results thus suggest that infants' worse performance on the word comprehension test in the look contingent and the yoked control condition was not simply because they looked at the target object for a shorter amount of time, or were irritated or uncooperative in the task.

Comparing pointers with non-pointers. In the initial experimental design, we wanted to eliminate infants' pointing gestures in the look contingent condition so that we could investigate whether infants learn word-object associations when they have pointed than when they did not. We thus had Experimenter 1 hold objects instead of presenting them behind the curtain. However, some infants still pointed in this condition: 2 infants pointed with index-fingers: one infant pointed to a distractor in 1 training trial and one infant pointed to a target in 1 training trial; in addition, 5 infants pointed with whole-hands. This thus raises a question: was infants' worse performance on the word comprehension test in the look contingent condition due to fewer pointing gestures produced, or due to the labels not being contingent on pointing gestures?

We explored this issue by comparing pointers' and non-pointers' word comprehension performance. Did pointers learn words better than non-pointers? The descriptive data is shown in Table 17.

The pointers were infants who pointed at least once during the training phase in which the novel labels were introduced, regardless of index-finger pointing or whole-hand pointing. Independent samples Mann-Whitney U test showed no significant differences between pointers and non-pointers overall in the known label test trial (standardized U = .15, p = .91), novel label easy test trial (standardized U = .19, p = .88), novel label hard test trial (standardized U = -.24, p = .85), and novel label test trial in total (standardized *U* = .04, *p* = .97). There were no significant differences between pointers and non-pointers in each individual condition either, *p*s > .10.

Table 17. Mean proportion (standard deviation) of pointers' and non-pointers' performance on the word comprehension test in each condition.

			Word comprehension test			
		n	Known	Easy	Hard	Total
Point contingent	Pointer	12	.82(.23)	.63(.17)	.68(.23)	.64(.13)
	Non-pointer	0	\	\	\	\
Look contingent	Pointer	7	.70(.27)	.50(.43)	.43(.28)	.42(.18)
	Non-pointer	5	.88(.16)	.48(.29)	.48(.15)	.48(.17)
Yoked control	Pointer	10	.70(.31)	.46(.37)	.42(.16)	.45(.24)
	Non-pointer	2	.38(.18)	.63(.18)	.63(.18)	.63(.18)
Total	Pointer	29	.75(.26)	.54(.32)	.53(.25)	.52(.20)
	Non-pointer	7	.74(.29)	.52(.26)	.53(.16)	.52(.17)

Second, we further compared the differences between *target* pointers and non-pointers, because it may be that pointing to the *target* object made a difference in word learning. The target pointer refers to infants who pointed at least once to the target objects during training. The descriptive data is shown in Table 18.

Similar results as above were found: Independent samples Mann-Whitney U test showed no significant differences between pointers and non-pointers overall in the known label test trial (standardized *U* = 1.07, *p* = .31), novel label easy test trial (standardized *U* = .52, *p* = .63), novel label hard test trial (standardized *U* = -.09, *p* = .93), and novel label test trial in total (standardized *U* = .56, *p* = .59). There were no significant differences between target pointers and the others when investigating infants' performance in each individual condition either, *p*s > .10.

Table 18. Mean proportion (standard deviation) of target pointers' and others' performance on the word comprehension test in each condition.

			Word comprehension test			
		n	Known	Easy	Hard	Total
Point contingent	Target Pointer	12	.82(.23)	.63(.17)	.68(.23)	.64(.13)
	Others	0	\	\	\	\
Look contingent	Target Pointer	5	.70(.33)	.60(.45)	.30(.11)	.44(.19)
	Others	7	.83(.16)	.42(.30)	.56(.23)	.45(.17)
Yoked control	Target Pointer	7	.79(.17)	.38(.37)	.45(.08)	.42(.19)
	Others	5	.45(.37)	.63(.28)	.45(.27)	.56(.28)
Total	Target Pointer	24	.78(.23)	.55(.31)	.53(.23)	.54(.19)
	Others	12	.67(.32)	.51(.30)	.51(.24)	.50(.21)

Third, we compared the differences between index-finger pointers and non-pointers because index-finger pointing gestures have been proposed to be more advanced communicative behavior (Tomasello et al., 2007), and may function differently than whole-hand pointing, which is much like reaching (Cochet & Vauclair, 2010b). The descriptive data is shown in Table 19.

Table 19. Mean proportion (standard deviation) of index-finger pointers' and others' performance on the word comprehension test in each condition.

			Word comprehension test			
		n	Known	Easy	Hard	Total
Point contingent	IF pointer	8	.76(.25)	.69(.18)	.66(.25)	.67(.15)
	Others	4	.95(.13)	.50(.00)	.73(.21)	.60(.07)
Look contingent	IF pointer	2	.46(.29)	.00(.00)	.63(.53)	.20(.08)
	Others	10	.84(.18)	.59(.32)	.42(.15)	.50(.13)
Yoked control	IF pointer	6	.79(.19)	.43(.34)	.47(.07)	.46(.16)
	Others	6	.50(.35)	.54(.37)	.43(.25)	.50(.30)
Total	IF pointer	16	.73(.24)	.51(.33)	.58(.24)	.53(.22)
	Others	20	.76(.29)	.56(.29)	.48(.22)	.52(.18)

Note: IF = index-finger; IF pointer = infants who pointed with an index-finger at least once during the training phase; others = infants who pointed but did not point with an index-finger and infants who did not point at all.

The index-finger pointers were infants who pointed with an index-finger at least once during the training phase in which the novel labels were introduced. Similar results as above were found: Independent samples Mann-Whitney U test showed no significant differences between pointers and non-pointers overall in the known label test trial (standardized $U = -.60$, $p = .58$), novel label easy test trial (standardized $U = -.18$, $p = .86$), novel label hard test trial (standardized $U = 1.03$, $p = .34$), and novel label test trial in total (standardized $U = .31$, $p = .77$). There were no significant differences between index-finger pointers and the others when investigating infants' performance in each individual condition either, *p*s > .10.

Discussion

Infants showed stronger associations between novel objects and their labels when the labels had been presented contingently on a point, compared with being presented on a look alone, or at a predetermined time schedule. These findings were robust after controlling for the amount of time looking at the target object and infants' performance on the familiar label trials. These results suggest that the longer amount of time looking at target objects was not the main factor influencing infants to learn better in the point contingent condition. Instead, it was labeling contingently in response to infants' pointing gesture that made a difference.

Before the experimenter uttered a label, the amount of time looking at the target object was shorter in the look contingent condition compared to the point contingent condition and the yoked control condition. This looking time difference was not significant *after* the experimenter uttered a label. Thus, it is unlikely that the amount of time looking at the target object is the reason that infants successfully picked the correct referent in the point contingent condition. First, the time spent looking at the target object was not different between the point contingent condition and the yoked control condition, but infants' performance was significantly better in the point contingent condition than the yoked control condition. Second, we used the amount of time looking as a covariate in an ANCOVA analysis, and found no significant effect of the amount of time looking on word learning performance; even after controlling for the amount of time looking, infants' performance on the word comprehension test was still significantly better in the point contingent condition.

Fewer infants (7) pointed in the look contingent condition than the point contingent condition (12). However, simply pointing to objects might not account for the difference in learning the word-object associations according to an analysis that compared the pointers and non-pointers in their performance on the word comprehension test and found no significant differences. In addition, infants in the yoked control condition were allowed to point as freely as infants in the point contingent condition, but the yoked control infants did not learn word-object associations better than look contingent infants did. However, the conclusions were drawn from small samples, thus future research is required to investigate whether pointing gesture itself influences language learning.

What seemed to really matter was the *contingency* between infants' pointing and the experimenter's labeling. Labeling occurred contingently on infants' pointing in the point contingent condition, but not in the yoked control condition. The amount of time looking at target object and distractor and the number of looks to the target object when labels occurred did not differ between these two conditions, nor did the vocabulary of the child (we matched infants' vocabulary in these two conditions). Nonetheless, infants in the point contingent condition learned the word-object associations significantly better than infants in the yoked control condition.

One may wonder if it is the contingency that matters, why infants in the look contingent condition learned words worse than infants in the point contingent condition. One possibility is that the probability of contingency was higher in the point contingent condition than that in the look contingent condition, because it is impossible to label toys every time the child shifts gaze direction. Another possibility is that infants' pointing gestures may organize a special time window for the social partner to provide linguistic input when infants might be *ready* to learn. Previous studies have shown that infants' pointing gestures are efficient in eliciting label responses from caregivers (e.g., Wu & Gros-Louis, 2014b). By eliciting verbal reactions from social partners, infants' pointing gestures might open a social gateway for language learning, which was suggested by studies on infants' object-directed vocalizations (Goldstein et al., 2010). A typical response to infants' pointing gestures is a verbal response; pointing gestures thus organize the timing of linguistic input so that it occurs when the infant is in a state conducive to learning.

Future research is required to specify what effective learning state pointing gestures might reflect, such as the state of attention, motivation, perception, memory, etc. For example, some earlier accounts suggest that the initial function of pointing is to focus infants' own attention on interesting things (Bates et al., 1975), or to communicate their own interest to others (Tomasello et al., 2007). While there is debate on whether infants intentionally point to direct others' attention and further influence other's mental states, I believe infants' pointing gestures at least indicate their own interest. It is well established in adults that there is a positive relationship between interest and learning (e.g., Kang et al., 2009). The current finding that infants learn better when the information is provided in response to their pointing gestures suggests that when pointing, infants single out an object of interest, and they may be in an optimal state for assimilating information. In addition, pointing gestures may also help memories last. For example, Delgado, Gómez and Sarriá (2011) found that children aged 2-4 used pointing gestures to help themselves remember the location of an item. Cook et al. (2008) found that school-aged children's memory about methods of solving mathematical problems was better retained when they were allowed to gesture than when they were not allowed to. Consistently, in the current study, infants' pointing gestures might help them remember the word-object associations.

It is not clear in the current study whether it is the high contingency between pointing and adult's labeling, or the specific timing window organized by pointing that really helped infants learn. However, the study nonetheless contributes to the understanding of the relationship between pointing gestures and language learning by demonstrating, for the first time in the literature, that pointing helps with word learning in the moment. The findings suggest that the extent to which infants learn information in everyday life depends, in part, on the extent to which caregivers both detect and appropriately respond when infants initiate communication as they do when they point. By presenting direct evidence that responding to infants' gestures affects their word learning, I hope to open new opportunities to study how the dynamic interactions between infants and the environment facilitate learning.

CHAPTER IV: GENERAL DISCUSSION

In summary, the results of this study confirm a significant concurrent correlation between infants' pointing gestures (elicited by an experimental setting) and their language measurements in infants younger than 18 months old. Furthermore, this study provides evidence that 16-month-old infants' pointing gestures signal a readiness to learn, which may help explain the observed positive association between pointing and language learning. In Experiment 1, infants were presented with variable objects one by one out of window openings on a curtain, and were provided with a label response after they pointed. Their language abilities were measured by having parents report children's vocabularies. We found that infants' receptive vocabulary size contributed to their spontaneous pointing, even with age effect partialled out in analyses. Experiment 2 experimentally manipulated the timing of when labels were provided, and found that labeling an object contingently on a point facilitated learning associations between words and objects. By contrast, infants who received the same labels when they were just looking (look contingent condition), or after an equivalent amount of exposure to the objects but not contingently on infants' pointing or looking (yoked control condition), did not learn the word-object associations. Taken together, these results suggest that pointing gestures may prepare infants in-the-moment for word learning.

Our findings indicate a new function of pointing gestures in the development of language. In the past, pointing gestures were considered as an advanced communicative act. The observed correlation between pointing gestures and language skills were usually attributed to social functions such as infants' elicitation of linguistic input from the environment (Masur et al., 2005; Olson & Masur, 2011, 2013, 2015; Wu & Gros-Louis, 2014b). The present experiments provide evidence that gesture itself might play a role in developing language skills, as we found that infants learned word-object associations better when the words were provided in response to pointing gestures than looking alone. Pointing gestures thus create opportunities for socially guided learning to facilitate language development. A natural question, then, is how?

Mechanism

What mechanisms might underlie the observed correlation between infants' pointing gestures and vocabulary size? There are several theories that attempt to explain the relation between pointing gestures and language development. For example, one classic developmental theory considers pointing as a first step toward *symbolization*, which is a critical aspect of language (Vygotsky, 1986). Rather than focusing on the abstract idea that pointing may indicate the development of symbolic thought, we will mainly discuss how pointing helps in a more direct way: pointing influences the learning environment, and pointing influences the learner.

Influence of Pointing on the Learning Environment

One line of work in the literature on the function of pointing focuses on the social function of pointing gestures, that is, the idea that pointing elicits social feedback from the environment. Studies have shown that, in comparison to other behaviors, pointing elicits more reliable contingent responses from social partners. Natural observations of caregiver-infant interactions have found that caregivers provide more verbal responses to infants' points compared to infants' other behaviors, such as vocalizing (Kishimoto, Shizawa, Yasuda, Hinobayashi, & Minami, 2007; Wu & Gros-Louis, 2014b). Among these verbal responses to pointing, about half of them contain labels referring to the objects that infants gesture to (Masur, 1982; Olson & Masur, 2011; Wu & Gros-Louis, 2014b). Therefore, parents translate pointing gestures into object labels at a time when most infants at this age – the end of their first year – are acquiring object labels, which predominately comprise their lexicons (Goldfield, 1990; Goldfield & Reznick, 1990; Nelson, 1988). Furthermore, these translations support word learning; words translated from gestures by caregivers are more likely to enter children's subsequent vocabulary than the words that gestures refer to but are not translated (Goldin-Meadow et al., 2007). Therefore, the fact that points elicit linguistic input is one way that pointing contributes to language learning.

In addition to pointing gestures eliciting essential linguistic input, it is important to note that pointing gestures create a joint attention moment. That is, caregivers can identify infants' attention by their points, and caregivers' responses to infants' points show that they both are attending to the same thing. Therefore, pointing elicits input during a "joint attention" moment in which both the pointer and the partner are attending to the same object (Brooks & Meltzoff, 2008). "Joint attention" has been shown to facilitate language development. For example, children learn words better when the partner provides reference to objects that are in the child's focus of attention than when the child is not focusing on the labeled objects (Baldwin & Markman, 1989; Tomasello & Farrar, 1986; Yu & Smith, 2012). These findings together suggest that the contingent labeling responses elicited by pointing gestures at a "joint attention" moment contribute to infants' language learning.

These prior examples focus on the social mediation function of pointing gestures. That is, infants' pointing elicits social responses from the environment better than other communicative behaviors such as reaching or vocalizations; furthermore, the research also implies that it is actually the contingent responses provided when infants are attending to the target object that benefit infants' word learning. However, pointing is just one way to elicit contingent responses from caregivers. Previous studies have shown that a partner could also follow the child's gaze and establish joint attention with the child – a situation that supports word-learning (e.g., Baldwin, 1991, 1993; Tomasello & Farrar, 1986). Therefore, based on these findings, children could learn words equally well when a word is provided contingently on infants' attention, regardless of whether infants point or not.

The current study, however, casts doubts on this hypothesis. We found that 16-month-old infants learned word-object associations better when they received the same labels after pointing than after just looking. In this study, infants saw novel objects protruded out of window openings of a curtain, which was behind an experimenter who interacted with the infant. The experimenter labeled a novel object immediately after infants pointed to it, just looked at it, or at a predetermined time and thus the labeling was not contingent on infants' behavior. During the word comprehension test, infants demonstrated better association of novel labels with the correct objects when they had received labels after pointing. This suggests that pointing not only effectively elicits label responses from the environment (Masur, 1982; Olson & Masur, 2011; Wu & Gros-Louis, 2014b), but the gesture itself may also facilitate word learning. In the next section, we discuss three potential ways that the act of pointing itself may influence the learner in a way that benefits learning.

Influence of Pointing on the Learner

The second line of research attempting to explain the observed correlation between pointing and language learning comes from the perspective of infants. Pointing gestures may reflect, or even create an effective state that is conducive for learning, and signal that state to others. This effective state could involve multiple facets, ranging from low level perceptual states of focused attention and arousal, to higher cognitive level of motivation to learn and communicate, and/or to actively using pointing as a cognitive tool to learn.

Focused attention or increased arousal by pointing. A pointing gesture shows infants' interest in, and attention to, a particular object (Delgado et al., 2009). At a more mechanistic level, pointing may, in fact, increase infants' attention to an object. For example, Goldstein and colleagues (2010) found that the more infants vocalized to an object, the more likely they would learn the shape of that object, as well as the word associated with it. They interpreted these results as vocalizations focusing infants' attention on the target object, which helped infants process object properties and learn word-object associations (e.g., Goldstein et al., 2010). A related idea comes from work by Campos and colleagues (2000), who propose that infants' actions may focus their attention to aspects of the environment that are important for acquiring important skills (reviewed in Rakison & Woodward, 2008). Consistent with this hypothesis, Begus, Gliga and Southgate (2014) found that infants replicated the actions on objects to which they pointed more successfully than the actions on objects to which they did not point. Begus et al. (2014) thus argued that pointing gestures indicate what infants are interested in learning. Although these results may not speak specifically about vocabulary development, they suggest that infants' pointing gesture may focus their attention to targets and perhaps the labels accompanying them, thus facilitating learning labels for objects (see also LeBarton, Goldin-Meadow, & Raudenbush, in press).

Motivation to communicate with the world. Researchers have proposed different motivations underlying infants' pointing gestures. For example, Bates, O'Connell and Shore (1987) considered pointing gestures to be the quintessential acts of reference; that is, one person singles out an object and offers it to another person for consideration. This argument is further elaborated by the social pragmatic theory (Liszkowski, 2005, 2008; Liszkowski, Albrecht, et al., 2008; Liszkowski et al., 2004, 2006, 2007; Liszkowski, Carpenter, & Tomasello, 2008; Tomasello et al., 2007). Liszkowski and his colleagues have shown that by 12 months old, infants' points involve two social motives: (1) to share their attention to and interest in something, and (2) to provide information for adults who appear to be in need of it (e.g., point to an object that an adult partner is searching for). For example, infants show variable pointing behaviors that suggest that they are attempting to share attention and interest in something with a social partner. Starting around 12 months old, infants repeat their pointing if an adult partner does not see or incorrectly identifies the target object, and infants point less over trials if the adult continuously ignores the referent or shows no positive affect toward the target object (e.g., Liszkowski et al., 2004, 2007).

This social-pragmatic account of infant pointing thus argues that pointing gestures share common cognitive processes with speech, in particular the cooperative motivation to communicate, and the ability to represent and influence another person's mental states (Tomasello et al., 2007). Studies on the relationship between handedness and language development provide further support of this shared cognitive process. These studies argue that most pointing is right-handed, and is localized to the same left cerebral hemisphere for both communicative gesture and language (Cochet, Jover, & Vauclair, 2011; Cochet & Vauclair, 2010a, 2010b). Therefore, the internal motivation to communicate with others underlies pointing gestures, and is shared with language processes. This underlying referential motivation may account for the observed correlation between pointing gestures and language learning.

Motivation to request information. Another motivation that has been proposed for pointing is to obtain information from knowledgeable adults (e.g., Southgate et al., 2007). In this view, preverbal infants actively seek information through pointing. Consistent with this hypothesis, studies have shown that 12-month-old infants displayed more pointing gestures when an adult partner provided valence information (surprise, delight, disgust, or fright attitudes) about the object compared to when she simply shared attention by following the infant's points and acknowledging that she has seen it (Kovács et al., 2014). Further evidence in support of infants' motivation to "request information" comes from an assessment of infants' production of points with partners who express different knowledge states (Begus & Southgate, 2012). In this study, 16-month-old infants interacted with an experimenter who either labeled familiar objects correctly or incorrectly, which established infants' perceived knowledge state of the experimenter. If infants point to gather information, then they would point to novel objects more frequently when the partner is perceived to be knowledgeable than someone who is perceived to be ignorant. Results supported the information-gathering view: infants pointed significantly more to novel objects when interacting with a knowledgeable experimenter than when interacting with an ignorant experimenter (Begus & Southgate, 2012).

Researchers who focus on the information requesting function of pointing thus argue that the pointing gesture is an example of a cultural-learning tool. Infants use pointing gestures to request information from the environment, and the information solicited by pointing is more likely to be learned than the information they do not request. This might explain why learning linguistic input is facilitated by pointing.

The current study, however, did not provide clear evidence on the interrogative function of pointing gestures. If infants pointed to elicit information, we would expect to find that infants pointed more often to novel objects than to familiar ones, because the experimenter did not provide new information about known objects. This was not what was found in the present study, however. Instead, we found that infants pointed equally often to familiar objects and novel objects, when the experimenter provided just a label response ("that's a dog"). But we did find that 19-24 month old infants repeated pointing more to familiar objects than to novel objects, which might suggest that these older infants were not satisfied with the adult's label response. It is possible that these older infants may want more information about familiar objects rather than the experimenter's simple response of labeling, because they already know the names of those familiar objects. It is also possible that infants' pointing gestures are not driven by one certain motive; instead, it is likely that they point for various reasons in different contexts. If infants learn to point to gather information about what they are interested in learning, however, they may in a better position to learn language.

Brief summary on the above two motivation accounts. The social-pragmatic and cultural-learning approaches suggest that infants' intrinsic motives, either to communicate with others or to solicit information from others, underlie infants' pointing behavior. These rich interpretations argue that infants' pointing involves advanced cognitive processes of understanding and influencing others' mental states, which are shared with language and communication processes. The challenges to these accounts include a leaner interpretation of infants' pointing without assuming that infants have such advanced cognitive abilities (e.g., D'Entremont & Seamans, 2007; Dice & Dove, 2011). In this view, infants may perceive that a partner is attending/responding to their gesture or not, which can still *function* to share reference and obtain information, but does not necessarily involve infants' understanding and influencing of others' mental states (D'Entremont & Seamans, 2007). Given that motivations are hard to measure, it is difficult to determine how much of infants' pointing gestures originate from infants' intrinsic motivation to communicate or to learn.

A cognitive tool that promotes learning. A less-well explored possibility to explain how pointing supports language development is suggested by the evidence that pointing gestures facilitate learning in older children. In this view, pointing serves as a cognitive tool to lessen the strain on memory and cognitive load during learning. For example, Delgado et al. (2011) found that children aged 2-4 used pointing gestures to help themselves remember the location of an item. Furthermore, they found that 4-6 year old children who spontaneously pointed to solve an attention task performed significantly worse when they were not allowed to point in a second condition. Similarly, studies on older school-aged children have also found that children are better at solving math problems if they are encouraged to use gestures (Cook & Goldin-Meadow, 2006; Cook et al., 2008, 2010); moreover, individuals' performance explaining how to solve a math problem decreased if they were restrained from gesturing (Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001). These researchers thus propose that gesture may serve as a "cognitive prop", conserving some cognitive resources that can be used on other tasks. Young children usually use pointing gestures to express words that cannot be conveyed via speech yet. Furthermore, it has been suggested that pointing at an object rather than producing a label for an object may ease the pointer's processing and memory demands (Iverson & Goldin-Meadow, 2005). Therefore, it is possible that easing the pointer's cognitive load and memory demands could facilitate language learning in a way similar to what has been found for the role of gestures in math learning and problem solving.

The current study did not test this hypothesis. Further research is needed in younger children to assess this hypothesis as it relates to language learning.

In sum, prior research on infants' motivations and cognitive processing associated with pointing has attempted to explain the observed correlation between pointing gestures and language learning from the perspective of *infants*. Researchers propose that pointing gestures may influence infants' own attentional, motivational, or cognitive states, which facilitate or support learning. Future studies are required to fill the gap between infants' "learning states" and infants' "actual learning". That is, even if pointing gestures change infants' readiness to learn, it is unclear how this state change mediates learning and memory. How do infants acquire knowledge and retain information? What are the mechanisms that support learning?

Dynamic Interactions between Infants and Environment

As discussed above, previous studies have focused on the role of pointing influencing either the social environment that provides linguistic input and support, or infants' own learning state, in infants' learning. However, infants and the environment cannot be separated; they interact and mutually influence one another. Infants' interest and attention expressed via pointing gestures is translated by caregivers via speech, thus caregivers' contingent label responses might provide exactly the word that the child is *ready* to hear (Goldstein-Meadow, 2003, 2007). Considering the perspectives of both the infant and the social environment, pointing may create a special attentional, arousal, motivational and/or cognitive state such that pointing to an object might facilitate the learning of associated labels (Goldin-Meadow, 2007). Thus, infants' pointing could serve both to influence infants' readiness to learn a word, and a tool to create more word learning opportunities.

The present study does not argue for a specific mechanism underlying infants' word learning; instead, it establishes the first step in showing that infants' production of spontaneous pointing gestures is influenced by their receptive vocabulary. Furthermore, pointing gestures may play a causal role in infants' forming word-object associations. Together with previous work, the current study is a good illustration of the dynamic interaction between infants and the environment: infants point and hear words (e.g., Wu & Gros-Louis, 2014b), and the pointing gesture helps them better learn the words (Experiment 2). This then increases their vocabulary, resulting in points to more things in the environment (Experiment 1), etc.

Study Limitations

There are limitations of the present study. First, in the second experiment, we did not prevent children from gesturing in the look contingent and the yoked control conditions. Children were allowed to gesture spontaneously in these two conditions to prevent fussiness and to ensure that their behavior was not unnaturally modified. The manipulation check in Chapter 3 did show there was variability in the number of infants who pointed during training: 7 infants pointed in the look contingent condition (2 with index-finger and 5 with whole hand points), 10 infants pointed in the yoked control condition (2 pointed with index-finger, 4 pointed with whole hand points, and 4 with both), and 12 infants pointed in the point contingent condition (7 with index-finger, 4 with whole hand points, and 1 with both). Critically, infants in the point contingent condition heard labels contingently after their pointing behavior, but infants in the other two conditions did not. Only 8 naming events (out of 96) occurred within 2 seconds of infants' gesturing in the look contingent condition, and 6 in the yoked control condition. Therefore, the experimental manipulation was successful in terms of labeling at different times: contingently in response to pointing, or to looking, or at predetermined time schedule.

However, because of the variability in infants' production of pointing gestures, it is unclear whether the significant difference in infants' word learning performance was due to the difference in the production of pointing gestures, or the difference in the *timing* of providing labels. Our analyses showed that pointers and non-pointers did not differ significantly in their word learning performance, which provided suggestive evidence that simply pointing to target objects does not account for word learning performance. It appears to be more helpful for infants' learning to provide a label response contingently after infants' pointing; however, the conclusion drawn from this analysis should be treated with caution because the sample was small after splitting by pointers vs. non-pointers. Future studies with larger samples of children can investigate the individual differences in infants' production of pointing gestures, and whether the act of pointing itself matters for infants' word learning, or it is actually the timing it organizes for linguistic input.

Second, the experimental set-up for the look contingent condition was different from the other two conditions: the experimenter who interacted with the child held up two objects rather than the objects being shown through windows in a curtain behind the experimenter. The design in the look contingent condition was employed so that we could better differentiate providing labels contingently on infants' looking versus pointing, because a pilot study showed that infants pointed and looked quickly when seeing object popping out of window openings on the curtain. It is possible that the difference in learning is due to this presentation difference. For example, maybe it's more exciting to learn when the infant and the communicative partner both get surprised by the unexpected new toy. However, objects were protruded unexpectedly out of window openings on a curtain in the yoked control condition, but these infants did not learn the word-object associations better than infants in the look contingent condition. This result suggests that the way of presenting objects is unlikely to be the main cause of better learning in the point contingent condition. Nevertheless, coding infants' expressions (e.g., smiles, excitement) will be helpful in understanding whether infants were less excited in the look contingent condition, and whether their level of excitement was related to word learning performance.

In addition to different styles of presentation, another possible confound relates to how good the experimenter was at detecting infants' looking. If the experimenter was more reliable at detecting points than looks, there could be a confound with simply how "contingent" the responses were. Blind offline coding of the infants' responses would clarify whether this is an issue. Although it is relevant to note that higher contingency between pointing and hearing labels than looking and hearing labels is probably representative of everyday life, so the high contingency may be a characteristic of pointing gestures. Future studies can investigate whether the act of pointing itself, or the contingency matters for infants' word learning.

Future Directions

Mechanism

This dissertation research has thus found a significant correlation between infants' pointing gestures and receptive vocabulary (Experiment 1), and further found that pointing gestures could help infants learn word-object associations in the moment (Experiment 2). There are many different mechanisms may be operating in these studies. These theories reviewed above can provide a starting point for extensions of the current study. The pointing gesture elicits contingent responses from caregivers at a "joint attention" moment, which helps infants learn language; moreover, the pointing gesture itself may create an effective state for language learning. The effective state may involve infants' focused attention and interest on a target object, an aroused state that supports learning, motivation to communicate and to request information, and/or a cognitive tool to ease processing burden, etc. A particular challenge for future research is to explore how the multiple possible functions of pointing interact to facilitate language learning.

For example, one possible explanation for the observed findings is that gestures allow children to express complex meanings that cannot yet be expressed verbally

(Goldin-Meadow, 2007). Therefore, infants may learn labels more effectively when they point because they are ready to learn the information. Or, using gestures may ease the learner's processing burden such that additional cognitive resources can be applied to word learning. Gestures may also sustain the memories as shown in school-age children and adults (Cook et al., 2008, 2010). A second possibility is that the pointing gesture elicits contingent responses from caregivers at a "joint attention" moment, which helps infants learn language. It is also possible that these functions intersect to create a maximally supportive learning moment that consists of joint attention in which infants are ready to learn because their processing burden is reduced by the external reference to the named stimulus.

Generalization of the Elicited Information

What exactly do infants learn from the information they elicit? The current study shows that infants associate labels with referents better when a point rather than a look is used to elicit the label. This does not tell us, however what the infants thought the label meant. Future studies should aim to determine how infants generalize the newly learned labels because this is a critical step towards understanding the full process of word learning from mapping to flexible use of newly mapped words.

Intervention with Atypical Population

Lastly, future studies can investigate the role that training infants to point may play in facilitating language in atypical populations. Teaching infants to point during an 8-week at home intervention significantly increased typically developing infants' gesture production, and also increased infants' speech production when interacting with parents during a free-play interaction (LeBarton, Goldin-Meadow, & Raudenbush, 2013). In addition, training infants to use gestures as symbols for objects and requests has been shown to improve infants' language abilities on the vast majority of language acquisition measures (Goodwyn, Acredolo, & Brown, 2000). The present study suggests that infants' pointing gestures may prepare them for word learning. These results might be generalized to atypical populations, because a similar correlation between gestures and language skills has been found in atypically developing children, such as children at-risk for exhibiting delayed expressive language (Sauer et al., 2010). The findings of the present study and previous training studies together suggest a promising model for interventions with children at risk for language delay. If we uncover the mechanism(s) that account for how pointing gestures facilitate language learning, the findings could contribute to the development of interventions to help children with language delay.

Conclusion

In conclusion, our study furthers the understanding of the relationship between pointing and language development. We studied the features of 12- to 24-month-old infants' pointing when presented with both familiar and unfamiliar items. We found that infants often pointed spontaneously and that older infants pointed more frequently and more quickly than younger infants did. Importantly, 12-16 month old infants who had larger receptive vocabulary size also spontaneously pointed more often when communicating with an experimenter who did not see the objects being shown. Together with previous studies, the current study suggests a possible positive feedback loop between pointing and language skills in infants younger than 18 months of age: the bigger vocabulary size infants have, the more likely they point, especially when their pointing can elicit new information; the more words they hear, and the faster they develop vocabulary.

Our second experiment further investigated the role of pointing in word learning by examining how pointing helps infants form robust word-object associations. We found that infants learned labels introduced in response to their pointing better than those produced in response to looks alone. This suggests that pointing may organize a special time window for the social partner to provide linguistic input when infants might be *ready* to learn. Future research is required to study what this "readiness" is, and how to apply these findings to develop interventions for children at risk for language difficulties.

Together, these two studies suggest that the relation between pointing gestures and later language ability is a combined result of individual and environmental factors. For infants younger than 18 months old, who are frequent gesturers and are at the cusp of transition to linguistic communication, they are motivated to point spontaneously during social interactions; more importantly, the more words they know, the more likely they are to point. Meanwhile, the environment provides linguistic input in response to infants' pointing gestures, which is not only related to infants' attention and interest, but is also provided at a time when the child is ready to learn. In sum, the pointing gesture is one of the first forms of non-linguistic communication that highlights infants' own contribution to learning; at the same time, it is also a behavior that helps other people to better understand and stimulate infants' language learning.

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APPENDIX

QUESTIONNAIRES

Object Checklist

Participant ID:

Child’s DOB:

Test Date:

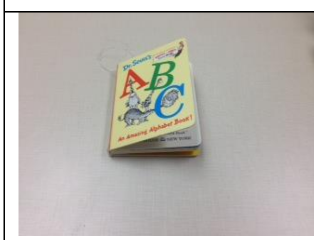
Have you seen your child point to something? Yes No

Below are some pictures of objects that will be used in the study and their labels. Please indicate if your child knows (uses/understands) a label for that particular object. If so, please write down the label your child uses for the object. In addition, please rank how familiar your child is with the following objects on the given scale *(Please circle: 1 =completely unfamiliar; 5 = familiar)*.

Do you think you child knows this is a shoe?

No Yes

1 2 3 4 5



Do you think you child knows this is a book?

No Yes

1 2 3 4 5

Do you think you child knows this is a puppy/dog?

No Yes

1 2 3 4 5

Do you think you child knows this is a kitty/cat?

No Yes

1 2 3 4 5

	Do you think you child knows this is a duck? No Yes 1 2 3 4 5
	Do you think you child knows this is a car? No Yes 1 2 3 4 5
	Do you think you child knows this is a bus? No Yes 1 2 3 4 5
	Do you think you child knows this is a cup? No Yes 1 2 3 4 5
	Do you think you child knows this is a ball? No Yes 1 2 3 4 5
	Do you think you child knows this is a hat? No Yes 1 2 3 4 5
	Do you think you child knows this is a banana? No Yes 1 2 3 4 5
Novel objects that may be used in the study	

Do you think your child knows (uses/understands) a label for this object?

No Yes__________

1 2 3 4 5

Do you think your child knows (uses/understands) a label for this object?

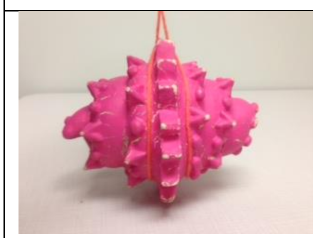
No Yes__________

1 2 3 4 5

Do you think your child knows (uses/understands) a label for this object?

No Yes__________

1 2 3 4 5



Do you think your child knows (uses/understands) a label for this object?

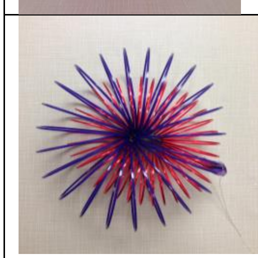
No Yes__________

1 2 3 4 5

Do you think your child knows (uses/understands) a label for this object?

No Yes__________

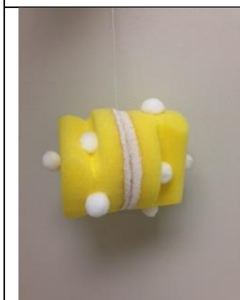
1 2 3 4 5



Do you think your child knows (uses/understands) a label for this object?

No Yes__________

1 2 3 4 5

	Do you think your child knows (uses/understands) a label for this object? No Yes__________ 1 2 3 4 5
	Do you think your child knows (uses/understands) a label for this object? No Yes__________ 1 2 3 4 5
	Do you think your child knows (uses/understands) a label for this object? No Yes__________ 1 2 3 4 5
	Do you think your child knows (uses/understands) a label for this object? No Yes__________ 1 2 3 4 5
	Do you think your child knows (uses/understands) a label for this object? No Yes__________ 1 2 3 4 5
	Do you think your child knows (uses/understands) a label for this object? No Yes__________ 1 2 3 4 5

	Do you think your child knows (uses/understands) a label for this object? No Yes__________ 1 2 3 4 5
	Do you think your child knows (uses/understands) a label for this object? No Yes__________ 1 2 3 4 5

Participant Questionnaire

Infants' communication during social interaction

1. Who is completing this questionnaire?

 □ Mother

 □ Father

 □ ______________________

2. What is your marital status?

 □ Single

 □ married

 □ divorced

 □ widowed

3. Are you employed outside of the house?

 □ yes, full time

 □ yes, part time: _____%

 □ no

4. Is your spouse / domestic partner employed outside the house?

 □ yes, full time

 □ yes, part time: _____%

 □ no

5. What is your age? ________ What is your spouse's age (if married)? ________

6. Is English the primary language spoken at home? ____________

 List any other languages your infant hears regularly:

7. What is your racial/ethnic identity?

White (non-Hispanic)

African American

Puerto Rican

Mexican

Cuban

Japanese

Chinese

Vietnamese

Korean

American Indian

Pacific Islander

Asian Indian

Other (please specify)

8. What is the highest level of education that you and your spouse have completed?

(Indicate number of years of school, college, or degrees you have attained)

You __________ your spouse __________

9. What is your occupation? ___________________

10. What is your spouse's occupation? ___________________

11. How many other children do you have and what are their ages?

12. How much time per day does your baby spend with your other children? __________

With you? ________ With your spouse? ___________

In daycare/with a babysitter?____________

13. Does your baby have a favorite sounds that s/he makes? If so, please describe the sounds. Do these sounds resemble any word?

14. Does your baby use sounds consistently to name things or ask for things (toys, food, to be picked up etc…) or in certain circumstances (before a bath, when playing alone, when playing with others)? If so, please describe these sounds.

15. Please list any other behaviors that you consider to show that you infant is trying to communicate with you.

Thank you very much for taking the time to answer this questionnaire!