

Do Questions Get Infants Talking? Infant Vocal Responses to Questions and Declaratives in
Maternal Speech

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Abstract

Maternal questions play a crucial role in early language acquisition by virtue of their special grammatical, prosodic, and lexical forms, and their abundance in the input. Infants are able to discriminate questions from other sentence types and produce rising intonations in their own requests. This study examined whether caregiver questions were related to the quantity of infant vocalizations. Thirty-six infants aged 10 and 14 months participated in laboratory play session with their mothers. In separate blocks, mothers were instructed to ask questions and to refrain from asking questions. Both block-level and utterance-level analyses found no evidence that maternal questions affected the amount of infant-response vocalizations. Mothers of 14-month-olds (but not 10-month-olds) tended to repeat questions.

Key Terms: maternal questions, infant vocal behavior, turn-taking

Do Questions Get Infants Talking? Infant Vocal Responses to Questions and Declaratives in
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Questions have an important role to play in the acquisition of language. Questions have unique syntactic (e.g., auxiliary inversion), morphological (e.g., the presence of *wh*-words) and/or prosodic (e.g., rising intonation) characteristics. In addition, many researchers over the last several decades (e.g., Newport, Gleitman, & Gleitman, 1977; Soderstrom, Blossom, Foygel, & Morgan, 2008; Theakston, Lieven, & Tomasello, 2003) have pointed to questions as an important component of the language input, both because these unique characteristics provide clues to the underlying structure of the language, and also because they provide a stimulus for beneficial linguistic interactions between infants and caregivers. Yet, despite a surge in interest in the topic over the last few years (e.g., Frota, Butler, & Vigario, 2014; Geffen & Mintz, 2014; Soderstrom, Ko, & Nevzorova, 2011), there is still much to learn about how infants respond to questions. The current study examines whether infants vocalize more to questions than declaratives.

One reason to believe that questions are important to language development is that maternal speech contains a high frequency of questions, typically around a third (Newport, et al., 1977; Soderstrom, et al., 2008; but c.f. van de Weijer, 1997). Further, a high proportion of questions contained in the maternal speech stream is a good predictor of infant syntactic development, vocabulary acquisition, and utterance complexity (e.g., Furrow, Nelson, & Benedict, 1979; Hoff-Ginsberg, 1985; Huttenlocher, Haight, A., Seltzer, & Lyons, 1991). One possible mechanism for this might be by soliciting infant vocalizations, leading to faster linguistic development.

Relatedly, questions have long been posited to play an important role in the development of turn-taking skills, even with young infants. When mothers speak to their infants, they often wait an appropriate length of time for a response regardless of whether one is given by the infant, and will be liberal in interpreting infant sounds as intentional, particularly at young ages (Bateson, 1975; Snow, 1977). Infants model this maternal speak-listen pattern of turn-taking and also pause after vocalizing (Bloom, 1988). Infants as young as 3 months old show influences of maternal speech on their vocalizations, but these influences are immature (Masataka, 1993; Mayer & Tronick, 1986) as turn-taking skills develop with time. One recent study found a U-shaped curve in the development of infants' response latencies, with faster responding at 5 and 18 months compared with 9 and 12 months (Hilbrink, Gattis & Levinson, 2015). Children's ability to track others' turn-taking also develops from age 1 to 3 years (Casillas & Frank, 2017; Keitel, Prinz, Friederici, von Hofsten, & Daum, 2013; Von Hofsten, Uhlig, Adell, & Kochukhova, 2009). Appropriate responsiveness to caregiver speech is a key component of the development of conversational interaction. Such development would be greatly simplified by early knowledge of the differential role that questions play in this conversational process – namely that questions typically require a response, while declaratives do not.¹

In order to respond differently, infants must discriminate questions from declaratives. There is good reason to believe that infants can, in fact, make this kind discrimination. There is a broad spectrum of research demonstrating infants' responsiveness to a variety of prosodic and intonational features of language, such as discriminating prosodic contour types and responding differentially to prosodically cohesive word groupings versus groups of words that cross

¹ The task is obviously more complex than this, since some kinds of "questions" do not require a response, while some "declaratives" demand one. Indeed even the definition of "question" is up for grabs, as it is dependent on a complex interaction of lexical, syntactic, prosodic and pragmatic features. For our purposes here, we will define a question broadly as one in which sufficient contextual and structural properties converge to clearly label it so.

prosodic boundaries (e.g. Fernald & Kuhl, 1987; Kuhl & Miller, 1982; Mandel, Jusczyk, & Kemler Nelson, 1994; Soderstrom, Seidl, Kemler Nelson, & Jusczyk, 2003; Trehub, Bull, & Thorpe, 1984). Indeed, there is significant evidence that infants are specifically able to discriminate the intonational characteristics of questions from those of statements in both English and European Portuguese, and prefer to listen to questions over statements (Frota, et al., 2014; Geffen, 2014; Kaplan, 1969; Soderstrom, et al., 2011; Sullivan & Horowitz, 1983). These studies suggest, more specifically, that final rises play a central role in this perceptual differentiation. However, two recent studies suggest that children do not use intonation or the presence of questions to predict turn-taking in overheard speech until 3 years of age (Casillas & Frank, 2015; Keitel et al., 2013).

Furthermore, despite common intuitions (in North American English speakers in particular) that rising pitch at the end of an utterance indicates a question, formal linguistic analysis has generated a much less straightforward relationship between pitch and meaning. Not all questions end in a rising pitch in English. Wh-questions in particular generally do not, yet even yes/no questions may not (e.g., Bartels, 1999; Cruttenden, 1986; Ladd, 1996). Structurally, questions may be indicated not only with terminal rising, but with higher pitch overall across the utterance (e.g. Bolinger, 1989). In fact, some researchers have suggested that terminal falls for questions are as common as terminal rises (Cohen, 1972; Fries, 1964). Furthermore, the meaning associated with “question-like” intonation can be viewed more broadly, as indicating *openness* (Cruttenden, 1986), *incompleteness* (Bolinger, 1989, p. 102), *lack of assertiveness* (Bartels, 1999) or *uncertainty* (Ladd, 1996) rather than questioning *per se*. Overall, the relationship between rising intonation and questions (both structurally and meaningfully in the sense of requesting a response) is best viewed as a probabilistic one.

Another consideration is the extent to which this relationship holds cross-linguistically. If there are universal or at least widespread relationships between intonational form and the meaning of questions, even if those relationships are imperfect, then it is much more likely that infants will be sensitive to that relationship at an early age than if the relationship is an arbitrary or unstable one. A strong argument for such a relationship came from Ohala's (1983, 1984) assertion that higher and rising pitch on questions is related to not only a cross-linguistic, but a cross-species association to a frequency code where higher pitch is associated with submissiveness and lack of threat. This idea has been developed further in more recent work relating acoustic paralinguistic characteristics to mechanical properties of producing speech that are interpretable meaningfully by the listener (Chen, Gussenhoven & Rietveld, 2002; Gussenhoven, 2002). More detailed cross-linguistic analyses, however, show that different languages have very different intonational patterns associated with questions (Frota, 2002; Hirst & Di Cristo, 1998; Jun, Sun-Ah, 2005, 2014). For example, for Brazilian Portuguese, the perception of yes/no questions is more closely associated with overall higher pitch than with a final pitch rise (de Moraes, 1998). There does appear to be a tendency toward associating high or rising pitch with questions, but as with the details of English itself, this relationship is far from perfect.

However, these linguistically-focused analyses have generally focused on characterizing the breadth of potential structures and meanings, rather than examining their relative frequency in real-world conditions. Moreover, these studies have largely examined adult-directed speech. Infant-directed speech has different prosodic characteristics, including exaggerated intonation and overall higher pitch in and of itself, and use of stress, as well as lexical and grammatical characteristics and different pragmatic functions (Soderstrom, 2007). All of these characteristics

will have important implications for the intonational structure of sentences in general, and questions in particular. Many of the special structural properties and specialized meanings discussed in the literature that influence what type of intonation is used are not pragmatically likely to be used in conversations with infants. Furthermore, paralinguistic meanings (such as communicative intents) may be communicated more effectively in infant-directed speech than adult-directed speech (Fernald, 1989). Studies specifically examining the properties of infant-directed speech have found evidence supporting the idea of final rises in English infant-directed questions (Geffen, 2014; Soderstrom et al., 2011; Soderstrom, Blossom, Foygel & Morgan, 2008; Stern, Spieker & MacKain, 1982). Therefore, while the linguistic relationship between rising intonation and the structure and meaning of questions is complex, there is evidence that such a relationship does exist (at least for English) in the real-world experience of infants.

However, these studies leave open the question of whether infants change their own vocal behaviors in response to questions. Discrimination of, and even preference for, the acoustic properties of questions, does not tell us whether infants (consciously or otherwise) treat questions as having a different communicative function from declaratives. If infants understand that particular intonational forms associated with questions signal a request for information and/or are an attentional bid, we may expect infants, like adults, to respond to questions with increased vocalization. One piece of evidence in support of this view comes from research that in the second year of life, infants are beginning to use intonation in their own utterances to indicate requests. For example, Galligan (1987) reported the gradual development of grammatical use of rising intonation up until about 18 months old, and Macros (1987) found use of rising intonation to be associated with requests around this age. One study found that infants use rising intonation for questions and requests and falling intonation for statements and turn termination in a group of

12-month-olds in their interactions with their mothers (Ferrier, 1985). Ferrier analyzed videotaped conversations between infants and their mothers, and selected infant vocalizations which fit a set of criteria to determine intentionality and exclude babble. These utterances were then classified according to function (e.g. requests, rejections, affirmations) based on context and analyzed prosodically. However, despite these early uses of rising intonation in toddlerhood, young children have difficulty in producing final rises as late as 4-5 years (Snow, 1998; Loeb & Allen, 1993; Patel & Grigos, 2006), and although 5-olds are capable of identifying final rises as indicating “asking”, their performance is reduced compared with older children and adults (Saidon, Trehub, Schellenberb, & Van Lieshout, 2015). Furthermore, infants’ use of these intonational distinctions in semantic/discourse appropriate ways in their own vocalizations does not in and of itself demonstrate that infants understand the meaning of this information in the caregiver’s speech, nor whether it influences their own behavior.

Another reason that we might expect increased vocal activity in response to maternal questions is that it may reflect a behavioural manifestation of increased arousal in response to particular kinds of pitch contours. Infants are highly responsive to maternal communicative behaviors, and will dynamically increase or decrease vocalization in response to maternal behaviors (Goldstein & Schwade, 2008, 2009). While these studies did not compare different types of utterances in this manner, utterance-final rises and other prosodic characteristics of questions may be acoustically structured to draw infants’ attention via the same mechanisms as maternal speech itself (Soderstrom, 2007), leading to increased vocalization due to increased arousal. While this might suggest a less mature responsiveness to maternal questions than responding for discourse-appropriate reasons, it would nonetheless be an important stepping stone toward mature conversational interchanges.

In sum, by the onset of the first word, infants show a reliable ability to detect the prosodic characteristics of questions, and an overall bias to attend to pitch properties characteristic of questions. In addition, infants' conversational skills are developing, supported by maternal scaffolding, and there is evidence that they use intonational rises in their own speech to indicate requests. However, there is evidence that infants' ability to use intonational information in conversation and turn-taking may still be developing. In this study, we examined the vocal responses to maternal utterances of infants aged 10 and 14 months, during the transitional period from preverbal to verbal. We asked three questions: Will infants show differences in the number and duration of their vocalizations when mothers ask more questions, both at the global (across a block of time) and local (immediately following a maternal utterance) level? Will infants show increased vocalization in response to utterances that contain the prosodic characteristics of questions? Are there age-related differences in maternal speech patterns and infant responding?

Method

Participants

Participants included mothers and their infants living in Winnipeg, Canada and surrounding area. Two groups of mother-infant dyads were recruited for this study with infant ages of 10- and 14-months. Six-month-olds were also recruited during the initial stages of the study, but excluded because the infants from this age group did not vocalize enough during the recordings for data analysis. Each age group consisted of 18 dyads. Conditions of participation specified that English was the primary language spoken in the home. Participants were ineligible if the infant or mother was hard of hearing or deaf, had significant cognitive deficits or notable language impairment.

The recordings from six additional mother-infant dyads (all 14-month-olds) contained unusable data. Two of these recordings included infants who vocalized rarely or not at all. These recordings were coded before the decision was made to exclude them. One recording contained a mother's speech that was quiet to the point of being largely inaudible. The decision to exclude this recording was made after partial coding. The remaining three recordings were excluded prior to coding: Two sessions involved mothers who spoke in one part of the session but not the other, which was likely due to misinterpretation of study instructions. One recording was discarded due to experimenter error that involved placement in the wrong condition.

Procedure

Mother-infant pairs were invited to visit the laboratory for a play session, which was recorded with the Digital Language Processor (DLP) of the Language Environment Analysis (LENA) system (Gilkerson & Richards, 2008). For this study, the DLP was used to obtain high-quality recordings – the software components of LENA were not used. Sessions took place in an area of the laboratory with bright coloured walls containing a small child's play table, toys and an alphabet patterned play mat. Mothers were asked to allow their infants to wear a cloth vest for the duration of the experiment that was designed to accommodate the DLP device.

Each session was approximately 20 minutes in duration and consisted of two 10 minute parts. Mothers and their infants engaged in a brief 'warm-up' period before recording began. A brief break was permitted half way through the session at the mothers' discretion. Each mother-infant dyad was provided with two sets of 5 age-appropriate toys (one set for the first part and a different set for the second part).

In the question part, mothers were instructed to ask questions to their infants related to the set of toys provided or about what they were seeing or doing. No specific instructions were

given regarding what types of questions to use. Mothers were otherwise instructed to play with their infants as they would normally at home. We encouraged mothers to use gestures and touch to further engage infants in the play activity. In the declarative part, mothers were instructed to avoid asking questions and were instead asked to use statements and descriptions (i.e., declaratives). All other instructions remained the same.

Every mother-infant dyad completed both the question and declarative parts of the experiment. Dyads were randomly assigned to complete the question part first and the declarative part second or the reverse. Any effect of condition was therefore independent of condition order. The toy set participants received first was also randomized.

For the duration of the play session, the experimenter remained outside the room and observed through a one-way window.

Data Analysis and Results: Infant Responding by Block Type and Sentence Type

Subsequent to data collection, mother and infant vocalizations were coded and analyzed by the first author. Each mother-infant recording was listened to in its entirety and coded manually throughout. Infant vocalizations were included for analysis if they contained reasonable acoustic and articulatory approximations of syllables that were characteristic of babbling. Involuntary sounds including cries, whimpers, coughs, grunts, sneezes, burps, etc. were excluded. Virtually all maternal vocalizations were included for analysis except for laughter, kisses and the occasional inaudible sound. Maternal utterances such as ``oh'', ``hmm'', ``shh'' and ``uh-huh'' were included as meaningful vocalizations.

Vocalizations were coded by speaker and, for mothers only, utterance type (yes/no question, wh-question, or declarative). Each maternal utterance was categorized based primarily on the content/context of the utterance (i.e. word order and preceding/following utterances) and

secondarily the qualitative prosody if the content/context was ambiguous. Vocalization boundaries were determined via careful visual inspection of spectrogram representations of the audio recordings in Praat (Boersma & Weenink, 2010). Vocalization boundaries were confirmed by listening to each segment individually.

Vocalizations by the same speaker were separated into distinct utterances when they included a 0.75 s pause or greater. Listening judgments confirmed that a 0.75 s pause was sufficiently long to mark a clear breath or break in vocalization. Several files were coded using a 1 s pause, but this method was terminated in favor of a shorter pause length. A shorter pause ensured that vocalization boundaries were more true to actual vocalization time. The 0.75 s pause did not apply to closely spaced utterances by different speakers. Vocalizations by different speakers were often separated by very short pauses and occasionally overlapped.

All ANOVAs were conducted with age as a between subjects factor. Age effects were non-significant except where explicitly mentioned. Order effects were also examined. There was no effect of condition order (i.e., whether the infant heard questions or declaratives first) or of toy set presentation order (i.e., if toy set A or toy set B was provided first) on infant vocalizations, so findings reported below collapse across these conditions.

Global effects across conditions

Maternal responses to instructions

Mothers were far from perfect at restricting their use of declaratives and questions to the appropriate 10-minute block. However, there was a clear attempt on the part of the mothers to follow instructions. An ANOVA was conducted with 2 within-subjects factors (block type and utterance type) and one between-subjects factor (age) to compare the mothers' use of questions and declaratives across the two blocks. There was a main effect of utterance type ($F(1, 34) =$

40.33, $p < .001$), with more declaratives spoken across both blocks (Mean = 144, SD = 34.2) than questions (Mean = 103, SD = 31.7). In addition, there was a significantly larger number of utterances spoken in the question block than the declarative block ($F(1, 34) = 48.45, p < .001$). Importantly, there was a strong block by utterance interaction, indicating that parents spoke more questions in the question block and more declaratives in the declarative block ($F(1, 34) = 266.19, p < .001$). See Table 1. In the question block, on average 63% (mean $N = 88/140$) of utterances were questions, while in the declarative block, 86% (mean $N = 92/107$) of utterances were declaratives. However, the main effect of block above indicates that mothers may have followed instructions in part by speaking less overall during the declarative block (mean $N = 140$ versus $N = 107$). A 3-way interaction ($F(1, 34) = 4.55, p < .05$) indicated a slightly stronger effect of the block by utterance interaction in the 14 month old group. However, separate analysis of the two age groups found the interaction to be significant for both the 14 ($F(1, 17) = 235.7, p < .001$) and the 10 month olds ($F(1, 17) = 78.7, p < .001$). There were no significant differences in the durations of maternal utterances in the question and declarative conditions, or effects of age.

Global measures.

Across both blocks, on average 42% (mean $N = 103$) of the maternal utterances were questions and the other 58% (mean $N = 144$) were declaratives. Questions were further divided into two categories: yes/no questions and wh-questions. Expressed as a proportion of the total number of questions, most were yes/no questions (71%) and fewer were wh-questions (29%). There was no effect of infant age group and no differences between mothers of male and female infants with respect to the proportion of questions or declaratives spoken or the type of questions used.

Infant response to condition.

Despite significant differences in maternal use of question across conditions, no significant differences in infant vocalizations were found, either in terms of frequency ($F(1, 34) = .259, p = .614$) or duration ($F(1, 34) = .001, p = .980$) with no effects of age. There was therefore no evidence that infants were vocalizing more during the question block than the declarative block, contrary to our hypothesis.

Local utterance-level effects

Infant responses to questions and declaratives.

Although we did not see condition-level effects of maternal use of questions and declaratives, it is possible that utterance-level effects might exist that were not detectable with the block-level analysis. In order to determine the specific effects that questions and declaratives had on subsequent infant vocalizations, an analysis was performed including only those infant utterances that were contingent on a previous question or declarative. An infant vocalization was considered to be contingent on the preceding maternal utterance if it occurred within 2 s of the maternal utterance. Infants responded to approximately 18% of their mothers' questions and 18% of their declaratives. Similarly, infants responded to approximately 18% of mothers' yes/no questions and 20% of their wh-questions, which was not significantly different. The duration of infant responses did not vary as a function of the preceding maternal utterance type (i.e., questions or declaratives) nor as a function of question type (i.e., yes/no questions or wh-questions). We therefore saw no evidence at the local level that infants were influenced to vocalize more following a maternal question, again contrary to our hypothesis.

Data Analysis and Results: Infant Responding by Independent Ratings and Acoustic

Grouping

Rating of Maternal Utterances

A potential limitation of the first author's coding system was that she used structural and contextual information that may or may not have been available to the infants. Geffen and Mintz (2014; Geffen, 2014) found evidence that 12-month-olds discriminate questions from declaratives based on word order, but even this does not show that infants attend to these differences in their responses under real-world conversational interactions. We therefore subjected the mothers' utterances to rating by independent listeners who were blind to the structural and contextual information and examined infants' responding based on these ratings.

Each utterance was low-pass filtered at 400 Hz with 100 smoothing using Praat (Boersma & Weenink, 2010) and rated by 3 independent raters based on a scale from 1 (Not at all like a question) to 4 (A lot like a question) using a custom Python program written for the purpose. Because of the large number of utterances in the full sample, each rater listened to only 2 dyads – one at 10 months and one at 14 months. There were therefore $18 \times 3 = 54$ different raters. Raters were selected from a pool of undergraduate students taking Introductory Psychology, and were screened to ensure that English was their first language and they did not have any hearing deficits. Raters received course credit for participating in the rating task. During piloting of the rating system it was determined that very short utterances were particularly hard to rate, so utterances shorter than .8 s were excluded from the rating in order to reduce the number of items to be rated. A total of 2605 utterances, or 28% of the utterances, were excluded based on this criterion.

A composite score was created for each utterance by taking the mean across the 3 raters. We then classified the utterances from the mother into “declarative” (< 2), “question” (> 3) and “uncertain” (2-3). A total of 3063 utterances fell into the “uncertain” range.

As can be seen from Table 2, this rating of low-pass filtered speech by naïve listeners matched well with the original classification based on context and content of the utterances. Similarly, there were no significant differences in the rate of infant vocalization to utterances rated less than 2 (18%) or greater than 3 (17%), providing additional evidence that the mothers' use of questions did not influence infant vocalization.

Acoustic Grouping

Our human ratings using low-pass filtering were intended to capture the complex prosodic characteristics that differentiate yes/no questions from declaratives and wh-questions. However, in this analysis a large proportion of the maternal utterances were excluded due to the difficulty of the rating task for listeners. As a further check on the possibility that infants might respond differentially to the utterances based on their acoustic properties, we isolated two basic features that have been implicated both in the demarcation of questions and in directing attention – rising intonation and increased pitch excursions.

Rising Intonation.

We first identified utterances with “rising” intonation using a simple metric based on a rise of 50 Hz or more from the beginning to the end of the utterance using Praat (Boersma & Weenink, 2010). Such rises would typically occur on the final syllable. However, given the large number of utterances being analyzed and the fact that many of the utterances in question are very short (less than 1 s), we chose to use this simple metric rather than conduct a phonological analysis to isolate the final syllable. This analysis was similar to our raters' judgments of low-pass filtered speech in how well it matched with the author's judgments of utterance type. Across participants, on average 67% (SD = 12%) of the utterances coded by the author as yes/no questions were categorized as “rising”, compared with only 25% (SD = 7%) for Declaratives and

23% (SD = 12%) for Wh-Questions. There were no significant differences in the percentage of infant responses to rising (Mean = 17%, SD = 11%) versus non-rising (Mean = 18%, SD = 11%) maternal utterances, providing no support for the notion that infants respond to rising maternal intonation by vocalizing more.

Large Pitch excursions.

We also examined the possibility that infants might vocalize more to larger pitch excursions, regardless of contour or utterance type. We therefore generated a median split for each mother based on the pitch range (maximum pitch – minimum pitch) for each maternal utterance and examined how often infants responded in each group. The mean split point across mothers was 237 Hz (SD = 45 Hz). Utterances in the “large range” had an average pitch range of 345 Hz (SD = 42 Hz), while utterances in the “small range” had had an average pitch range of 137 Hz (SD = 30 Hz). There was no significant difference in amount of vocalizing following large versus small maternal pitch ranges.

Data Analysis and Results: Maternal responding

Maternal responses to infant vocalizations

In this analysis, we examined the possibility that mothers might provide a conversational model of responsiveness for infants by responding with more declaratives after an infant vocalization. In other words, while declaratives and questions should both be plausible as conversational initiators, maternal responses to infant vocalization should be skewed toward declaratives. However, the proportion of declaratives (58%) in response to child vocalization was highly similar to that of the total proportion of declaratives in maternal utterances (also 58%), so there was no evidence of differential responding by mothers to infant vocalizations.

Consecutive maternal questions

Lastly, we examined mothers' behavior following their own questions. If mothers do use questions as a means of soliciting conversational interaction with their infant, their own behavior across successive utterances may provide some insight into the development of these interactions, particularly given the lack of responsiveness our analysis finds on the part of the infants. We therefore examined consecutive utterances spoken by mothers within a 2 s margin (i.e., any successive maternal utterances spoken within 2 s after a previous maternal utterance). Within a 2 s margin, mothers followed their own questions with a subsequent question more often than they followed a question with a declarative ($F(1,34)=5.456, p = .026$). However, there was an interaction of maternal utterance type with infant age group ($F(1,34)=5.325, p = .027$). Mothers of 10-month-olds were equally likely to follow a question with either utterance type ($t(17)=0.026, p=.980$), whereas mothers of 14-month-olds were more likely to follow a question with a subsequent question rather than with a declarative ($t(17)=2.779, p = .013$). See Figure 1.

Discussion

With respect to our first two questions, we found no evidence that maternal questions increase the frequency of infant vocalization at either 10 or 14 months. There was no effect of maternal utterance type on infant vocalization at either the global or local level. This null finding was robust across several kinds of analyses. Infants did not increase vocalization in time blocks with larger percentages of questions, nor did they vocalize more immediately after a question than immediately after a declarative, whether categorized by the author based on context, prosody and meaning, nor when judged based on the prosody alone by naïve listeners. Furthermore, infants did not vocalize more in response to utterances with two prosodic characteristics associated with questions that might have attentional effects: rising intonation and

larger pitch range. Given the difficulty in interpreting null findings, we are necessarily hesitant to conclude that maternal question behavior has no effect on infant vocalization at these ages. There are a number of reasons why our study may have failed to detect such effects. For one, the length of our recordings was relatively short (10 minutes per block). Note that it was difficult for mothers to maintain an artificially high and low level of question use over an extended period of time, so longer recordings would have been problematic. It is possible that longer term effects of questions might emerge if it was possible to test over a larger time scale, or that such effects might be present in a more naturalistic context than our laboratory setting. For another, since mothers did not perfectly isolate questions to the question block and declaratives to the declarative block, the increase/decrease in these rates compared with baseline may not have been enough to generate a detectable effect in infants. However, given that the difference was quite large (14% versus 63% questions across blocks), this insensitivity on the part of the infants is striking, even if a larger difference across blocks or a larger sample of utterances would have generated a detectable infant response. At the very least, our results suggest that short-term manipulation of maternal question use does not easily or directly impact infant vocal responding.

Assuming, then, that these null results are indicative of a larger insensitivity on the part of the infants, what are the implications for infants' knowledge of questions? As described in the introduction, infants are highly sensitive in other contexts to the prosodic characteristics of yes-no questions (Frota, et al., 2014; Soderstrom, et al., 2011; Sullivan & Horowitz, 1983), and one study found that infants use rising intonation in contextually appropriate ways in their own vocalizations by 12 months (Ferrier, 1985), although other studies suggest this may emerge more gradually (Galligan, 1987; Macros, 1987). Our finding therefore suggests not that infants fail to detect the intonational qualities of questions, but rather that they fail to translate this knowledge

into contextually appropriate responding. One possible source of the breakdown is in the knowledge of the semantics of question intonation. Infants' own appropriate use of rising intonation does not necessarily translate in semantic knowledge of its meaning – infants may not have full knowledge of the meanings of their own behaviors. An alternative possibility is that infants do understand that the mother's intonation is inviting a response, but are not yet fully able to translate this knowledge into a response in an online conversational context. The recent findings on children's developing ability to use intonational and question information in predicting turn-taking in observed conversations (Cassilas & Frank, 2015; Keitel et al., 2013) provide converging evidence that the ability to use this information in dynamic contexts is not fully mature by 14 months.

With respect to our third question, we found little evidence of age-related changes in infant vocal behavior in response to questions. Despite a significant shift in infant vocal ability between 10 and 14 months as infants begin producing their first words, we did not see evidence of this translating into more mature responding to questions. The one area in which we saw some evidence for age-related effects was on the part of the mothers, in their utterances following their own questions. Mothers of 14-month-olds, but not 10-month-olds, were significantly more likely to follow a question with another question (rather than a declarative), despite there being overall no difference in the rates of questions and declaratives across age. This may indicate a greater expectation on the part of the mothers for a response from the infant. Upon failing to receive an answer, an additional prompt is given. Bornstein, Tamis-LeMonda, Hahn & Haynes (2008) similarly found an increase in mothers' use of questions in response to *infant* vocalization and action from 14 to 21 months. Although the ages and experimental contexts are not identical, both

studies may be tapping into a similar transition on the part of the mother toward greater expectations of infant responsiveness to questions.

The apparent insensitivity on the part of the infants in responding to maternal questions does not challenge the larger notion that maternal questions are a key component of early language development. Maternal questions provide important clues about the grammatical and prosodic structure of the language, and are a salient part of the early linguistic input. Despite the exaggerated prosodic characteristics inherent in infant-directed speech itself, our analysis supports the idea that maternal speech differentiates prosodically (as well as grammatically/lexically) between declarative and yes/no questions, at least in a probabilistic sense, and that it patterns similarly to the adult input in that wh-questions pattern like declaratives. Nonetheless, our findings do challenge the notion that maternal questions actually prompt a response on the part of the infant, something that mothers would at least appear to be attempting to do when asking questions of their infants. Interestingly, in the Speech-Language Pathology community, advice is sometimes given to parents to *reduce* the number of questions they pose to their children as a means of increasing the amount of child speech, by giving them more room to talk.² While we did not see this effect either, a post hoc comparison of the number of infant vocalizations in our experimental data with data from an ongoing study of child language environments in real-world settings using the LENA device (Soderstrom & Wittebolle, 2013) suggests that the number of infant vocalizations in our laboratory sample may be reduced

² This was first pointed out to the authors by one of our participants who happened to be a Speech-Language Pathologist, and later supported by an audience member in a symposium discussion at the 2014 International Congress on the Study of Child Language, though we have been unable to find a published reference to support the idea.

compared with that in a real-world setting, while mother-infant contingent vocalization was increased. It is possible that maternal vocalizations in general (whether questions or declaratives) may inhibit infant vocalization, although since these data were not designed to be directly comparable, this would require further research to determine. In addition, our finding suggests that, at least by 14 months, a simple arousal-vocalization response to maternal questions is not evident.

In sum, across a broad spectrum of measures, we found no evidence that 10 or 14 month old infants respond to maternal questions by increasing their vocalizations. Between 10 and 14 months, mothers engaged in more directed prompting of their infants with questions, but infants did not respond with greater frequency. Infants at this stage are clearly still in the process of developing their understanding of question-answer conversational exchange.

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Table 1. Number and duration of maternal utterances and infant vocalizations in each condition. Means across participants are given, with standard deviations in parentheses. In this table, all the utterances (both declarative and question) produced during the question block are reported as a single number (Question condition), and all the utterances produced during the declarative block are reported as a single number (Declarative condition). Material Ns are also reported within each block by utterance type (Question or Declarative).

	Question Condition	Declarative Condition
N of maternal utterances		
Total	140 (30.9)	107 (29.6)
Questions	88 (25.9)	15 (12.4)
Declaratives	52 (16.1)	92 (25.9)
Duration of maternal utterances (s)	1.28 (.15)	1.31 (.25)
N of child utterances	38.6 (28.5)	40.8 (20.78)
Duration of child utterances (s)	.865 (.326)	.863 (.317)

Table 2. The first 3 data columns provide the mean number (distribution) of maternal utterances rated by a naïve listener under low-pass filtering conditions as Declarative (< 2) or Question (> 3) on a scale from 1-4. The first three columns show these utterances distributed by the author’s original classification. The final column two provide these rating distributed by whether they have rising intonation.

Age/Rating	Declarative	Y/N	Wh	Rise	Non-rise
10 month olds					
(< 2)	57.1 (20.5)	6.0 (4.1)	9.3 (6.2)	16.2 (6.8)	55.1 (21.4)
(>3)	2.4 (2.0)	14.7 (9.2)	1.2 (1.4)	12.3 (7.8)	6.1 (4.4)
14 month olds					
(< 2)	54.9 (22.8)	7.2 (4.4)	12.3 (11.0)	16.2 (7.8)	58.1 (23.3)
(>3)	5.3 (4.9)	19.8 (10.3)	2.3 (2.7)	19.1 (11.0)	8.3 (5.2)