INFANT VOCAL RESPONSES TO QUESTIONS AND DECLARATIVES IN MATERNAL SPEECH

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This work is dedicated to my grandfather Herb Breitkreutz and in memory of my grandmother Helen Moritz.

Abstract

Infants are perceptually sensitive to rising pitch over falling pitch (Sullivan & Horowitz, 1983) and this is reflected in their ability to discriminate between questions and declaratives in maternal speech (Soderstrom, Ko, & Nevzorova, 2011). Questions are proposed to play a fundamental role in the acquisition process by soliciting vocalization on the part of the infant (Snow, 1977). How infants respond vocally to questions and declaratives, however, is currently unknown. In the current study, we explored whether infant vocal responses to questions were distinct from those to declaratives; in particular, whether the use of questions by mothers encouraged greater vocalization by infants. Contrary to our hypothesis, infant vocalizations were no more likely to occur in response to questions. An examination of the intonational properties of maternal utterances was more informative. Infants responded more to questions when they were defined by rising pitch contours rather than falling ones. Infants did not, however, respond to declaratives with rising pitch contours. Questions, in combination with rising pitch contour, may provide especially salient response cues for infants. We propose that infants rely on these perceptual cues to learn when to respond during vocal exchanges with their mothers. At the same time, infants learn about conversational turn-taking from the question and answer pattern of their mothers' speech.

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Chapter 1

Introduction

The process of language acquisition is complex and, yet, infants learn how and when to use language with seeming ease. The mother-infant bond is important to language acquisition and, in particular, the early vocal exchanges therein. Infants' sensitivity to certain acoustic cues embedded in the maternal speech stream exists in a positive feedback loop between mother and infant in which infant attention promotes maternal use of salient cues and vice versa. Infants are especially sensitive to pitch information in maternal speech. A myriad of data supports this claim: for example, infants show a preference for listening to low-pass filtered maternal speech over maternal whispered speech, which provides some evidence for a general importance of pitch (Spence & Freeman, 1996). Accordingly, Spence and Freeman (1996) suggested that pitch is critical for neonatal voice recognition. Furthermore, prenatal exposure to pitch information influences postnatal behaviour as evidenced by Satt (1989) who found that infants discriminate between novel melodies and melodies to which they were familiarized prenatally and show a preference for familiar melodies. Infants demonstrate a similar result during tasks using story excerpts and rhymes, perhaps relying on more general prosodic cues to do so (DeCasper, Lacanuet, Busnel, Granier-Deferre, & Maugeais, 1994). Kitamura and Burnham (2003) found that infants especially attend to pitch information more than they do other intonational characteristics such as amplitude or duration.

Given that infants' encoding of pitch cues is relevant for memory processes and perceptual biases, these same pitch cues may be pertinent within the vocal production domain. Infants' perceptual sensitivity to pitch in maternal speech may result in vocal responses that are contingent on particular pitch patterns. For instance, infants' vocalizations may differ according to the type of sentence they hear. The objective of the current research was to

determine whether infants respond differently to questions than to declarative sentences, based on their prosodic characteristics.

Questions are characterized by a prominent end of utterance rising pitch, whereas the end of a declarative has a falling or stable pitch contour (e.g. Stern, Spieker, & MacKain, 1982). The rising pitch of questions specifically applies to those that are yes/no questions. Wh-questions are less often defined by rising pitch. Infants are perceptually sensitive to end of utterance pitch patterns according to Soderstrom et al. (2011) who found that young infants discriminated between questions and declaratives and showed a reliable preference to the former. Sullivan and Horowitz (1983) observed among infants a perceptual preference for rising pitch over falling pitch, which supports the effect observed by Soderstrom et al. (2011). Moreover, Kaplan (1969) found that 8-month-old infants differentiated sentences based on their intonational contours.

Infants' ability to extract pitch patterns from phrasal units in speech may, in addition to promoting recognition of sentence types, initiate appropriate vocal responses. In the current study, it was hypothesized that distinct infant vocal responses would emerge in response to questions given infants' underlying perceptual preference for questions observed by Soderstrom et al. (2011). Infant vocalizations following questions were predicted to differ from those following declaratives within a context of mother-infant play. Specifically, infants' vocalizations may increase in both frequency and duration upon hearing questions. Increased vocal activity may represent a behavioural manifestation of infants' attentional bias to the rising pitch contour of questions. In this way, infant vocal behaviour may reflect a perceptual awareness that rising pitch signals a bid for attention or a request for action.

Furthermore, an especially important role of pitch production is proposed. Infants' vocalizations may possess distinct pitch contours that are dependent on sentence type. For instance, infants may respond with falling pitch contours to questions, which is a typical pattern of question and answer exchange found in adult conversation. Infants may already

be learning the rules governing conversation and respond in an adult-like way as opposed to with arbitrarily placed vocalizations containing random pitch contours. Together, these proposed infant vocal behaviours suggest that the end of utterance rising pitch of questions is an acoustic signal for proto-conversational responses that are distinguishable from other infant vocalizations. Infant responsiveness to pitch stimuli may reflect the earliest stage of preverbal semantic knowledge.

1.1 Intentionality in speech

The idea that infants' preverbal vocalizations may be distinguishable based on contextual information (e.g., preverbal vocal responses to maternal questions) is reasoned according to the theoretical principles of Hallaway (1975). Hallaway (1975) proposed that preverbal infant vocalizations carry meaning, which reflects a rudimentary understanding of semantics by the infant; however, whether such meaning is real or inferred is debatable. In some cultures, infant vocal behaviour is considered to be important and meaningful. For instance, infants are perceived as social beings in Western cultures and inferences about their intentions are readily made (Schieffelin & Ochs, 1983). Conversely, cultural views of child development in other parts of the world (e.g., New Guinea) do not indicate an important role of adult-infant interactions nor do they assign intention to infant vocalizations (Schieffelin & Ochs, 1983). However, Bryant and Barrett (2007) demonstrated recognition of intention by non-native speakers who listened to infant-directed speech with semantic information removed leaving only vocal cues available. As evidenced by several studies, the universality of certain pitch contours in terms of the meaning conveyed include those contours eliciting excitement or calmness (Papousek, Bornstein, Nuzzo, Papousek, & Symmes, 1990), approval or disapproval (Spence & Moore, 2004) and relief or achievement (Soderstrom, Sauter, & Reimchen, 2013).

The idea that there is a systematic relationship between meaning and sound in infant

babbling is supported in observational studies by Carter (1974), D'Odorico (1984) and Kent and Bauer (1985). For example, D'Odorico (1984) observed infants' pairing of vocal melodic output with communicative functions (e.g., call and request sounds had rising pitch contours, whereas, discomfort sounds had flat or falling pitch contours). Various adult rating studies provide evidence that parents have an intuitive ability to attribute emotional valence and communicative intent to these early infant vocalizations (e.g. Beaumont & Bloom, 1993; Oller, Eilers, & Basinger, 2001; Papousek & Papousek, 1989). Moreover, in studies evaluating adult listeners' ability to identify intention from only the intonational characteristics of either infant-directed speech or adult-directed speech, participants did so significantly more accurately in the case of infant-directed speech (Fernald, 1989). By extension, these findings suggest that the intonational patterns of infant-directed speech are exaggerated to be informative to infants in a way that adult-directed speech is not. Fernald and Kuhl (1987) claimed that the intonational contours of maternal speech are meaningful to infants even in the absence of linguistic content. Long before infants are able to communicate fluently, they may learn about categories of contextually relevant prosodic information. It may be an easier task to categorize a limited number of intonational patterns than to extract patterns from the highly variable segmental features of speech (Stern et al., 1982).

1.2   Pitch characteristics of maternal speech

Phrasal intonational features of maternal speech may possess an important communicative function for the preverbal infant. The intonational contours mothers use when speaking to their infants are unique from their speech to adults (Stern et al., 1982). Across languages, mothers have been observed to increase the fundamental frequency and pitch range of their speech to infants (e.g. Cooper & Aslin, 1989; Fernald, 1989). Notably, these characteristic pitch changes occur even in the speech of Mandarin Chinese mothers who use language-

specific fluctuations in pitch to signal phonemic distinctions (Grieser & Kuhl, 1988). By modifying the prosodic qualities of speech, mothers speaking tonal languages could confuse prosodic with phonemic information and, yet, the fact that they do suggests universality of exaggerated pitch in infant-directed speech.

Fernald and Kuhl (1987) proposed that pitch modulation is the most salient prosodic cue of infant-directed speech and is critical for infants' preference to this type of speech. The wide fluctuations of pitch could function to elicit attention and promote social interactions (Fernald & Mazzie, 1991; Kemler Nelson, Hirsh-Pasek, Jusczyk, & Cassidy, 1989). For instance, mothers use rising or rise-fall pitch contours to promote attention, bell-shaped contours to maintain attention or to show approval, slowly falling contours to soothe and comfort and rapidly falling contours to signal prohibition (Katz, Cohn, & Moore, 1996). A discrepancy emerges between Fernald and Mazzie (1991), who claimed that bids for attention were characterized by rising contours, and Katz et al. (1996), who reported that rising and rise-fall contours represent attentional bids. It is important to distinguish between attentional bids and those vocalizations intended to elicit a specifically verbal response. For instance, yes/no questions may elicit responses because they are consistently defined prosodically by rising intonation.

1.3   Intonation of early infant responses

The manner in which infants vocalize in response to speech progresses rapidly within the first few months of life. Specifically, the development of intonational control arises from relatively sophisticated pitch production abilities present at birth and shortly thereafter. As newborns, infants have already mastered the vocal ability to match a heard tone (Kuhl & Meltzoff, 218; Patterson & Werker, 2003). The melodic characteristics of newborn cries match properties of the spoken native language. Melodic complexity is a primary characteristic of early non-distress vocalizations by infants (Hsu, Fogel, & Cooper, 2000).

Lieberman (1985) and Kessen, Levine, and Wendrich (1979) found that infants as young as 3 months of age control their intonational output. Infants can imitate, discriminate and produce a variety of melodic patterns (Trehub, Bull, & Thorpe, 1984; Papousek & Papousek, 1989; Kessen et al., 1979). By 6 months, infant vocalizations resemble the intonational features present in native speech (Crystal, 1986). Late in the first year, infants' vocalizations frequently contain rising pitch contours to express requests as evidenced by several quantitative studies (e.g. Blake & Fink, 1987; Macros, 1987). In the one-word period, infants have been found to use rising tones to indicate interest in objects or to request information about them and a rising-falling tone pattern to label objects (Galligan, 1987). From this study, it is evident that infants use different intonational patterns in question and declarative contexts. Previously, infant vocalizations were thought to lack systematic use of intonation until the acquisition of syntax (Bloom, 1973). Instead, infants' use of intonation to express knowledge and requests for knowledge appears to precede verbal expressions of the same. Galligan (1987) found that the onset of grammatical use of intonation occurred at approximately 14 months of age. Hallaway (1975) proposed that grammatical use of intonation begins when infants realize that words have socially relevant meanings.

1.4 Vocal imitation

Vocal imitation in infancy is considered the earliest communicative behaviour preceding language (Nagy, 2006). Before infants are able to extract and recombine speech sounds from their entire repertoire of language knowledge, they use imitation strategies. Infants imitate the sounds that they hear and, in particular, those of the primary caregiver (Hsu et al., 2000). Kuhl (2007) is a proponent of the theory that learning speech is a social process and describes vocal matching is one instance of this. Imitation provides an opportunity for auditory feedback, which is critical to vocal learning in humans (Papousek & Papousek, 1989). Vocal imitation by infants provides an opportunity for mothers to scaffold vocal

development by engaging in supportive vocal exchanges.

Prosodic elements of speech are targeted in early instances of vocal matching. Mothers match the emotional expression of infants' vocalizations by adopting a similar quality of voice and intonation and, thereby, become attuned to the emotional state of the infant (Papousek & Papousek, 1989; Stern et al., 1982). Moreover, mothers may modulate these vocal imitations to maximize or minimize an infants' behavioural expression of emotion in order to arouse or soothe. Mothers' strategic use of intonation may originate from the human inclination towards social contingency rather than as a language learning strategy per se. Infants, too, alter the quality of vocalizations in response to social events (Bloom, 1988; D'Odorico & Franco, 1991). For example, Papousek and Papousek (1989) found that infants aged 2 to 5 months matched the intonation of maternal utterances in their vocal productions. A developmental trend was observed in the degree to which infants could match increasingly complex sounds (Papousek & Papousek, 1989). Once infants mastered simpler intonations via imitation, their attention appeared to orient towards reproducing more challenging intonations as a way to expand their intonational vocal repertoire. Mothers typically incorporated slightly more sophisticated pitch contours or new combinations of sound patterns than those reliably reproduced by infants at any given point of vocal development, which suggests that mothers contribute in an important way to infants' ability to produce increasingly complex intonations (Papousek & Papousek, 1989). On the other hand, mothers reinforced infants' learning of intonation through exaggerated corrective feedback or by contingent reinforcement (Papousek & Papousek, 1989). Over time, vocal matching becomes more a more frequent part of vocal interchanges and constitutes approximately half of infants' total number of vocalizations (Papousek & Papousek, 1989).

When speaking to an infant, mothers automatically raise the average pitch frequency of their speech to match the average pitch frequency produced by an infant (Fernald et al.,

1989; McRoberts & Best, 1997). Infants may better learn about intonation when the model speech input closely matches their own production. Papousek and Papousek (1989) noted that absolute pitch was the earliest and most reliable acoustic property of speech matched by infants during instances of vocal matching. Lieberman (1985) found that infants imitated both the pitch and pitch contours of maternal speech.

Mothers' use of exaggerated pitch contours may also aid infants' learning of intonational categories in speech. Before infants are able to manipulate intonation to represent communicative intent, they must be capable of associating intonation patterns with situational contexts. These associations may be solidified during experiences in which infants imitate that which they hear in maternal speech. In turn, they learn to associate their own production of an intonational pattern with the appropriate context by modelling the intonation-context relationship established by an adult caregiver. It may be that by modelling maternal vocal behaviour, infants learn to associate intonational output with meaning in their own vocalizations.

An ongoing discussion regarding the extent to which mother-infant vocal interactions are imitative has culminated in two recent studies by Balog (2010) and Gratier and Devouche (2011) examining the extent to which pitch contours match across contingent mother and infant vocalizations. Balog proposed a supportive role of maternal speech that is not directly imitative. Instead, maternal vocalizations created an enriched environment that promoted infants' expanding vocal repertoire. Specifically, Balog noted that infants' vocalizations directly following an adult utterance had a wider pitch range. However, the pitch range of infant vocalizations was still narrower than that of maternal utterances. Infants' vocal behaviour indicated a preliminary ability to acclimate the adult system of intonation by producing similar, but less mature, intonational contour shapes present in the maternal speech stream. Observations that the occurrence of intonation patterns resembling those in maternal speech were not contingent on maternal modelling of a particular intonational

contour immediately before. If imitation is a primary mechanism by which infants acquire intonation, one would expect to find more pronounced evidence for vocal matching.

In favour of this hypothesis, Gratier and Devouche (2011) found that 3-month-old infants imitated the pitch contours of utterances heard in maternal speech, in contrast to Balog. Further, infants repeated intonational contours they themselves produced, which were different than those contours most frequently heard in maternal speech. At the 3 month age mark, infants' vocal learning may benefit largely from imitative strategies. It appears that infants engage in two distinct types of vocal imitation depending on whether utterances have a communicative function or are part of solitary vocal play. The purpose of infants repeating the intonation of their own vocalizations may be to better the prosodic quality of sounds, whereas infants experiment with novel intonations in contexts of imitative interaction.

The disparity in observations across age groups may be explained by developmental trends in intonation acquisition. It is important to note that participants of the Balog (2010) study were significantly older at 13 months and within the single-word period of language acquisition in comparison to the young 3-month-olds of the Gratier and Devouche (2011) study. Early learning of intonation may occur through imitation, whereas older infants make use of a wider variety of intonational patterns, which are incorporated into their prosodic repertoire and employed in ways that are not imitative *per se*. The intonational contours of older children's vocalizations may match those found in maternal utterances but are found less often adjacent to one another as in the case of younger infants. Older infants may be beginning to use intonation in contextually relevant ways that are less dependent on direct maternal vocal modelling.

Ginsburg and Kilbourne (1988) proposed that there are two structurally different types of vocal interactions that occur within early infant-mother exchanges. The first, coactive vocalizations, occur when both parties vocalize simultaneously or when a portion of two

vocalizations overlap. Ginsburg and Kilbourne (1988) found that, at 3-months-old, infants' vocalizations were primarily coactive and a vocalization by either mother or infant was contingent on a vocalization by the other. Owens (1984) proposed that the co-active stage of vocal interaction proposed by Ginsburg and Kilbourne (1988) is predominant for the first six months of infancy. However, several authors contend that infants are capable of vocal turn-taking much earlier, by four months of age (e.g. Bateson, 1975). By 9-months-old, infants participate in a second type of vocal interaction described as an alternating vocal exchange, which is temporally coordinated in a turn-taking pattern. By the second year of life, vocal exchanges are predominantly alternating and co-active vocalizations are less frequent (Ginsburg & Kilbourne, 1988). It may be that imitation drives the co-active period, but not the alternating period, which coincides with the age-related disparity between evidence for imitation by Gratier and Devouche (2011) and a lack thereof by Balog (2010).

1.5   Social contingency of mother-infant vocalizations

Just as infants are predisposed to learn language, mothers may be predisposed to interact with their infants in ways that foster language, social and emotional development. A bi-directional relationship exists between preverbal infants' vocalizations and maternal vocalizations, which is rooted in social behaviour. Long before infants are able to demonstrate their comprehension of language and respond verbally to maternal speech, mothers respond to their infants instinctively (Oller et al., 2001). Infants are perceptually aware of these maternal responses and learn that their vocalizations influence the behaviour of a social partner (Goldstein & Schwade, 2009). Early vocal exchanges between mother and infant are part of a larger cohort of socially driven behaviours that precede linguistic conversational ability by an infant.

Typically, infants vocalize more frequently and with more complex speech sounds during instances of social contingency. For instance, Goldstein and Schwade (2009) reported that

infants' vocalizations were extinguished in those instances in which caregivers did not provide vocal feedback. Moreover, infants' positive social behaviour reinforces maternal adoption of infant-directed speech (Smith & Trainor, 2008). In a study during which mothers and infants were separated during testing (i.e., mothers viewed their infants via a silent video output), a third party experimenter provided positive reinforcement to infants in response to the rising pitch contours of mothers' infant-directed speech (Smith & Trainor, 2008). Infants' positive social responses in turn stimulated mothers to continue speaking to their infants with higher pitch contours though unaware that infants were responding to the experimenter's behaviour and not to that of their own speech (Smith & Trainor, 2008). Conversely, in the case that the experimenter positively reinforced lower pitch contours in maternal speech, mothers' speech was not infant-directed (Smith & Trainor, 2008). From this study, it can be hypothesized that infant feedback is a dynamic component of early mother-infant interactions. The degree to which an utterance is meaningful to an infant is, at least to some extent, related to the intonation characterizing that utterance (Beaumont & Bloom, 1993). Pitch cues characterizing infant-directed speech may therefore constitute a central acoustic property of mother-infant vocal interactions that facilitate social contact before mastery of linguistic content.

1.6   Conversational turn-taking

The ability to engage in conversation requires each participant to understand the protocols of turn-taking. Conversational exchange requires an understanding of social regularities that include initiation, termination, alternation and pacing (Bateson, 1975). At a fundamental level, these conversational regularities rely on rudimentary rhythmic structure to which infants must become attuned to. Early rhythmic experience may promote a perceptual bias to temporal information in the acoustic environment. Beginning in the final trimester, infants are familiarized with a variety of rhythmic sounds outside of the speech domain, including

the mother's heartbeat and digestive sounds (Busnel, Graneir-Deferre, & Lecaunuet, 1992). Beginning in the postnatal period, mothers engage in various forms of rhythmic gestures to comfort their infants, such as rocking. Rhythmic input from mothers is reciprocated by young infants who demonstrate rhythmicity in their own behaviours. For instance, rhythmic sucking bursts accompany a mother gently jiggling her infant during nursing (Ginsburg & Kilbourne, 1988). These early rhythmic experiences may prepare the infant for more sophisticated rhythmic behaviours, such as vocal turn-taking.

By 3 months of age, infants engage in vocal interactions that are resemble adult conversation (Bateson, 1975). These rudimentary conversations are achieved when infants learn to manipulate and recombine prosodic sequences heard in the maternal speech stream. However, given that the speech repertoire of an infant is relatively small in comparison to that of an adult, mother-infant vocal interactions are biased so that more of an onus is placed on the mother to sustain an exchange. The result of this imbalance is maternal scaffolding of the language learning process that accommodates an infant's immature cognitive abilities. For instance, mothers vocalize more often than do infants and these vocalizations often occur simultaneously with or in close temporal proximity to her infant's vocalization (Anderson, Vietz, & Dokecki, 1977). The infant-regulated timing of maternal vocal behaviours positively reinforce infant attempts to produce speech.

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 (Bateson, 1975). Infants model this maternal speak-listen pattern of turn-taking and also pause after vocalizing (Bloom, 1988). Infants appear to learn the general turn-taking protocols of conversational exchange long before their language production abilities reflect the capacity for complex adult conversation. Meanwhile, mothers interpret any response on the part of the infant as a communicative one, because conversational rules imply that utterances that follow questions be responses. Even the most vague vocalizations, such as coos and gurgles, are interpreted by mothers as

responses (Falk, 2004). If there is no communicative behaviour to interpret, then the mother can take the infant's turn or engage in conversational repair by repeating their previous utterance (Snow, 1977). During this process, infants begin to learn that utterances require replies and are prompted to figure out how to do so (Hoff-Ginsberg, 1986).

1.7 Questions embedded in maternal speech

According to Holzman (1972), questions are classified as statements that request information and behaviours or are questions designed to display or test the knowledge of the listener. Maternal speech contains a high frequency of questions (e.g. Newport, Gleitman, & Gleitman, 1977), which can be interpreted as a way of passing the turn to the infant (Snow, 1977). There are several explanations as to why mothers might ask their infants a large number of questions. For instance, mothers often ask questions when they observe their infant vocalizing while looking at an object or during handling of an object (Goldstein, King, & West, 2003). Responding to infant object play by asking questions inadvertently results in labelling objects for the infant's benefit. Before infants can respond in a verbally coherent way, mothers compromise by answering their own questions. When mothers provide object labels (i.e., via asking questions) in response to infant vocalizations that are in some way directed at an object, maternal speech helps prime associative learning of word-object pairings (Goldstein et al., 2003). This type of associative learning is thought to be especially relevant to language learning (Fernald & Morikawa, 1993). A high proportion of questions contained in the maternal speech stream is also 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). These effects on language development are thought to arise from infants' selective attention to questions and to the prosodic features therein (Soderstrom et al., 2011). The importance of acoustical cues in the speech stream to language development was proposed by Gleitman and Wanner

(1982) and later coined the *prosodic bootstrapping hypothesis* by Pinker (1984).

1.8 Summary and predicted findings

Previous research has shown that infants are sensitive to prosodic elements of speech and reliably distinguish question statements from declarative statements (Soderstrom et al., 2011). These sentence types are characterized by specific end of utterance pitch contours (i.e., rising pitch or falling pitch associated with questions and declaratives, respectively). Smith and Trainor (2008) and others have demonstrated an attentional bias to the higher pitch of infant directed speech as compared to the relatively monotonic adult-direct speech, which may partially account for infants' preference to questions. By the same token, rising pitch contained within infant-directed speech may be an especially salient response cue. The current study evaluated infant vocal responsiveness to question and declarative sentence types in maternal speech.

Infants selected for the current study were on average either 10 or 14 months of age. These age groups were chosen because they represent approximate markers before and after the single-word period of language development. Infants at these ages are exhibiting relatively complex babbling sounds and vocalize more than younger infants. By 14 months, infants exhibit grammatical use of pitch contour (Galligan, 1987). Age is also a factor in terms of the age at which infants become perceptually attuned to questions. Infants exhibit a preference toward questions within the first year of life (Soderstrom et al., 2011). However, behavioural indications of this preference may not manifest until some time later. Infants may be perceptually sensitive to the acoustical properties of questions before those perceptual skills are reflected in vocal production. Furthermore, older infants may orient toward speech sounds they prefer with postures, gestures and vocalizations.

Infants' perceptual sensitivity to questions was proposed to generate observable differences in infant vocal responses to questions and declaratives in maternal speech. Infants may

vocalize more in response to questions if the rising pitch contour of questions is recognized as being a prompt for a response. In this way, questions may provide a channel through which infants begin to learn about the question-answer exchange as an important structural element of adult conversation.

By studying moment-to-moment vocal exchanges, we observed how contingent vocal behaviour emerges from the close social proximity between mother and infant. This close emotional bond is the foundation for language development. Infants' first attempts to give vocal responses in a communicative way are reinforced by immediate feedback from their mothers. Continual attempts to elicit infant vocal responses are embedded in mothers' responsiveness. Mothers are inherently driven to communicate with their infants and infants thrive emotionally and socially on their mothers' efforts. Infants reciprocate their mothers' efforts to communicate as they learn how their own behaviours can be shaped to have intent.

Chapter 2

Method

2.1 Participants

Participants included mothers and their infants living in Winnipeg, Manitoba and surrounding area. Two groups of mother-infant dyads were recruited for this study based on infant ages of 10- and 14-months. Infants in the 10-month-old group ranged in age from 288–322 days ($M = 303$ days) and infants in the 14-month-old group were 412–447 days old ($M = 427$ days). There were 9 male infants and 9 female infants in each age group, which yielded a total of 36 mother-infant dyads. Conditions of participation specified that English was the primary language spoken in the homes of mothers and infants. Participants were ineligible if the infant or mother was hard of hearing or deaf, had significant cognitive deficits or notable language impairment. No other prerequisites existed for the study. Participants were not excluded based on socioeconomic factors, cultural background, marital status or number of immediate family members.

The recordings from six mother-infant dyads contained unusable data. Two of these recordings included infants who vocalized rarely or not at all. These recordings were coded, but not analyzed, before the decision was made to exclude them. 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. These recordings were not coded. One recording contained mother's speech that was quiet to the point of being largely inaudible. The decision to exclude this recording was made after partial coding. One recording was discarded due to experimenter error that involved placement in the wrong condition. The recording was not coded for analysis.

2.2 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). LENA was designed to capture the amount of speech produced by caregivers and the amount of vocalization by an infant or child. It performs a number of sophisticated analyses of acoustic properties of the speech in order to provide estimates of these and other characteristics of the child's language environment. For this study, the LENA system was primarily used to obtain high-quality recordings. 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. A 5-minute period is considered an adequate vocal sample (Breskin & Jaffe, 1970). 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 toys (one set for the first part and a different set for the second part). These toys were selected because they are commonly found in homes and daycares and, therefore, likely familiar to infants from previous experience. Toy set A included a rubber orange fish bath toy, a set of plastic stacking rings, a green toy car, a tambourine and a stuffed lady bug doll. Toy set B included a set of plastic keys, a set of 8 small wooden blocks, a plastic pig figure and a yellow rubber ball.

In part 1, mothers were instructed to ask questions to their infants related to the set of toys provided or about what they were seeing or doing. These questions included both yes/no questions and wh-questions. 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 part 2, mothers were instructed to avoid asking questions and were instead asked use statements and descriptions (i.e., declaratives). All other instructions remained the same.

Every mother-infant dyad completed part 1 and part 2 of the experiment. Dyads were randomly assigned to complete part 1 first and part 2 second or the reverse. Any effect of condition was therefore independent of condition order. The toy set participants received first was also randomized. Altogether, there were 4 possible combinations of condition and toy set (i.e., part 1 with toy set A/part 2 with toy set B, part 1 with toy set B/part 2 with toy set A, part 2 with toy set A/part 1 with toy set B and part 2 with toy set B/ part 1 with toy set A). This design minimizes a possible influence of condition order, toy set order or an interaction between the two.

For the duration of the study, the experimenter remained outside the room and observed through a one-way window. It was important that mother-infant dyads were alone in the study room to avoid distraction and influence of a third party.

2.3   Data analysis

Subsequent to data collection, mother and infant vocalizations were coded and analyzed. 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. Vegetative 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 utterance type (question or declarative, for mothers only). Vocalization boundaries were determined via careful visual inspection

of spectrogram representations of the audio recordings. Boundaries were confirmed by listening to each segment individually.

Vocalizations were separated into distinct utterances within a speaker when they included a 750 millisecond pause or greater. Pauses between speakers during mother-infant social interactions was previously found to be 660 milliseconds on average (Beebe, Alson, Jaffe, Feldstein, & Crown, 1988). Intra-speaker pauses were found by Beebe et al. (1988) to be 590 milliseconds on average. Listening judgments confirmed that a 750 millisecond pause was sufficiently long to mark a clear breath or break in a vocalization. Several files were initially coded using a 1 second pause, but this method was terminated in favor of a shorter pause length. A longer pause lead to notable inclusion of silence as vocalization time. Therefore, the previous files were recoded. A shorter pause ensured that vocalization boundaries were more true to actual vocalization time.

The 750 millisecond 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. When vocalizations by mother and infant overlapped, utterances were coded in their full form to the extent that they were discernible. The utterance of the speaker who began first was coded before that of the overlapping speaker. This preserved sequential order at least in terms of voice onset.

Basic analyses were conducted to provide information about frequency and duration of vocalizations, utterance type and the ability of mothers to abide by the instructions given. The randomization procedure described above was evaluated to reveal any effects of global condition related to maternal speech type and to the toy set provided. A brief description for each analysis is given below.

2.3.1   Measurement of global effects

1. Frequency of questions and declaratives in maternal speech

Frequency of each utterance type was calculated as a proportion of the total number of maternal utterances.

2. Effect of condition on vocalization frequency

The frequency with which mother and infant vocal vocalizations occurred within question and declarative conditions was examined. Raw data was collected as the total utterance count by each speaker for each condition. Utterance counts were then translated into proportions of the total number of utterances across conditions. The proportion of responses occurring in the question condition was then compared with the proportion of responses occurring in the declarative condition. These proportions were calculated for both mother and infant vocalizations and compared across variables of infant age and gender.

3. Effect of condition on vocalization duration

Vocalization duration was measured for both mother and infant utterances and reported as mean values for each condition.

4. Instruction accuracy

Instruction accuracy was expressed as the percent correct (i.e., the number of questions divided by the total number of utterances in the question condition and the number of declaratives divided by the total number of utterances in the declarative condition).

2.3.2   *Measurement of local effects*

In-depth analyses were necessary to isolate the immediate effects that questions and declaratives had on infants' vocalizations given that these utterances were not confined completely to their corresponding conditions. Furthermore, the effect of maternal utterances on subsequent mother or infant vocalizations was considered without regard for the condition in

which they occurred.

1. Infant responses

   The infant vocalizations that directly followed questions and declaratives were assessed to determine possible differences in infant vocal response to maternal utterance type. Raw measures of frequency and duration were reported for infant vocalizations that followed each utterance type. Subsequent analyses were based on the proportion of total infant responses occurring after questions and declaratives.

   Infant responses occurring within 2 seconds were included for analysis and defined as contingent responses. A 2-second margin was chosen after a thorough review of the literature related to mother-infant contingency. Various opinions have been expressed concerning how long a response remains meaningful after a signal. Some authors have shown that latencies of 3 seconds inhibit infants' ability to form associations between initial events and subsequent ones (Millar, 1972; Ramey & Ourth, 1971). Numerous others found that most infant responses occurred within 1 second of a signal and no more than 2 seconds after (Gros-Louis, West, Goldstein, & King, 2006; Keller, Lohaus, Volker, Cappenberg, & Chasiotis, 1999; Masataka, 1993; Schaffer, 1977). Van Egeren, Barratt, and Roach (2001) found that infant responses within 1 second were no greater than chance, whereas after 2 seconds, the likelihood of a response increased dramatically. Van Egeren et al. (2001) concluded the vast majority of responses were found to occur in the first 2 seconds and nearly all within 3 seconds. Based on the above findings, a 2-second margin was deemed appropriate.

2. Maternal responses

   A similar analysis to the above was conducted for maternal utterances that followed infant vocalizations. The proportion of contingent maternal responses that were questions was compared to the proportion that were declaratives.

3. Mothers' responses to their own questions

   Based on the same definition of contingency, speech patterns that involved contingencies of maternal vocalizations were identified. It was of particular interest whether mothers responded to their own questions.

4. Question type

   Questions in maternal speech were classified as yes/no questions or wh-questions. Relations between question type and infant response were examined in detail.

5. Inter-utterance lag time

   Response time was measured for infant vocalizations that followed maternal utterances, for maternal utterances that followed infant vocalizations and for maternal utterances that occurred in succession.

2.3.3 Pitch Analysis

A sophisticated series of analyses was performed to quantify the pitch characteristics of questions and declaratives. Pitch information was processed using custom scripts in PRAAT (Boersma & Weenink, 2013). At a primary level, the minimum, maximum and mean pitch values were calculated for contingent mother-infant utterances. The degree to which mothers and infants matched on these measures of pitch was established. Utterances were further characterized by rising or falling pitch contours. The pitch contour shapes of adjacent mother-infant utterances were compared.

Chapter 3

Results

3.1 Global effects

3.1.1 Amount of speech relative to condition

Mothers spoke significantly more overall in the question condition in comparison to the declarative condition. This was based on the proportion of total maternal utterances that occurred in each condition [$F(1,34) = 41.961, p < .0001$]; refer to Figure 3.1. This effect was found for both mothers of 10- and 14-month-olds. Mothers spoke more in the question condition, but their utterances were not longer. Utterance duration was on average comparable between question and declarative conditions [$F(1,34) = 0.588, p = .45$] regardless of infant age group; see Figure 3.3. The amount of maternal vocalization was therefore driven by utterance frequency rather than by utterance duration.

Contrary to the central hypothesis, infant vocalizations were similarly distributed throughout the question and declarative conditions [$F(1,34) = 1.463, p = .24$]. However, infants did vocalize slightly more in the declarative condition as shown in Figure 3.2. Infant vocalizations across conditions were nearly identical with respect to duration [$F(1,34) = .001, p = .98$] as shown in Figure 3.3. Maternal utterances were on average much longer than infant vocalizations when collapsed across conditions [$F(1,34) = 53.914, p < .0001$]. This difference is illustrated in Figure 3.4. There was no effect of age on the above measures.

3.1.2 Frequency of questions and declaratives

On average, 41.7% of the total number of maternal utterances were questions and the other 58.3% were declaratives; see Figure 3.5. These proportions were significantly different from that which was expected by chance alone [$z = 2.55, p < .01$]. This effect was consistent

Mothers' Vocalization Across Conditions
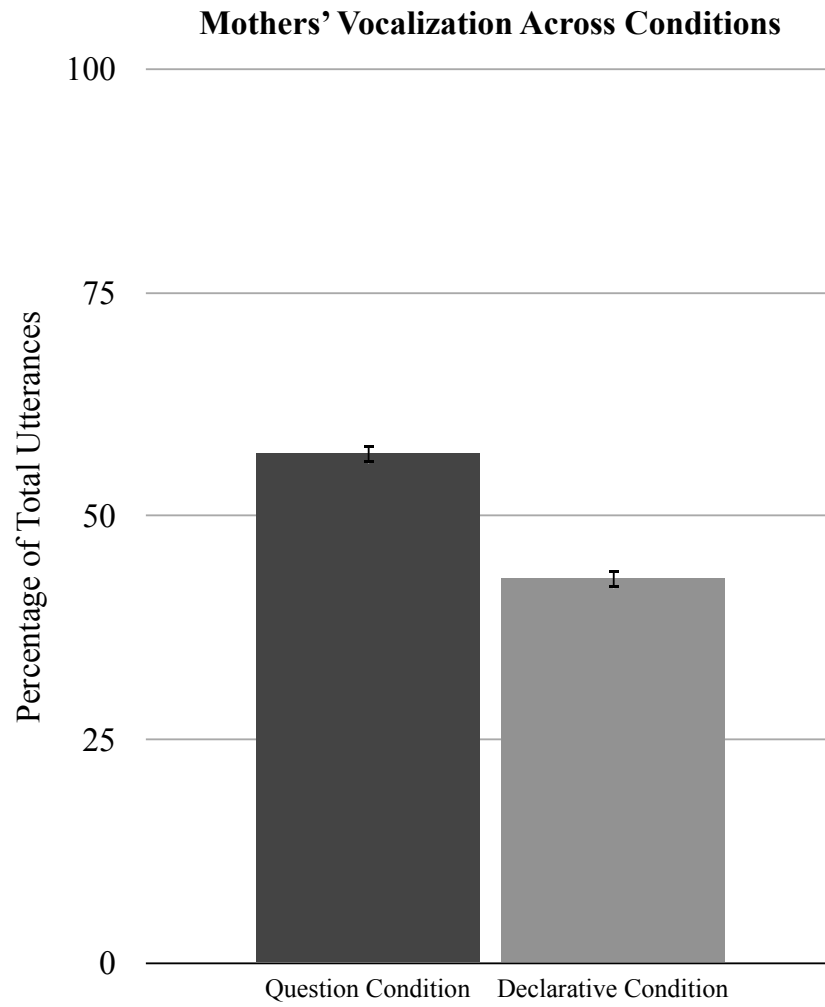
Figure 3.1: Proportion of the total number of maternal utterances that occurred in the question and declarative conditions
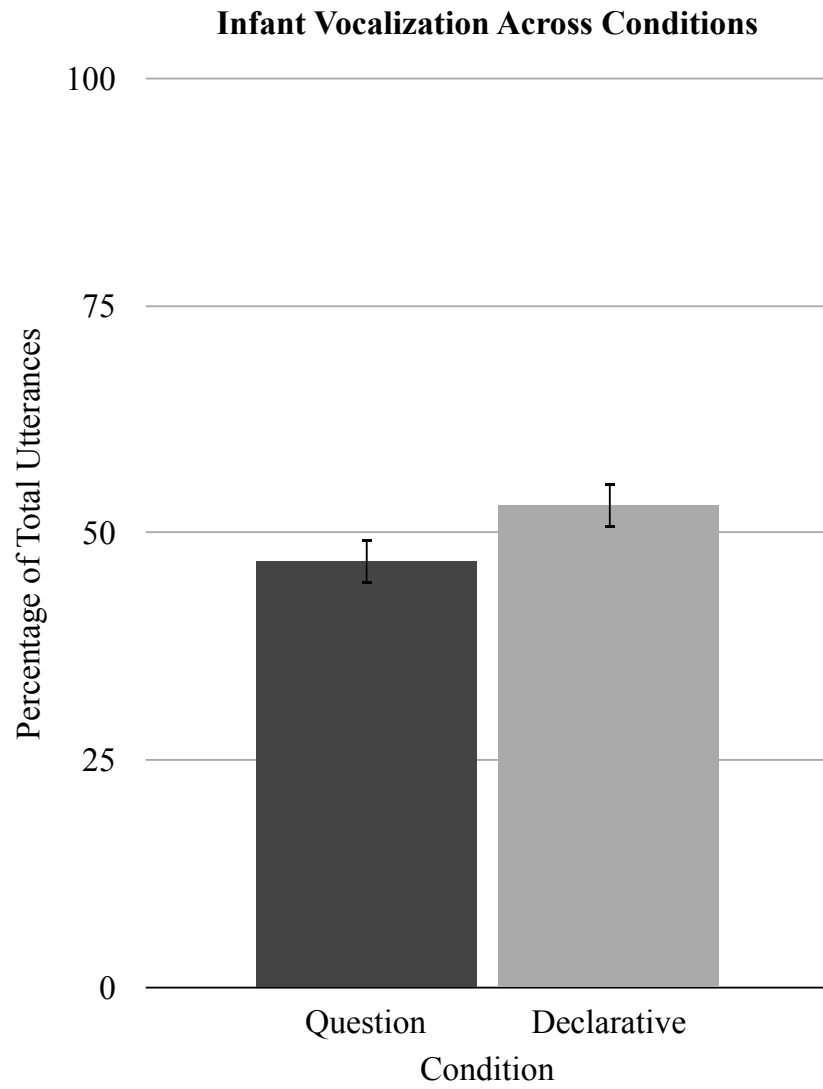
Figure 3.2: Proportion of the total number of infant vocalizations that occurred in the question and declarative conditions
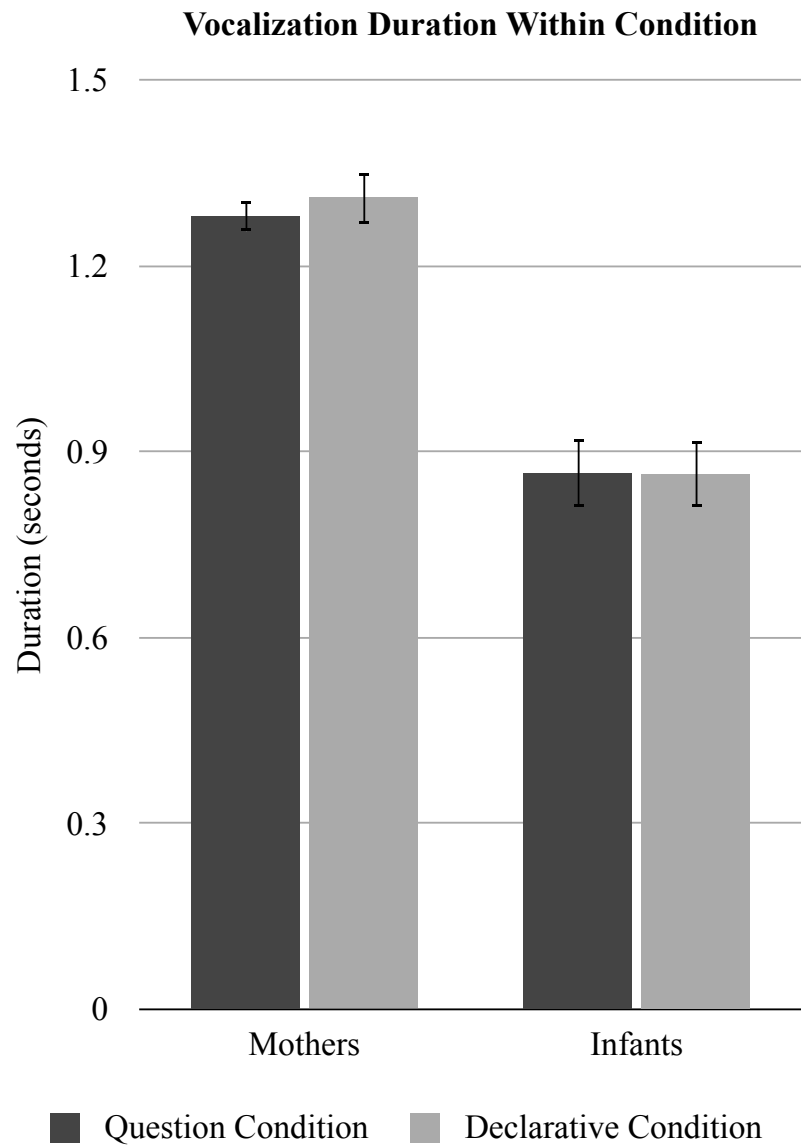
Figure 3.3: Average duration of mother and infant vocalizations within question and declarative conditions

Vocalization Duration Collapsed Across Conditions
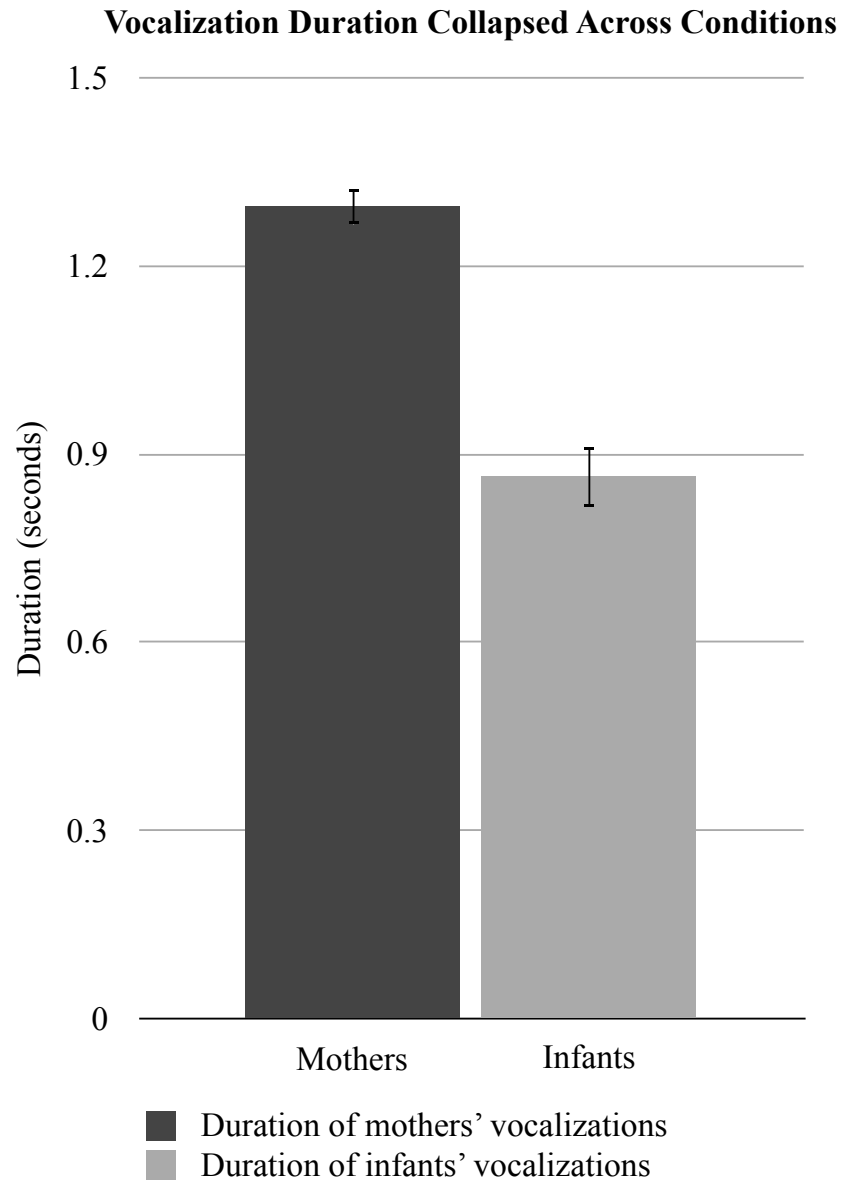
Figure 3.4: Length of mother and infant vocalizations collapsed across conditions

between mothers of 10-month-old and 14-month-old infants. 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 (69.2%) and fewer were wh-questions (30.8%). These percentages diverged by a significant amount from 50% [$z = 3.859, p < .0001$]. Refer to Figure 3.6 for an illustration. 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.

Gender differences

Male and female infants were comparable on measures of vocalization frequency in terms of the raw number of vocalizations. On average, there were 81 vocalizations per session by female infants and 78 by male infants. This difference was non-significant. The length of vocalizations by male and female infants was also similar. Vocalizations were on average 0.88 and 0.85 seconds long by male and female infants, respectively.

There were limited sex differences concerning the speech of mothers with infant sons and mothers with infant daughters. There was no difference in the quantity of speech, as a measure of total utterances, by mothers to 10-month-old male and 10-month-old female infants. However, mothers of 14-month-old infant boys spoke more overall than mothers of same aged infant girls. This difference was marginally significant [$t(17) = 1.962, p = .06$], which is shown in Figure 3.7.

3.1.3 Instruction Accuracy

The ability of mothers to follow instructions perfectly was constrained by their entrained way of speaking. Questions were inevitably interspersed throughout the declarative condition and declaratives throughout the question condition. Nevertheless, mothers were adequate

Relative Frequency of Questions and Declaratives
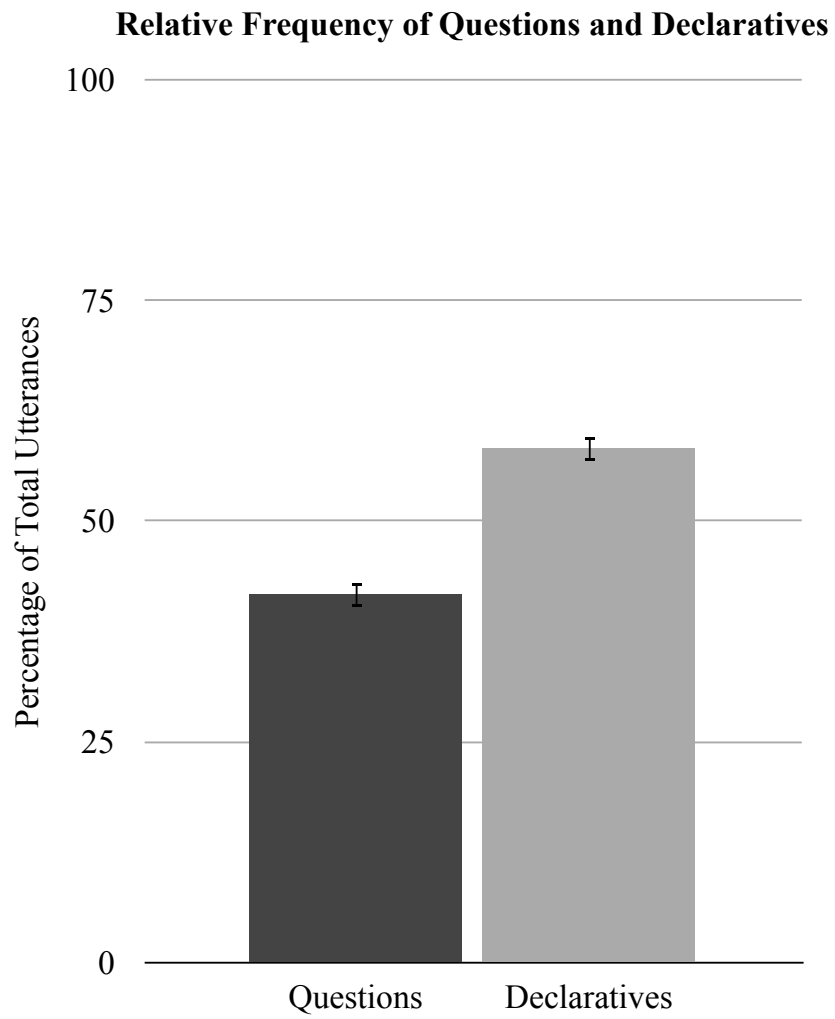
Figure 3.5: Proportion of the total number of maternal utterances that were questions and declaratives

Maternal Question Types
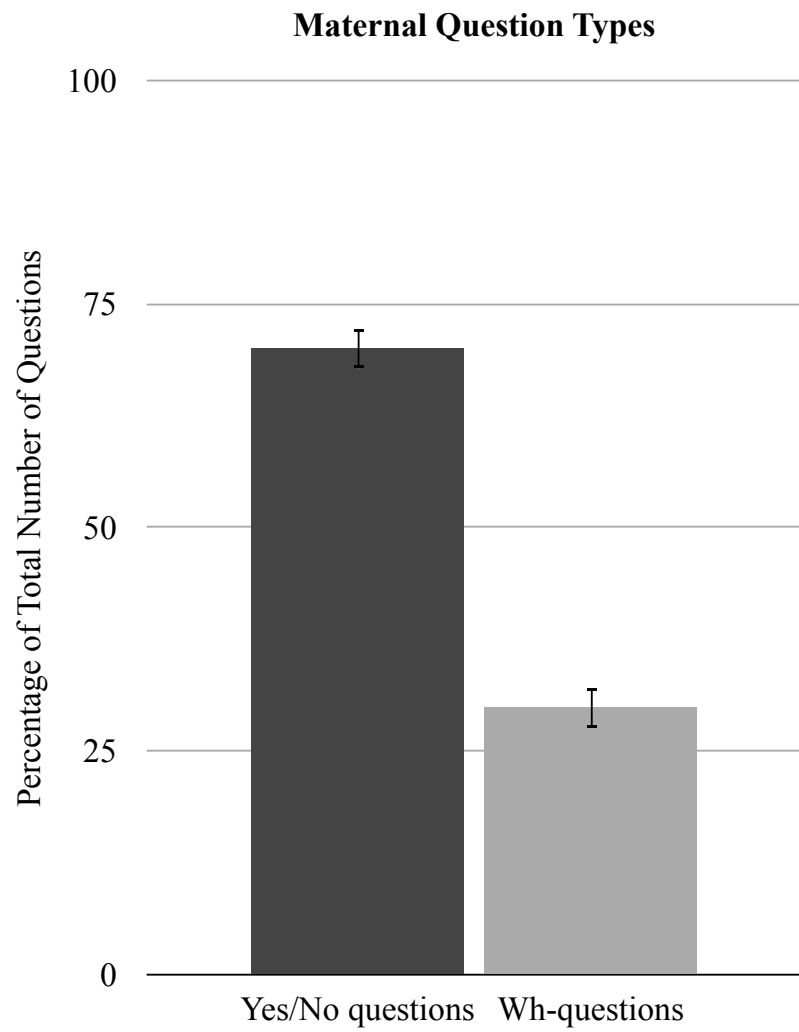
Figure 3.6: Proportion of the total number of questions that were yes/no questions and wh-questions

Maternal Speech as a Function of Gender
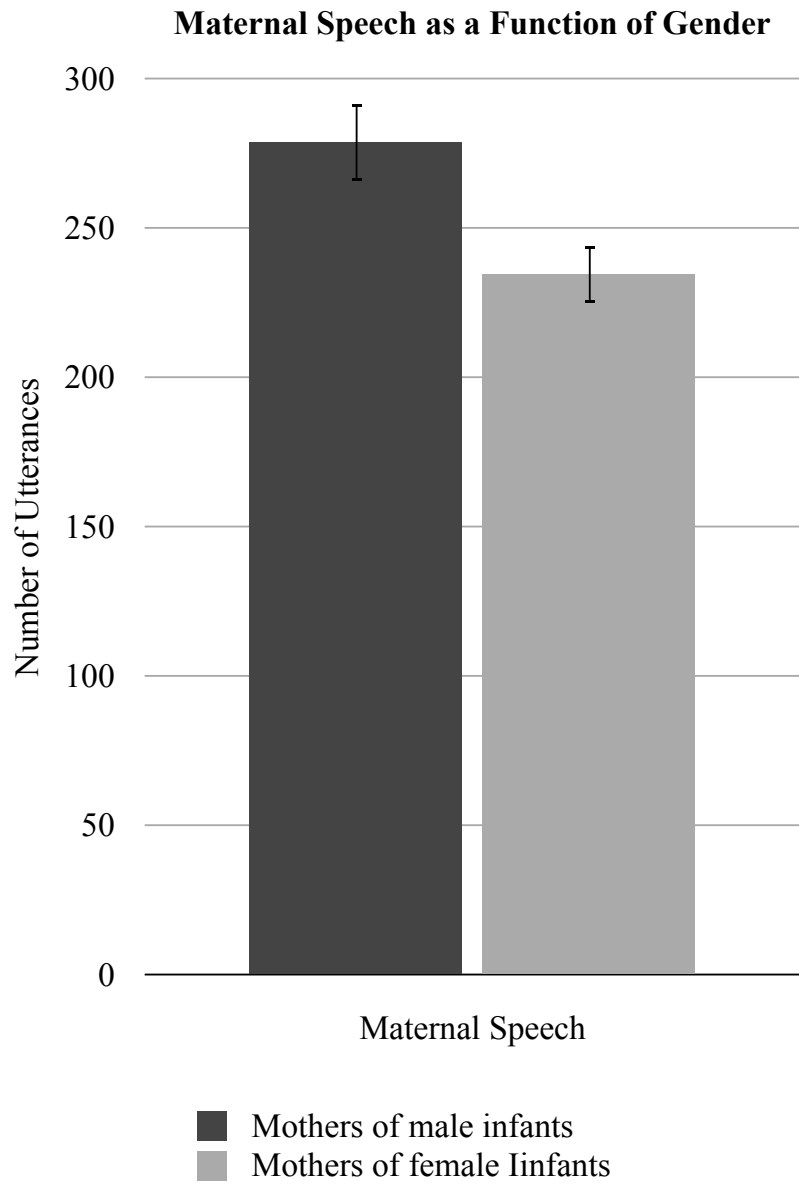
Figure 3.7: Raw number of utterances per session spoken by mothers of male and female infants averaged across participants

in following study directions by limiting their speech to a particular utterance type. Their accuracy was indexed by the percentage of total utterances that corresponded correctly to a question context (62.5%) and to a declarative context (85.9%). Mothers were more accurate in following experiment instructions for the declarative condition as compared to the question condition [$F(1,34) = 87.604, p < .0001$]. This was the case for mothers of 10-month-olds and 14-month-olds [$F(1,34) = 2.329, p = .14$].

3.1.4 Order of condition

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). None of the four possible combinations of condition and toy set revealed a different pattern of results.

3.2 Local effects

3.2.1 Proportion of contingent responses

The following analyses of local effects included only the subset of data that met contingency requirements. Consecutive utterances were contingent when they occurred within 2 seconds of each other. Utterances that fell outside of these parameters were excluded, which included approximately 36% of infant utterances. Refer to Figure 3.9 for an illustration of contingent versus non-contingent infant vocalizations. Of maternal utterances, 43% were not contingent on any previous utterance; see Figure 3.10.

Instruction Accuracy Across Conditions
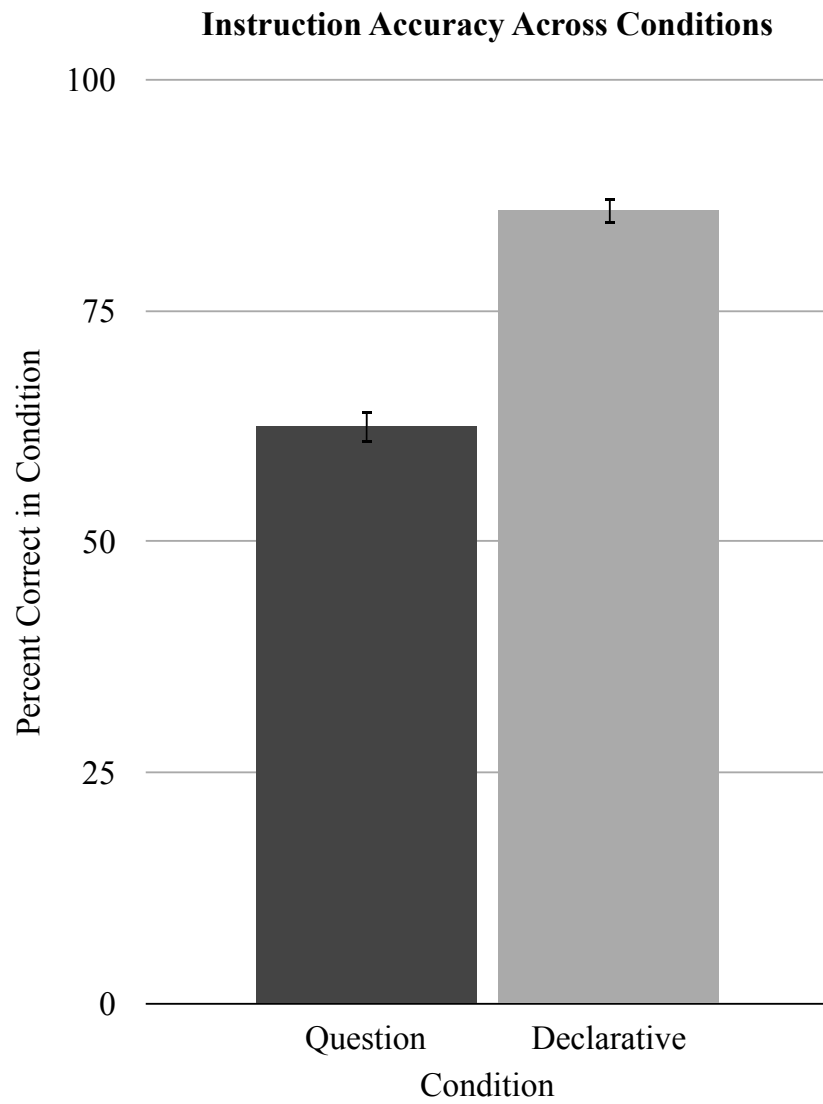
Figure 3.8: Mothers' accuracy in following study instructions shown as the percent correct for each condition

Contingent vs. Non-contingent Infant Responses

- ● Infant Vocalization followed by Maternal Utterance
- ● Infant Vocalization followed by Infant Vocalization
- ● Infant utterance with > 2 seconds silence on either side
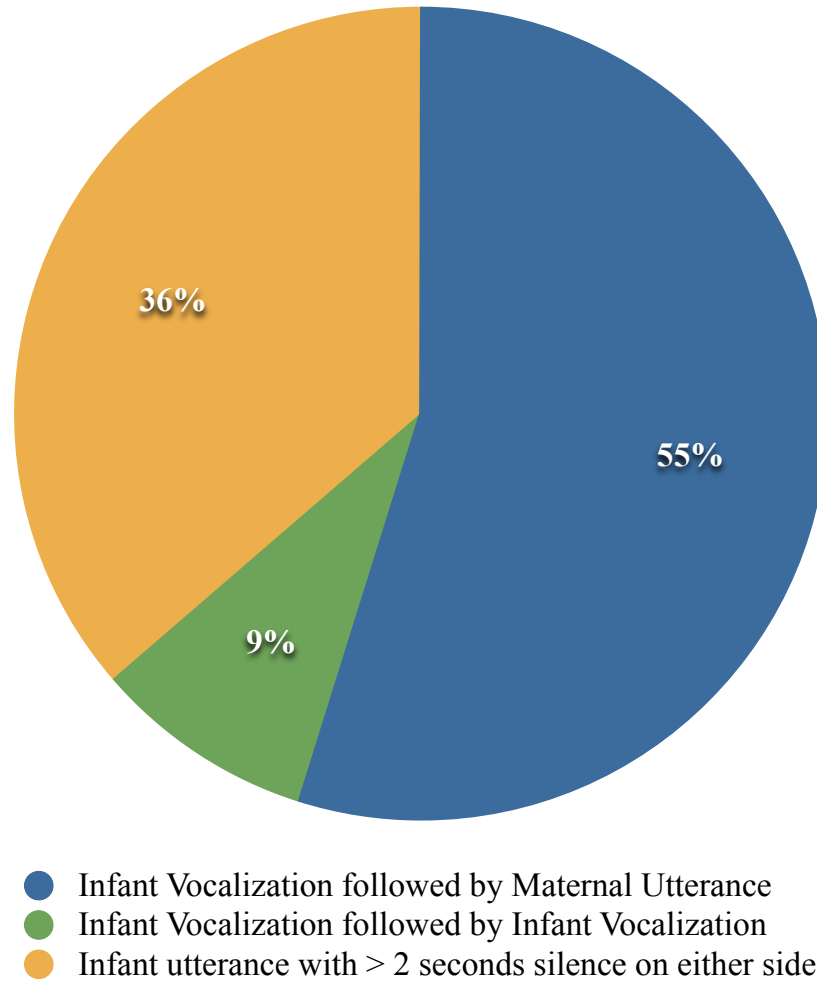
Figure 3.9: Proportion of the total number of infant vocalizations that were contingent on maternal utterances or a subsequent infant vocalization and those that occurred in isolation

Contingent vs. Non-contingent Maternal Utterances

- Maternal Utterance following Infant Vocalization
- Maternal Utterance following Maternal Utterance
- Maternal Utterance with >2 seconds silence on either side
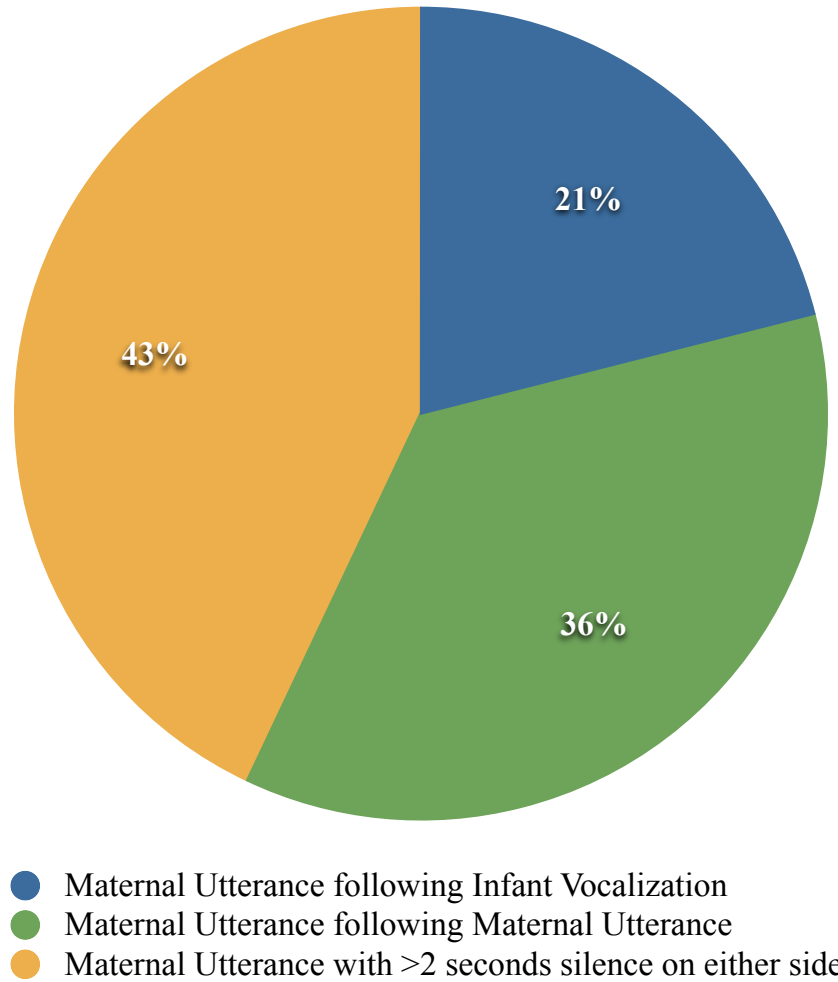
Figure 3.10: Proportion of the total number of maternal utterances that were contingent on infant vocalizations or a subsequent maternal utterances and those that occurred in isolation

3.2.2 Infant responses to questions and declaratives

There was no effect of condition at a global level; therefore, a subsequent analysis was performed to determine whether infant responses to questions and declaratives differed at the utterance level. Infant vocalizations that were contingent upon a previous question or declarative were counted. An infant vocalization was considered to be contingent on the preceding maternal utterance if it occurred within 2 seconds. Of infants' total number of vocalizations, 22.7% and 32.2% followed questions and declaratives, respectively. Although this difference was significant $[F(1,34) = 14.229, p < .001]$, it was not meaningful in the context of how many of each questions and declaratives infants had opportunities to respond to. There were considerably more declaratives spoken by mothers than questions (i.e., 58.3% versus 41.7%). The extent to which mothers used questions and declaratives was proportionally similar to how often infants responded to each utterance type. Therefore, a greater number of infants' vocalizations followed declaratives by chance alone. A more accurate picture was derived from calculating the relative proportions of questions and declaratives responded to by infants. Infants responded to 17.9% of their mothers' questions and 18.3% of their declaratives. Considered this way, infants were equally responsive to questions and declaratives $[F(1,34) = 0.061, p = .81]$. Refer to Figure 3.11.

When infants vocalized following a question, there was no effect of question type (i.e., yes/no question versus wh-question). The proportions of infant vocal responses to yes/no questions and wh-questions were 70.9% and 29.1%, respectively. The frequency with which mothers asked each of these question types reflected nearly identical proportions— 69.2% yes/no questions and 30.8% wh-questions. Accordingly, there was a negligible difference in how often infants responded to each question type. Infants responded to 18.1% of mothers' yes/no questions and to 20.4% of their wh-questions, which was not significantly different $[F(1,24) = 0.736, p = .40]$. Refer to Figure 3.12 for a visual representation.

The duration of infant responses did not vary as a function of maternal utterance type

Infant Vocalization as a Function of Utterance Type
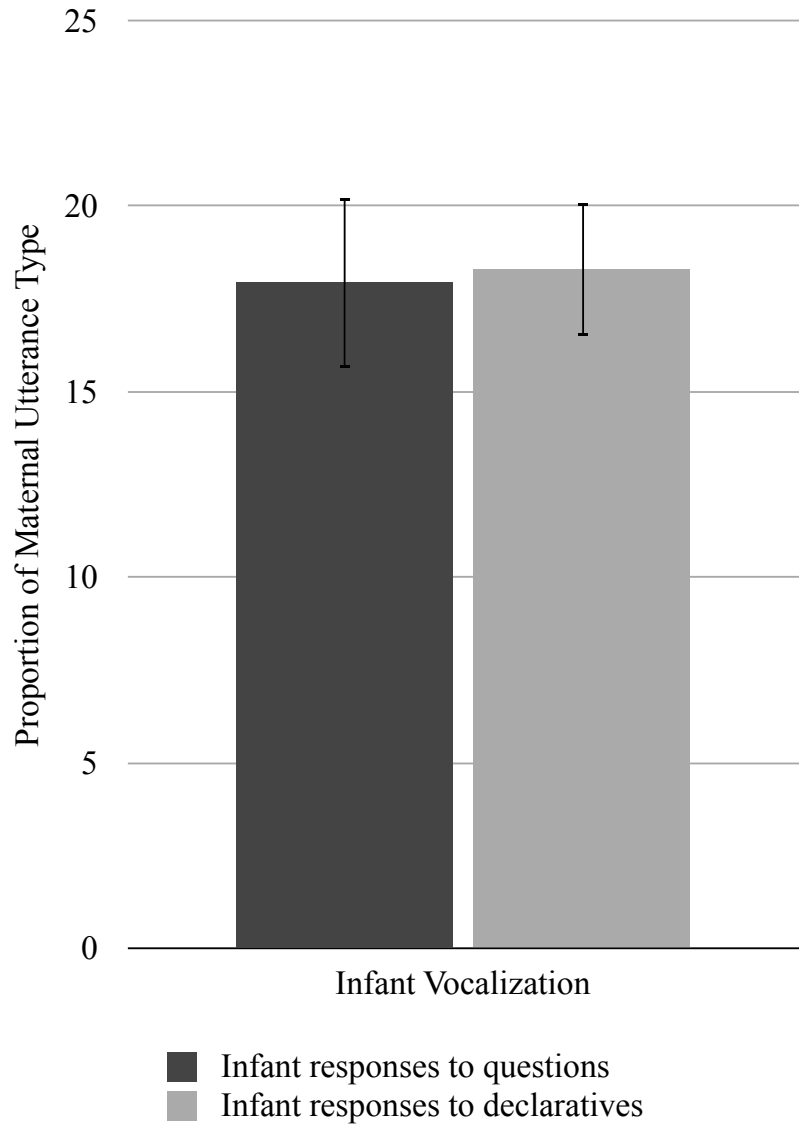
Figure 3.11: Proportion of the total number of infant vocalizations in response to maternal questions and declaratives

Infant Vocalization as a Function of Question Type
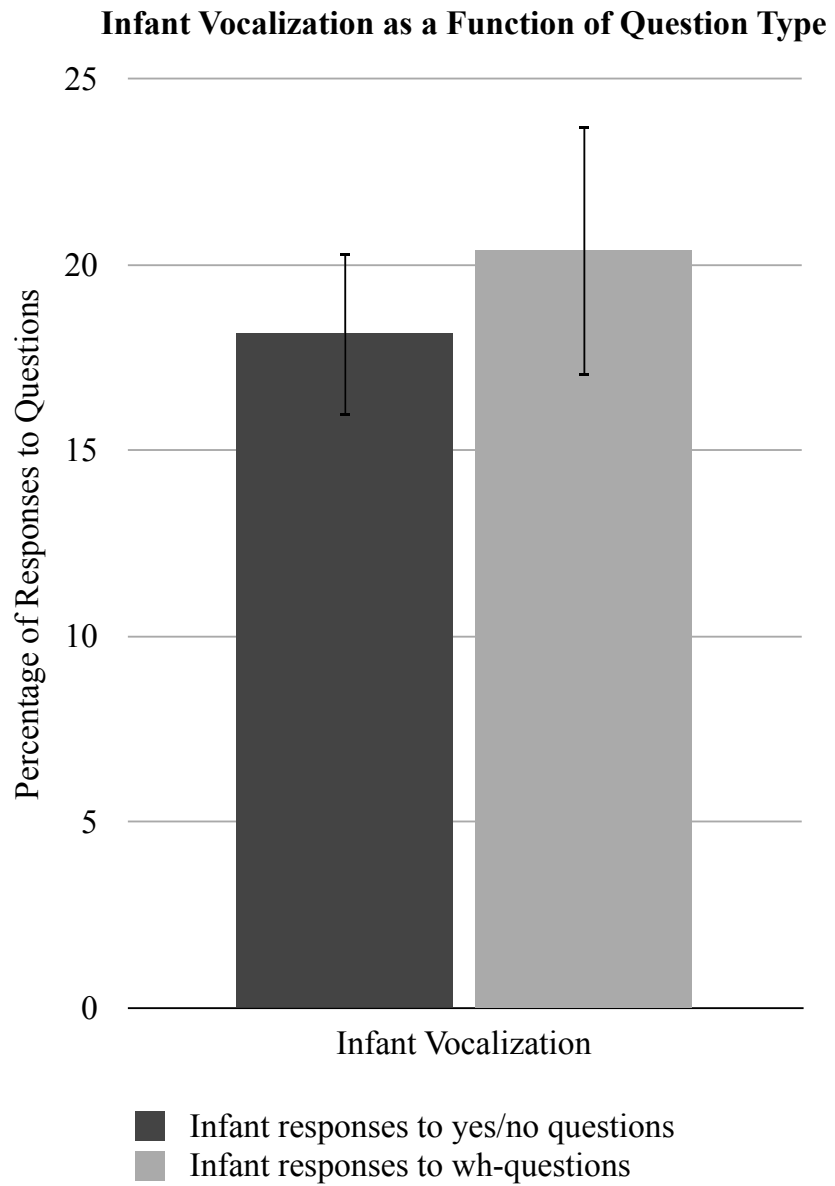
Figure 3.12: Proportion of the total number of questions that were yes/no questions and wh-questions

(i.e., questions or declaratives) nor as a function of question type (i.e., yes/no questions or wh-questions).

3.2.3 Maternal responses to infant vocalizations

A subsequent analysis showed whether mothers responded to their infants' vocalizations more often with questions or declaratives. Maternal utterances that followed infant vocalizations within 2 seconds were included in the analysis. Maternal responses were more often in declarative form rather than expressed as subsequent questions [$F(1,34) = 21.479, p < .0001$]. This effect was comparable between mothers of 10-month-old and 14-month-old infants; refer to Figure 3.13.

3.2.4 Consecutive maternal utterances

Consecutive utterances spoken by mothers were also examined. The act of asking a question was found to influence the type of utterance mothers used next. Within a 2-second margin, mothers followed their own questions with a subsequent question more often than they followed a question with a declarative [$F(1,34) = 5.878, p < .05$]; see Figure 3.14. There was an interaction of maternal utterance type with infant age group [$F(1,34) = 4.957, p < .05$]. Mothers of 10-month-olds were equally likely to follow a question with either utterance type [$t(17) = 0.073, p = .94$], whereas mothers of 14-month-olds were more likely to follow a question with a subsequent question rather than with a declarative [$t(17) = 2.741, p < .05$].

Maternal Responses as a Function of Utterance Type
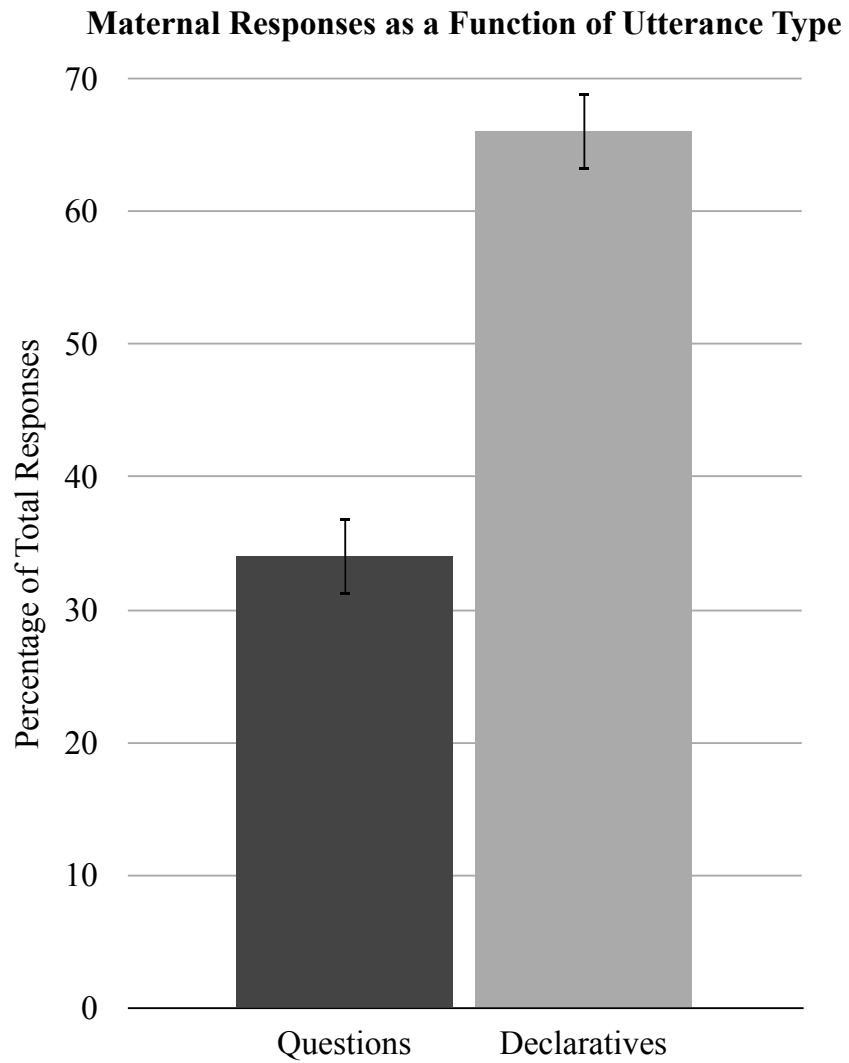
Figure 3.13: Proportion of the total number of maternal utterances that were responses to infant vocalizations in the form of questions and declaratives
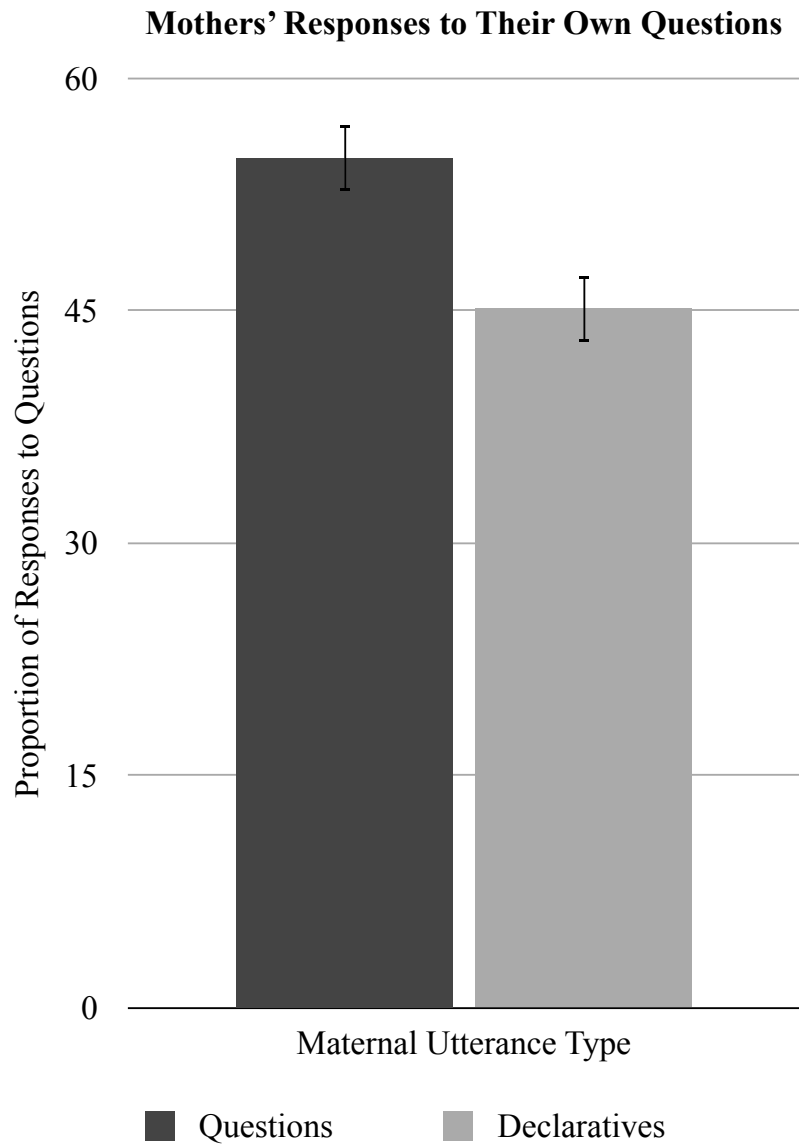
Figure 3.14: Proportion of maternal responses to their own questions in the form of subsequent questions and declaratives

3.3 Vocalization across dimensions of time

3.3.1 Convergence of utterance duration

Correlational statistics were used to assess whether contingent mother and infant vocalizations had similar durations. For each mother and infant, average utterance duration was measured and these values were compared across dyads to yield Pearson coefficients. Correlations were calculated for 10- and 14-month old age groups separately. A moderate negative correlation was found between utterance length by 10-month-olds and their mothers $[r = -.29, p = .24]$. Infants whose vocalizations were shorter on average typically had mothers who spoke in longer utterances. A different pattern emerged for mothers and infants in the older age group for whom a moderate positive relationship was found $[r = .31, p = .21]$. The difference between correlation coefficients approached statistical significance $[z = 1.7, p = .08]$.

3.3.2 Pause duration

A 2 second cut-off was used to determine utterance contingency, although the pause duration between utterances was on average much shorter. When infants responded to their mothers' utterances, they typically did so within 610 milliseconds. Response time was similar among 10-month-old and 14-month-old infants. Mothers took significantly less time to respond to their infants than infants took to respond to their mothers $[F(1, 34) = 6.341, p < .05]$. On average, mothers responded within 490 milliseconds regardless of whether their infant was 10- or 14-months-old.

In order to determine whether mothers might have expected a response following their questions and/or declaratives before they spoke again, the length of time between first and second utterances was measured. When two questions occurred consecutively, mothers waited an average of 1130 milliseconds before asking the second question. When

two declaratives occurred together, mothers waited an average of 1210 milliseconds in between. When consecutive questions occurred, the time between them was shorter than the time between consecutive declaratives $[F(1,34) = 4.124, p < .05]$ as shown in Figure 3.15. However, the mean values differed by less than a tenth of a second, which yielded a relatively small difference in the context of time. Mothers generally waited twice that of the 610 millisecond average infant response time before speaking the second of two consecutive utterances. During this time, an infant vocalization could theoretically occur without interrupting the rhythmic flow of a vocal exchange. There was no effect of infant age on the maternal behaviours outlined above.

3.3.3 Overlapping utterances

The vocalizations by mothers and infants overlapped a small amount of the time. Infants were less likely than mothers to overlap with the other speaker's utterances $[F(1,34) = 11.698, p < .01]$. Approximately 5.6% of infant utterances following maternal utterances overlapped while approximately 9.5% of maternal utterances overlapped the infant utterances preceding them. Refer to Figure 3.16 for a visual comparison.

3.4 Vocalization across dimensions of pitch

The following analyses were performed to disambiguate the pitch contours of maternal utterances and to examine how infants responded to the pitch contours contained in their mothers' speech. Mother and infant vocalizations were included for analysis if they occurred within 2 seconds of one another. Infant responses were measured according to the rising and falling pitch contours of the maternal utterances preceding them. A rise or fall of at least 50 Hz was required to fit the definition of rising or falling pitch contour. Pitch contour was measured from the middle of each utterance to 25 milliseconds before the utterance end

Time Between Consecutive Maternal Utterances
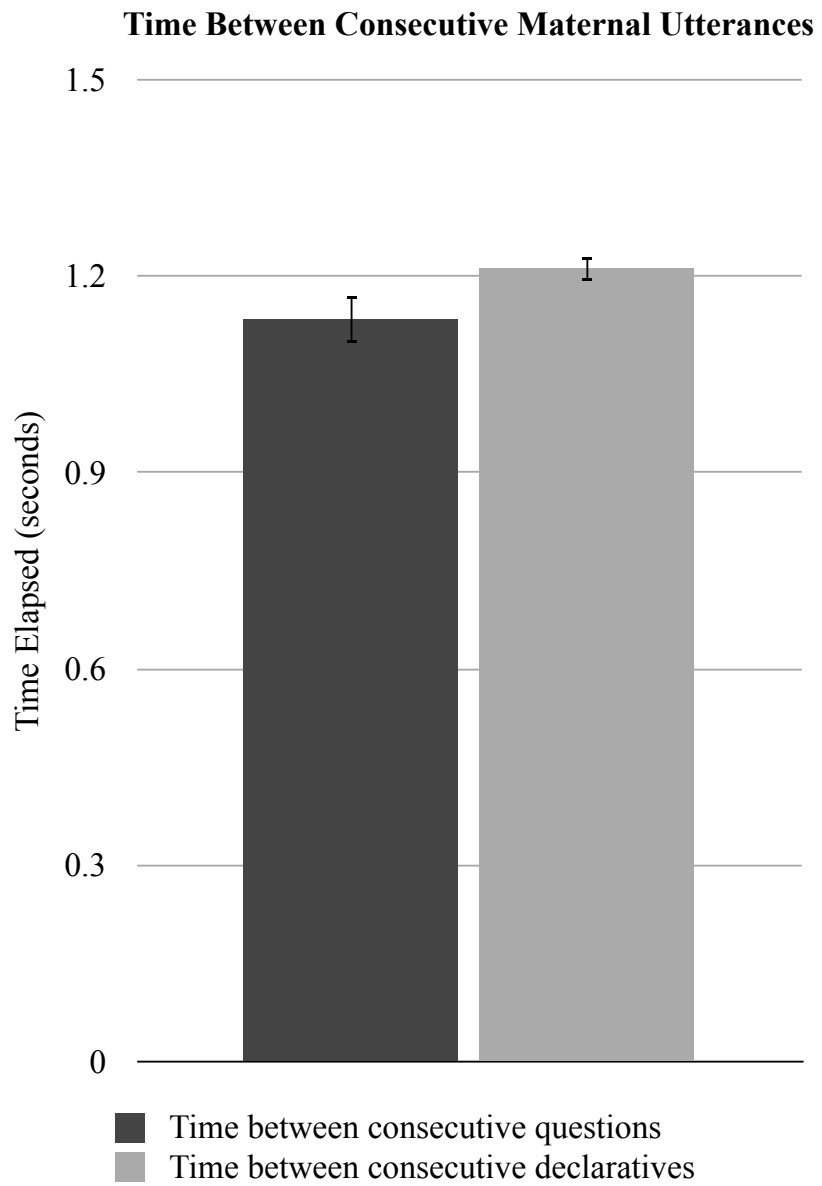
Figure 3.15: The average time between two consecutive questions and two consecutive declaratives

Overlapping Vocal Behaviour
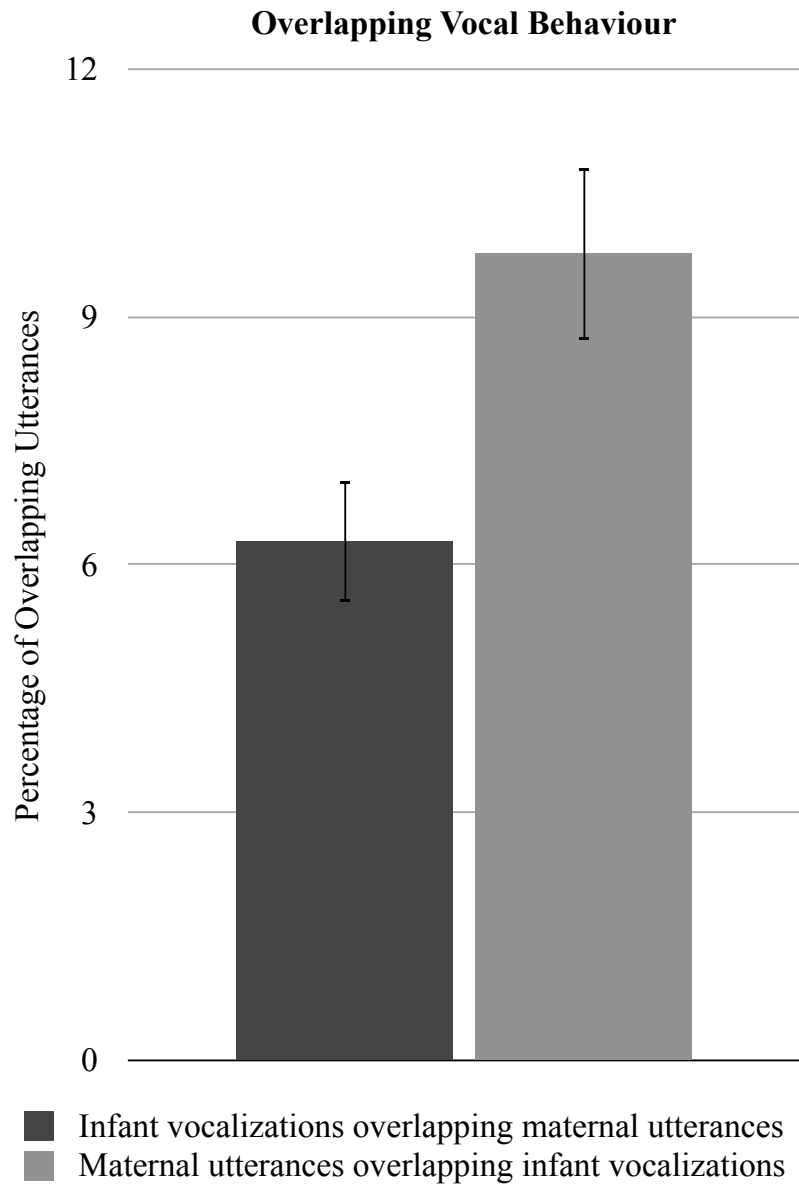
Figure 3.16: Proportion of total infant vocalizations that overlapped onto maternal utterances and the proportion of total maternal utterances that overlapped onto infant vocalizations

boundaries.

Infants responded to questions with rising pitch more often than they responded to questions with falling pitch [$F(1,34) = 30.298, p < .0001$]; see Figure 3.17. Note that 88% of infant responses to questions were accounted for. The remaining 12% included responses to questions that were characterized by neutral pitch contours. Very subtle rising or falling pitch contours and more complex pitch contour shapes were excluded for the purpose of pitch analysis.

Infants responded to declaratives with falling pitch more than they responded to declaratives with rising pitch [$F(1,34) = 35.053, p < .0001$]. This difference is represented in Figure 3.18. The pitch contours of declaratives were less dynamic and therefore more difficult to categorize. Still, 66% of declaratives were identified as having falling or rising pitch contours as shown in Figure 3.18.

There was no reliable evidence that infants matched the pitch contours they heard immediately before vocalizing. Infants responded to the rising pitch of questions with falling pitch slightly more often than they did with rising pitch. However, the difference was non-significant [$F(1,34) = 0.887, p = .35$] as illustrated in Figure 3.19. When questions had falling pitch, the pitch direction of infants' vocal responses was more often falling, which approached statistical significance [$F(1,34) = 1.857, p = .18$]. Refer to Figure 3.20. There was an overall tendency by infants to respond to questions with falling pitch contours regardless of whether the question had rising or falling pitch. The difference between infant responses with rising pitch and falling pitch did not reach statistical significance [$F(1,34) = 1.880, p = .18$]; see Figure 3.21

When declaratives had rising pitch contours, infants' vocalizations were more often characterized by falling pitch contours than by rising pitch contours. The difference approached statistical significance [$F(1,34) = 2.464, p = .13$] as shown in Figure 3.22. When declaratives had falling pitch contours, infants' vocalizations were characterized by falling pitch con-

Infant Responses to Questions with Rising and Falling Pitch
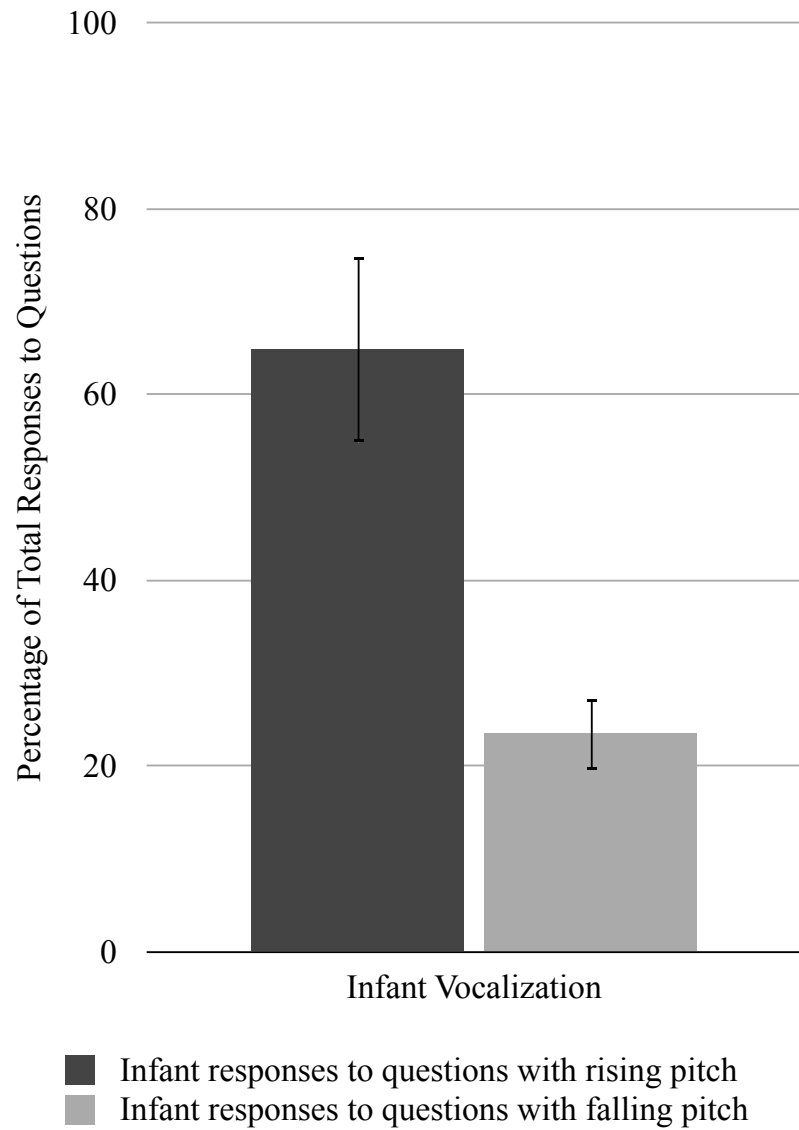
Figure 3.17: Infants responded more often to questions with rising pitch, which was expressed as proportions of the total number of infant responses to questions

Infant Response to Declaratives with Rising and Falling Pitch
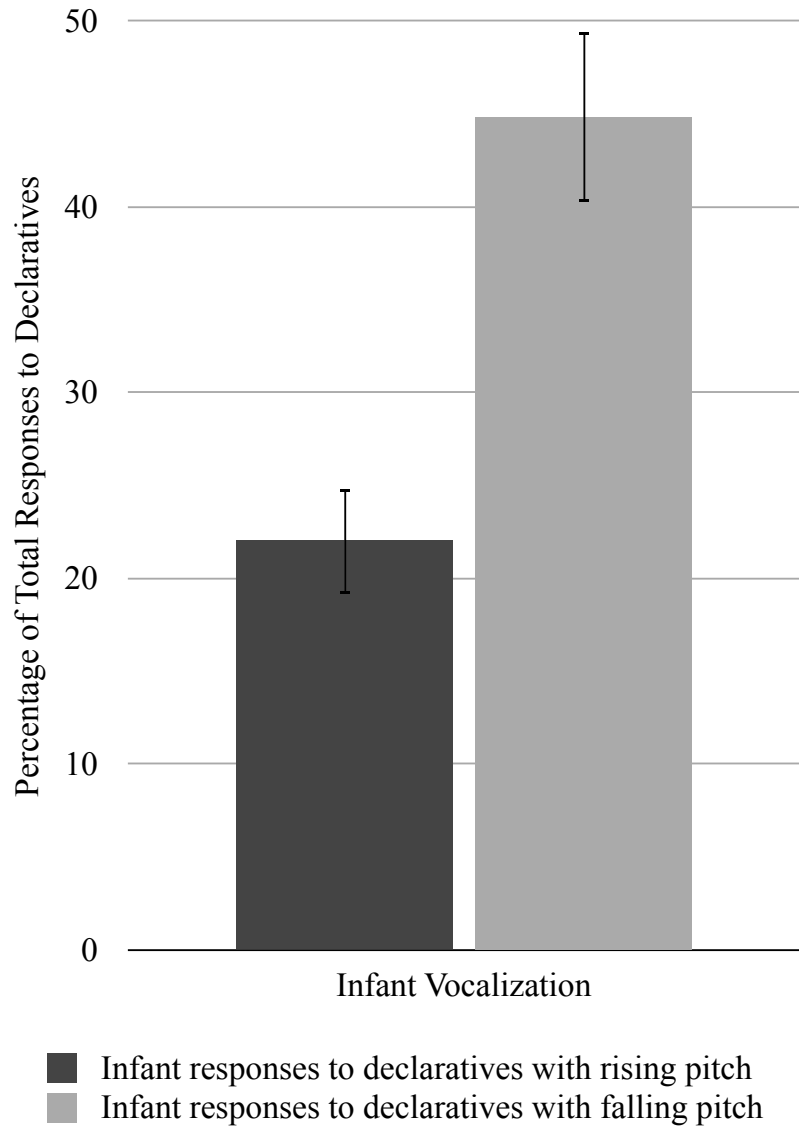
Figure 3.18: Infants responded more often to declaratives with falling pitch, which was expressed as proportions of the total number of infant responses to declaratives

Matching Pitch Contour of Rising Questions
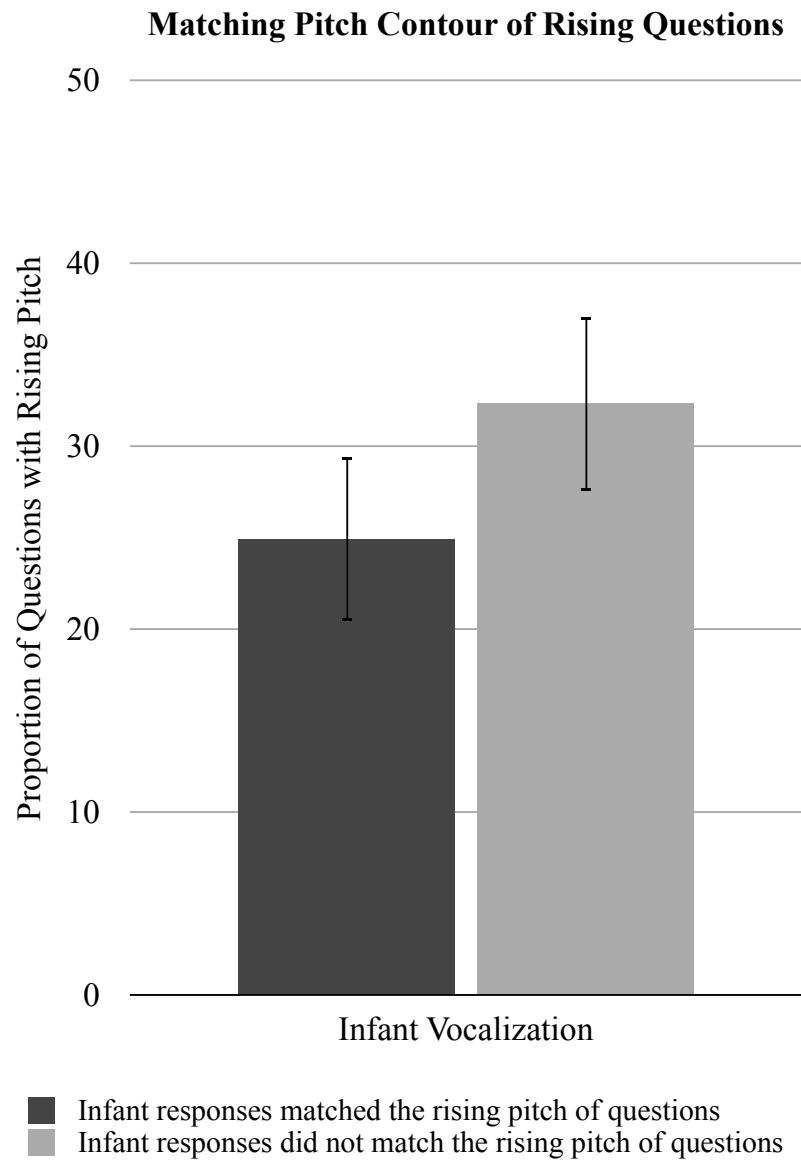
Figure 3.19: Infant vocalizations that were contingent upon questions with rising pitch had unmatched pitch contours more often than matched pitch contours, which was expressed as a proportion of questions with rising pitch

Matching Pitch Contour of Falling Questions

Proportion of Questions with Falling Pitch

Infant Vocalization

■ Infant responses matched the falling pitch of questions
■ Infant responses did not match the falling pitch of questions
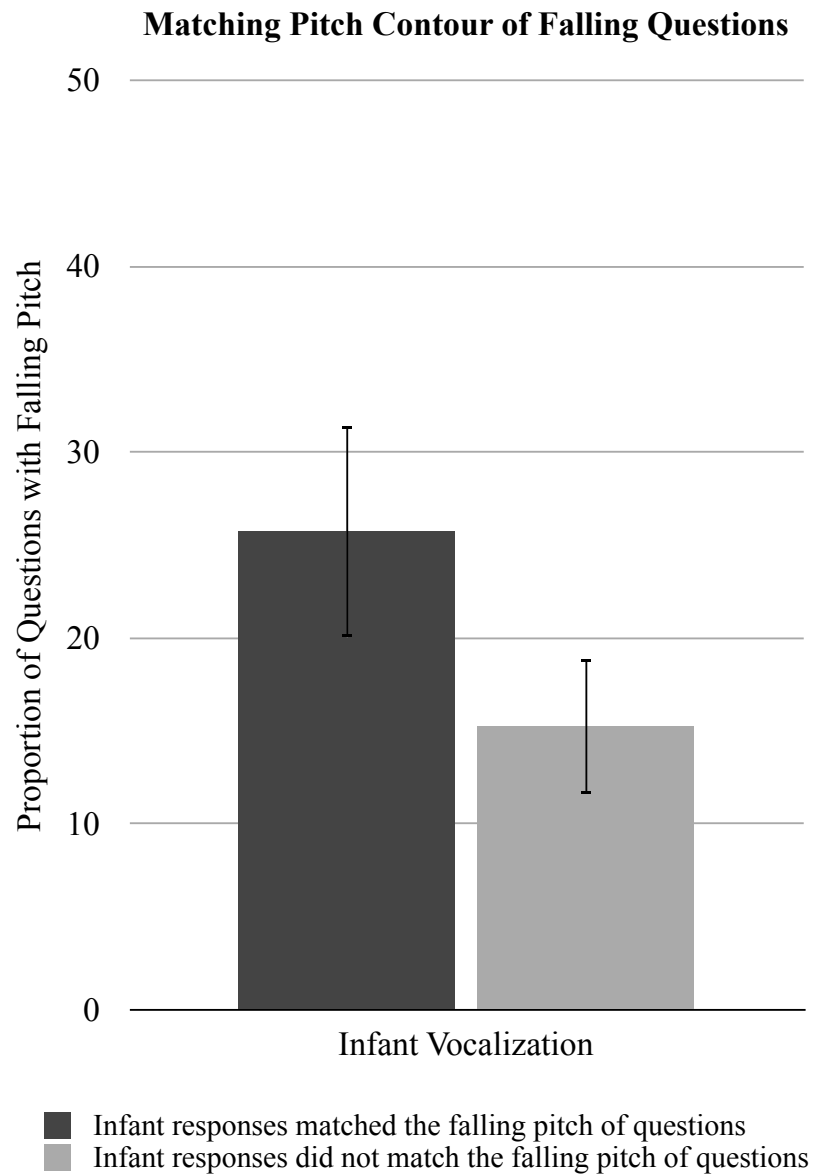
Figure 3.20: Infant vocalizations that were contingent upon questions with falling pitch had matched pitch contours more often than unmatched pitch contours, which was expressed as a proportion of questions with falling pitch

Pitch Contour of Infant Responses to Questions
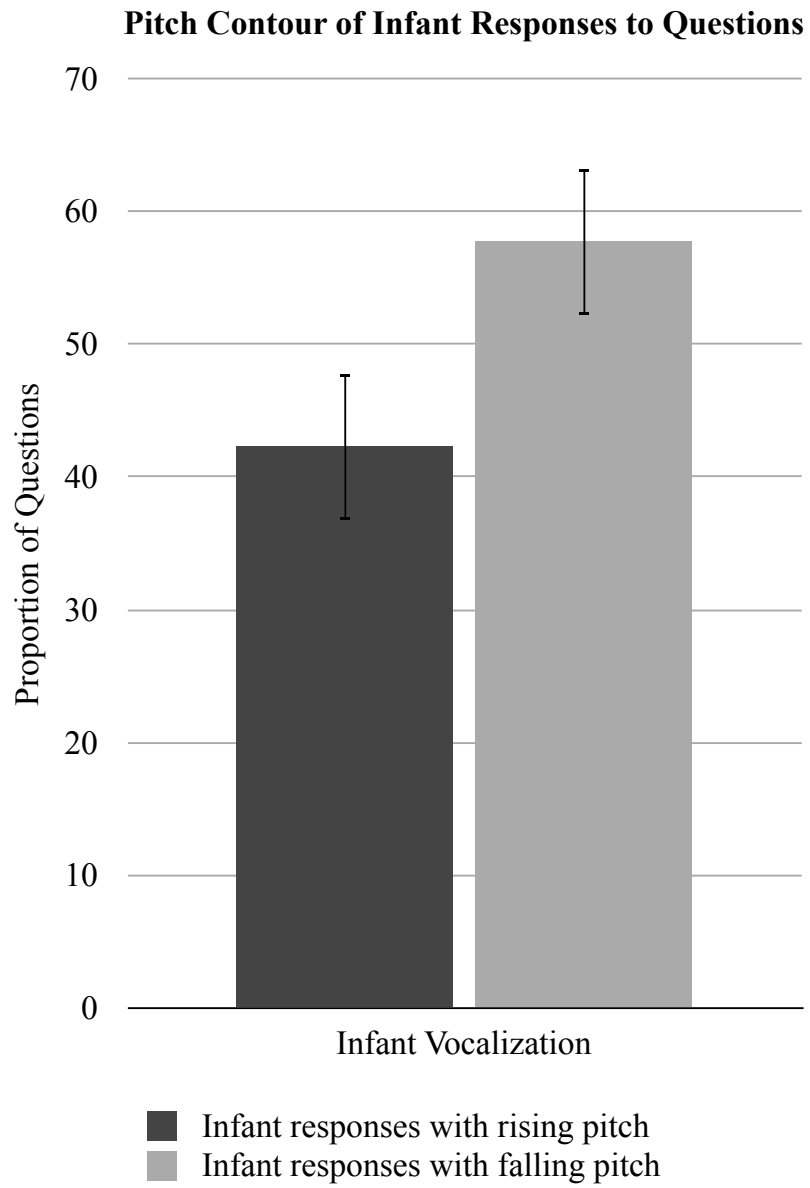
Figure 3.21: Infant vocalizations to questions that were characterized by rising and falling pitch contours

tours considerably more often than by rising pitch contours [$F(1,34) = 17.896, p < .0001$].
See Figure 3.23. Regardless of whether declaratives had rising or falling pitch contour,
infants generally responded with falling pitch contours. The difference between infant
responses with rising and falling pitch was highly significant $F(1,34) = 20.031, p < .0001$],
which is shown in Figure 3.24. This effect was especially strong when infants matched the
falling pitch contour of declaratives.

Fewer infant responses were eligible for inclusion in these analyses because it was
difficult to characterize vocalizations by pitch contour if they were short, not well formed
or quiet. Nevertheless, there was an adequate number of infant vocalizations that could
be accurately described as rising or falling and were therefore included in judgements of
mother-infant pitch contour matching.

3.4.1   Pitch structure of yes/no questions and wh-questions

The vast majority of yes/no questions had either rising or neutral pitch. Yes/no ques-
tions with rising pitch were much more common than those with falling pitch [$F(1,34) =$
138.044, $p < .0001$]. Yes/no questions were more often defined by rising pitch than neutral
pitch [$F(1,34) = 60.775, p < .0001$] and by neutral pitch more often than falling pitch
[$F(1,34) = 16.048, p < .0001$]. Refer to Figure 3.25 for an illustration of how often each
yes/no question pitch subtype occurred.

Wh-questions were most often defined by falling or neutral pitch contours. The num-
ber of wh-questions with falling pitch far exceeded those with rising pitch [$F(1,34) =$
11.358, $p < .01$]. A comparable number of wh-questions had falling or neutral pitch con-
tours [$F(1,34) = 0.003, p = .96$], but neutral pitch contours were much more common
than rising pitch contours [$F(1,34) = 10.620, p < .01$]. Refer to Figure 3.26 for a visual
representation of the above statistical measures.

Rising pitch contours were generally associated with yes/no questions and falling pitch

Matching Pitch Contour of Rising Declaratives
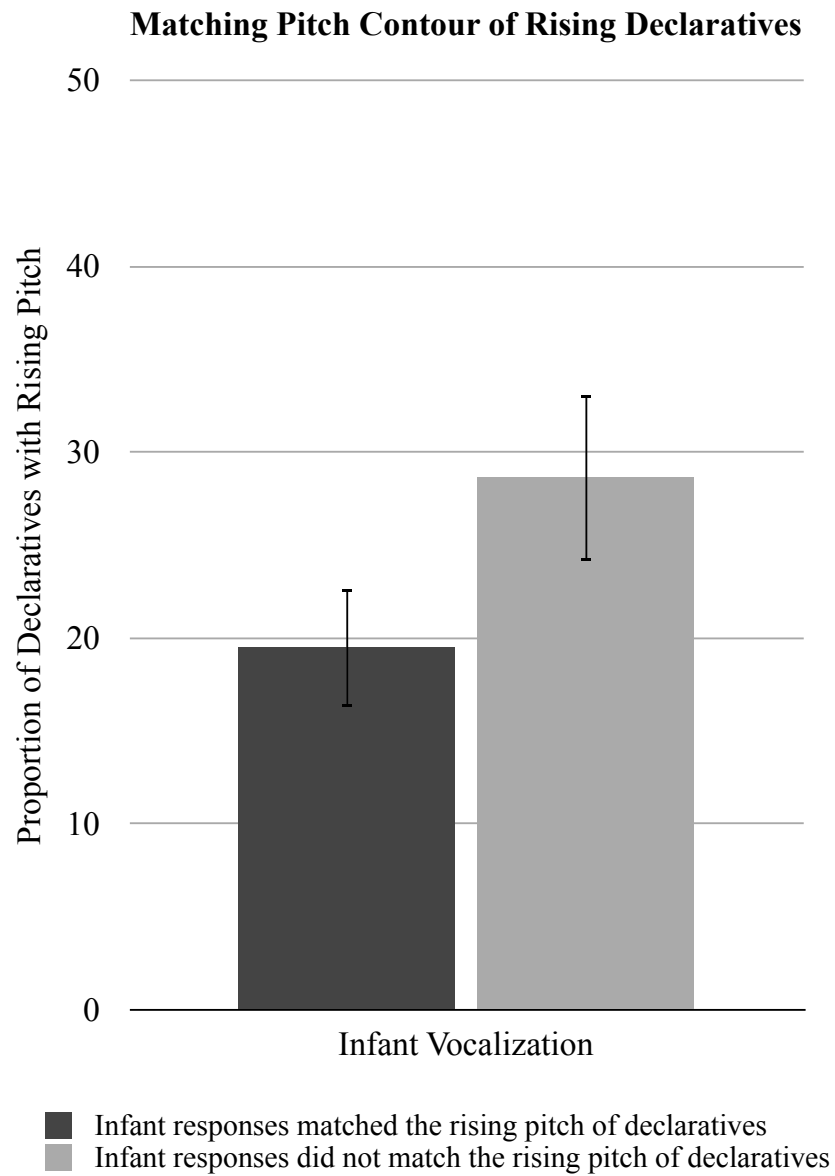
Figure 3.22: Infant vocalizations that were contingent upon declaratives with rising pitch had unmatched pitch contours more often than matched pitch contours, which was expressed as a proportion of declaratives with rising pitch

Matching Pitch Contour of Falling Declaratives
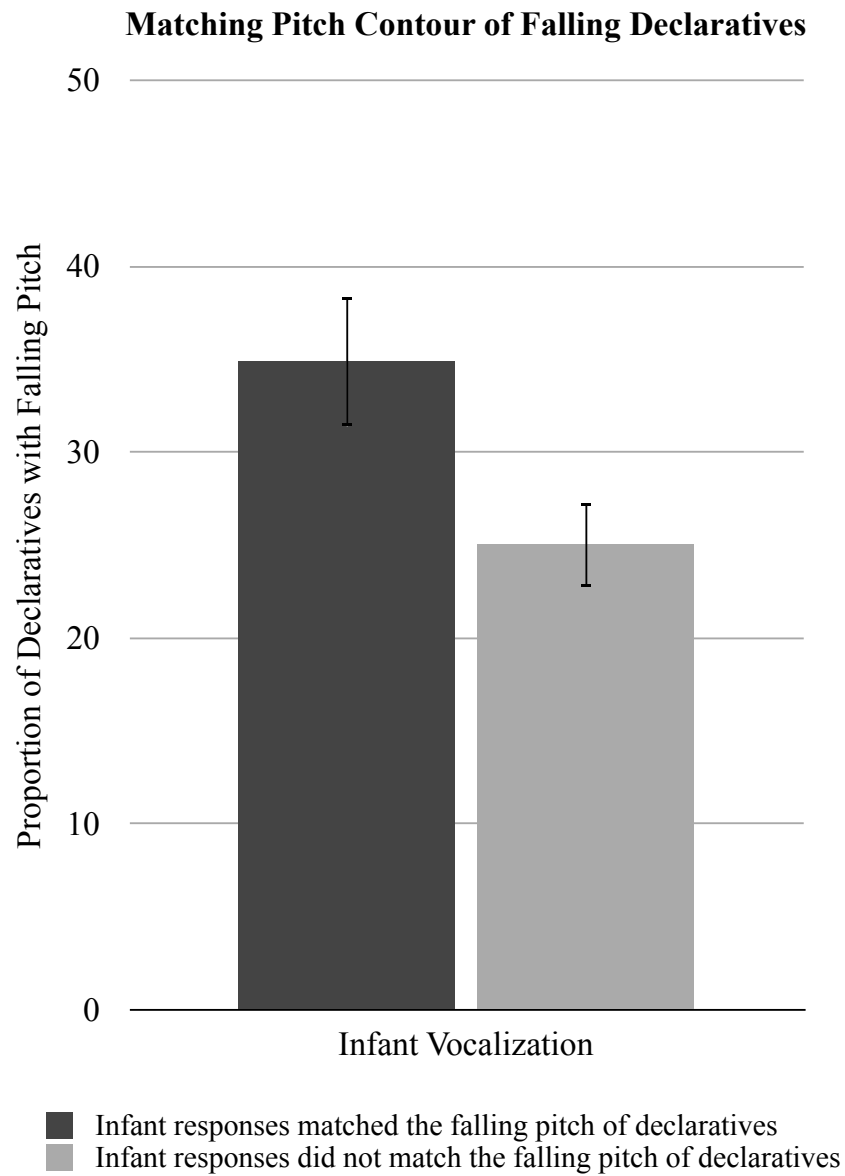
Figure 3.23: Infant vocalizations that were contingent upon declaratives with falling pitch had matched pitch contours more often than unmatched pitch contours, which was expressed as a proportion of declaratives with falling pitch

Pitch Contour of Infant Responses to Declaratives
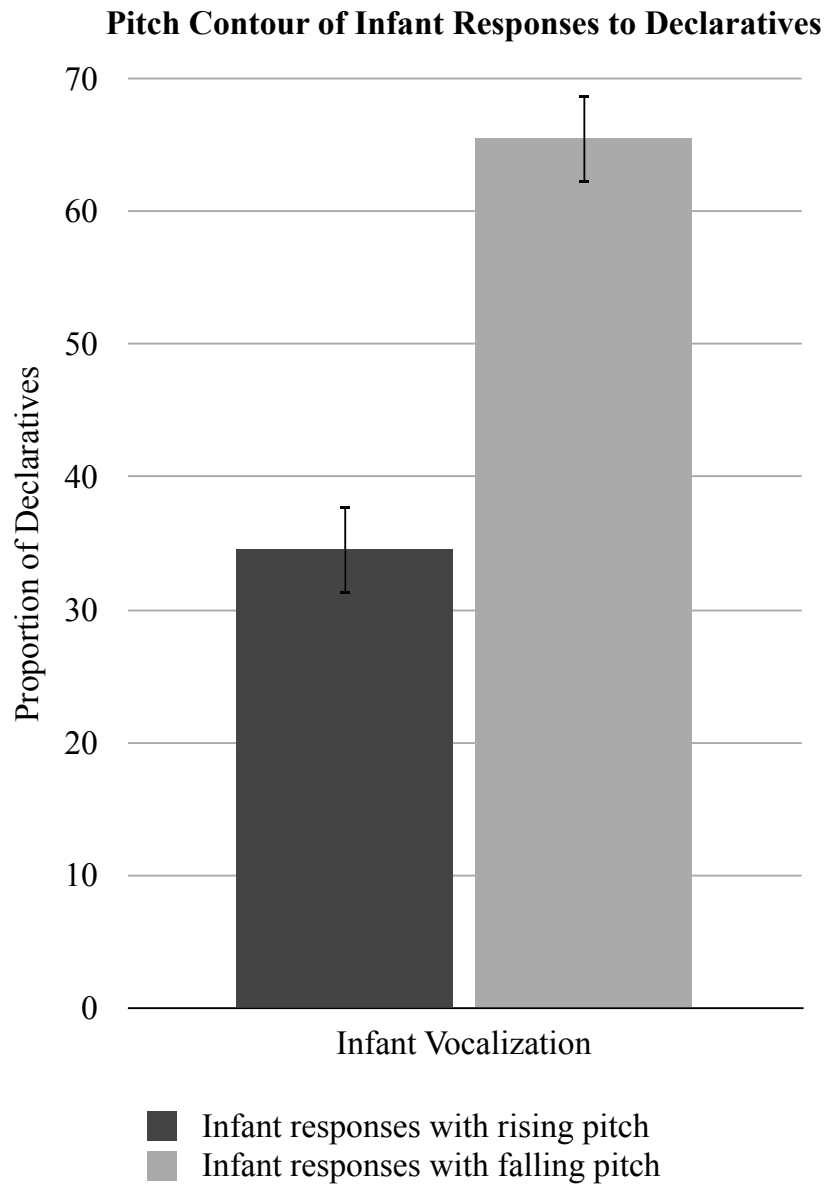
Figure 3.24: Infant vocalizations to declaratives that were characterized by rising and falling pitch contours

Pitch Contours of Yes/No Questions
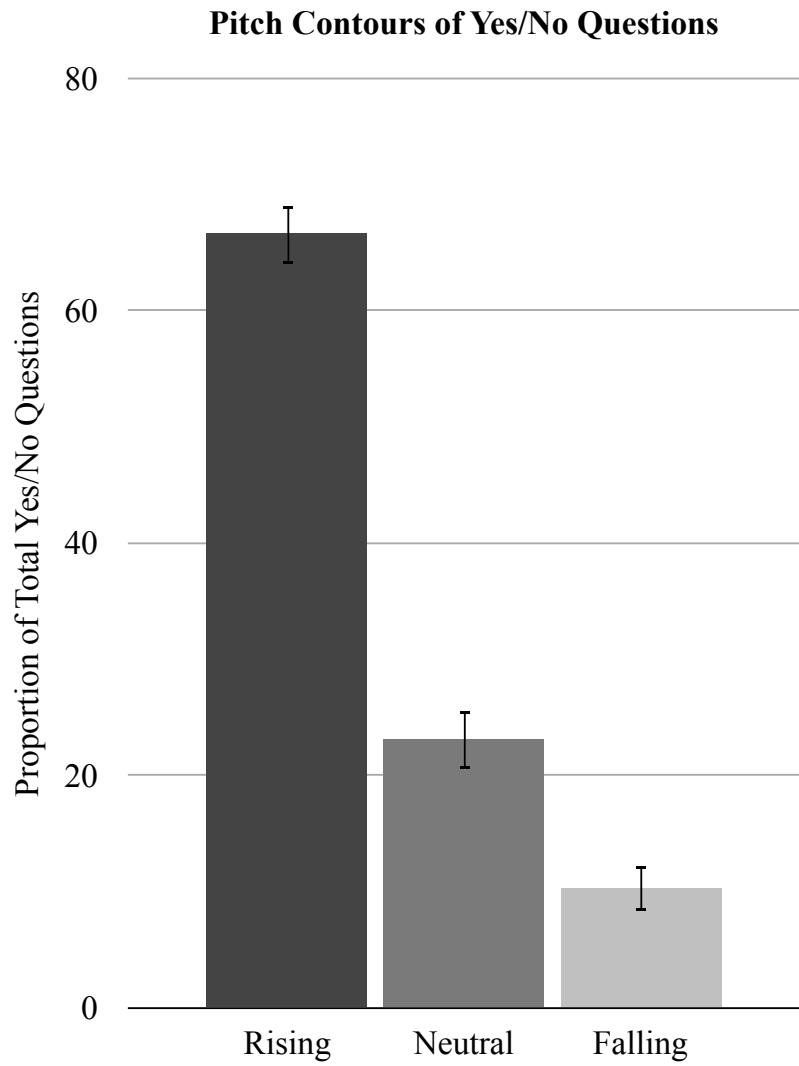
Figure 3.25: The proportion of mothers' yes/no questions that had rising, neutral and falling pitch contours

Pitch Contours of Wh-questions
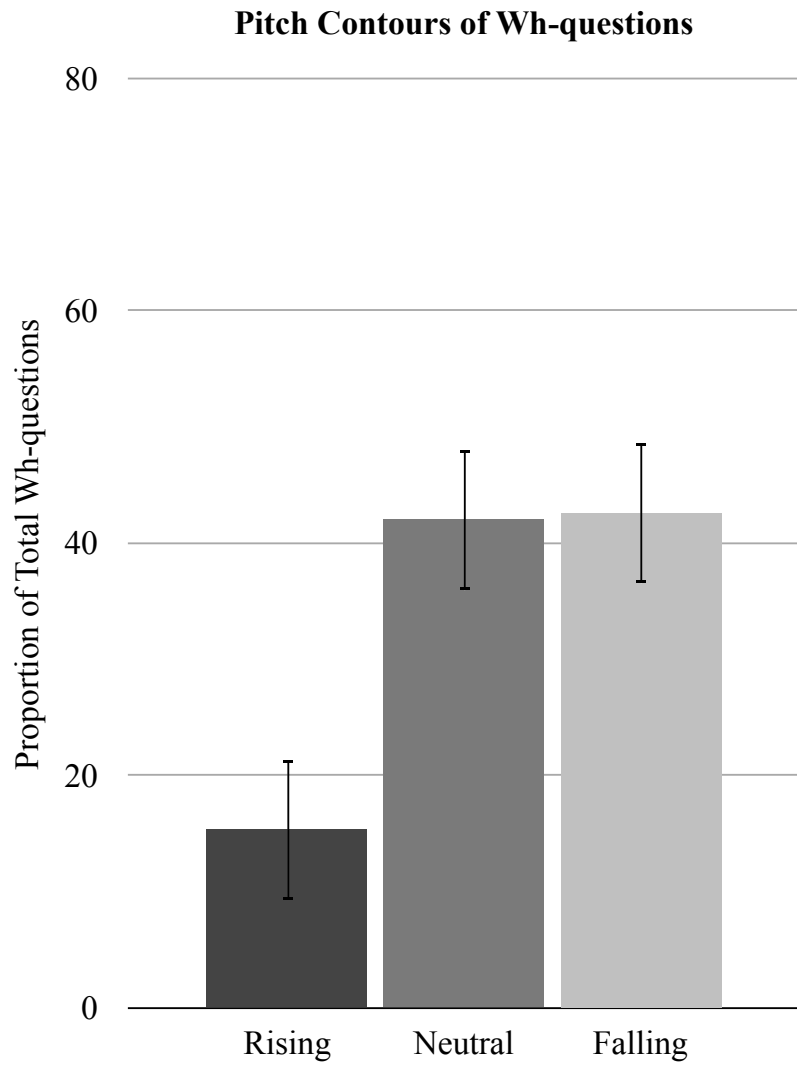
Figure 3.26: The proportion of mothers' wh-questions that had rising, neutral and falling pitch contours

contours were typical of wh-questions. There was no effect of infant age on the pitch contour patterns of mothers' questions. The preceding results were based on a sample of all questions, which included those questions with contingent infant responses.

3.4.2 *Pitch measures of mother-infant vocalizations*

Pitch measures from contingent mother-infant vocalizations were extracted as a representative sample of the total number of vocalizations. The pitch range for mothers was on average 204 Hz to 434 Hz and infants had a combined average pitch range of 285 Hz to 483 Hz. The combined mean pitch was 371 Hz for infants and 287 Hz for mothers. Refer to Figure 3.27 for a visual representation of minimum, maximum and mean pitch measures.

There was a weak positive correlation of mother-infant pitch range [$r(36) = .25, p = .14$]. There were moderate positive correlations of minimum and maximum pitch measures within mother-infant dyads [$r(36) = 0.38, p = .02$ and $r(36) = 0.31, p = .06$] for minimum pitch and maximum pitch, respectively]. A strong positive correlation was found between the mean pitch of a mother's utterances and the mean pitch of her infant's vocalizations [$r(36) = .41, p = .01$]. Mothers whose vocal ranges were higher typically had infants with higher voices. There was no effect of infant age on mothers' pitch range or average pitch measures.
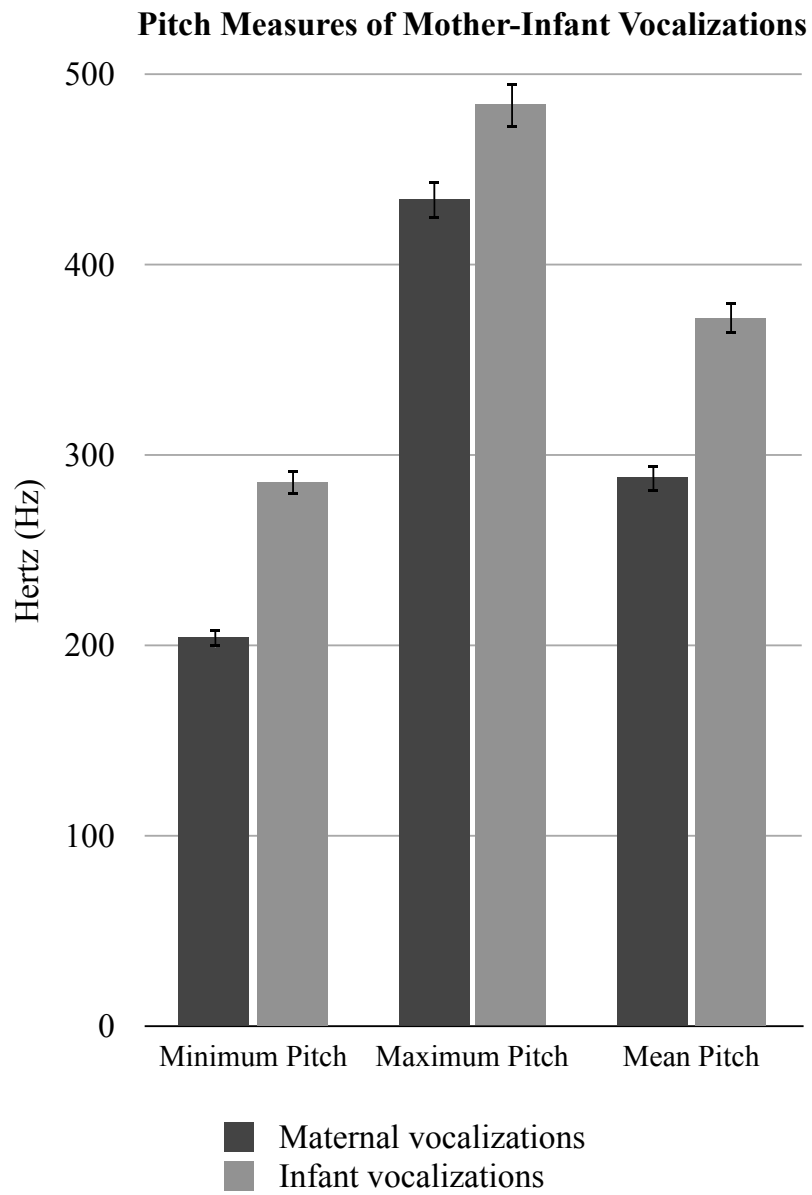
Figure 3.27: Minimum, maximum and mean pitch measures for contingent mother-infant vocalizations

Chapter 4

General Discussion

The notion that questions are salient cues to infants' perceptual systems was the impetus for the current study. The central hypothesis was that infants' perceptual preference for questions would drive vocal activity during mother-infant interactions that were rich with questions. Furthermore, infants were predicted to respond in a vocally unique way to the rising pitch of questions. Mother-infant play sessions were manipulated to create two different environments that could be used to test the above hypotheses. One environment contained maternal speech primarily in question form while the other environment contained mostly declarative speech.

Recordings from mother-infant play sessions were analyzed on multiple levels. The first was at a global level, which concerned the difference between interactions involving frequent maternal question use and ones that did not. Every mother-infant dyad participated in two interactions that captured both scenarios. A within-subject design facilitated clear comparisons between two conditions that were manipulated in opposite directions. Secondary analyses were performed at a local level to discover how infants responded to particular utterance types and to the pitch contours that defined them.

4.1   Mothers' speech

The semi-naturalistic design of the current study left residual variability in mothers' vocal behaviour. Questions were inevitably found in the declarative condition and declaratives in the question condition. Mothers could not perfectly adopt new ways of speaking with their infants in the confines of a laboratory experiment, nor did we want them to do so. Interactions between mothers and infants were intentionally constructed to have a naturalistic tone. Mothers' speech was semi-naturalistic and simultaneously biased to meet the requirements

of each experimental condition.

There was considerable variability in mothers' ability to speak primarily in question or declarative form. Mothers were considerably better at limiting their speech to declaratives, but mothers spoke less in favor of promoting accuracy to the instructions. Based on anecdotal reports, it was clear that a high level of attention was devoted to the avoidance of asking questions. The vast majority of mothers reported upon study completion that it was difficult to refrain from question use. Moreover, mothers occasionally caught themselves asking questions and stopped mid sentence. The propensity to ask questions is generally high in maternal speech; hence, the demand to do the opposite would be high. A high demand to reverse an inherent quality of maternal speech would presumably come at a cost, given the limits of human cognitive resources.

Mothers spoke more overall in the question condition perhaps because they were not concentrating on avoiding questions as they were in the declarative condition. Mothers were essentially speaking to their infants as they would have normally. Furthermore, because mothers became engaged with their infants by asking questions, they spoke more out of the momentum associated with being socially engaged.

4.2   Global effects of condition

There was enough cohesion in the level of accuracy across conditions to compare them. A positive correlation between maternal question use and infants' rate of vocalization was expected but not found. Instead, there was a modest increase in the amount of vocal behaviour by infants in the declarative condition. The effect was non-significant, but interesting because it occurred in the direction opposite of that predicted. In addition, infants spoke slightly more in the condition mothers spoke much less in. If mothers had been able to comply 100%, the trend toward greater infant vocalization in the declarative condition may have been more pronounced.

There are some potential theoretical implications related to the surprising distribution of infant vocalization. Infants may have vocalized slightly more in the declarative condition simply because they had more time do to so. Mothers spoke less overall, which increased the amount of silence and therefore the opportunities for infant vocalization also increased. Alternatively, there may be identifiable characteristics of declaratives that made infant vocal response to them viable and even preferable.

Declaratives may be conducive to infant vocal behaviour because they are not generally as engaging as questions. Questions may promote social proximity in a way that declaratives do not. When mother-infant social connectedness is already established, infants may be less driven to vocalize themselves. The infant has already captured the attention of its mother. Social proximity elicited by maternal questions may increase infant arousal to an optimal state such that any behavioural act on the part of the infant is unnecessary if its function is to increase arousal. Infants may instead acknowledge questions in more subtle ways through acts of joint attention, eye contact, gesture or touch. These nonverbal behaviours were not measured as part of the current study. However, it was clear from casual observation that these behaviours were frequent and continuous throughout mother-infant interactions.

The acoustic characteristics that define questions and declaratives influence the physiological processes that regulate infant arousal. For instance, rising pitch contours elicit infants' attention thereby increasing level of arousal (Fernald, 1985; Papousek & Papousek, 1989). Conversely, the steady or falling pitch contours of declaratives are associated with lower arousal states (Papousek & Papousek, 1989; Trainor, Austin, & Desjardins, 2000). Falling pitch contours are routinely present in a mother's speech when she attempts to calm and soothe her infant (Papousek & Papousek, 1989; Trainor et al., 2000). At certain times, however, declaratives may produce a less than optimal level of arousal. Infants may vocalize during low arousal states in order to elicit attention from their mothers. Mothers often engage with their infants in ways that increase the infant's level of arousal. Infants learn the

association between their bids for attention and maternal response in a way that makes the mother a vital regulator of infant arousal. In this way, infants are active agents in their own regulatory processes.

Mothers maintain an optimal level of infant stimulation by being attuned to their infants emotional states during social interactions (Field, 1994). Mothers modulate infant arousal through the use of vibrant prosody, which often includes rising pitch contours. Rising pitch is intended for the infant who shows neutral affect and signs of readiness to attend as well as the infant who is alert, comfortable and ready for interaction (Papousek, 1992). Mothers use rising pitch contours in both cases—first to engage their infants and then to maintain attention and arousal (Papousek, 1992). Once infants attend to their mothers, the function of rising pitch expands to include the communication of affect and the marking of turn-taking boundaries (Snow, 1977). In the declarative condition, mothers could not fill their speech with the sweeping rising pitch contours of questions, which may have compromised infants' arousal states. Furthermore, infant responses may have become somewhat dysregulated as a result of missing prosodic response cues. The nuances of maternal speech prosody are necessary for the maintenance of infant attention and arousal (Fernald, 1985).

It is apparent from many studies using the still-face procedure that infants are highly sensitive to even a short violation of typical adult-infant interaction (e.g., Mesman, van Ijzendoorn, & Bakermans-Kranenburg, 2009; Tronick, Als, Adamson, Wise, & Brazelton, 1978). In the still-face paradigm, infants are subject to an unexpected and quick shift in sensory stimulation produced by a caregiver-infant social interaction. The procedure was introduced by Tronick et al. (1978) to test the extent to which infants are active contributors to a face-to-face social interaction. After a period of normal adult-infant interaction, the adult becomes unresponsive and maintains a neutral facial expression for a period of time before normal interaction resumes (Mesman et al., 2009). Tronick et al. (1978) proposed that the still-face procedure violates the rules of face-to-face communication, which results

in the infant becoming confused. The infant initially tries to reengage the adult, but when reciprocity is not established, the infant withdraws and becomes upset (Tronick et al., 1978). Obvious infant distress did not occur when mothers spoke in declarative form; however, there may nonetheless have been a mild disruption in the maternal regulation of infant affect and physiological state.

4.2.1 Local effects of utterance type

There were no observable differences in the extent to which infants responded vocally to questions and declaratives at the utterance level. This was surprising for several reasons. Yes/no questions have rising pitch, which was hypothesized to promote vocalizations. In addition, yes/no questions require simpler answers as opposed to open-ended wh-questions. However, Olsen-Fulero and Conforti (1983) argued that questions restricting the form of a reply are weaker elicitors of a child's response. Another reason to expect greater response to yes/no questions is the influence of familiarity. Infants were exposed to more yes/no questions than wh-questions, which was an observation was made by Tamir (1980) in the case of slightly older infants than those reported on here. It appeared, however, that infant responses were instead driven by the pitch contours of utterances.

4.3 Infants' sensitivity to pitch

4.3.1 Vocal response to rising and falling pitch

In the first 6 months of life, infants learn to differentiate intonational patterns (e.g., Chang & Trehub, 1977; Morse, 1972) and by 8-months-old, infants discriminate sentences with rising and falling pitch contour (Kaplan, 1969). Infants' sensitivity to pitch was hypothesized in the current study to influence infants' vocal behaviour. There is strong evidence from the data presented here that infants do respond differently to rising and falling pitch contours.

Questions, specifically yes/no questions, were generally characterized by rising pitch, whereas declaratives were usually associated with falling or relatively stable pitch contours. Stern et al. (1982) previously found the same associations between utterance type and pitch contour. Infants responded to a large proportion of questions with rising pitch (approximately 65%) and a much smaller proportion of questions with falling pitch (approximately 23%). Questions with rising pitch contour were found to be especially salient cues for infant vocal response. Although, infants sometimes did respond to questions with falling pitch contours, which were likely wh-questions.

A different pattern of infant response emerged in relation to declaratives. Declaratives with rising pitch elicited fewer responses than declaratives with falling pitch. If rising pitch alone was enough to provoke infant vocalizations, infants would likely have responded more to declaratives with rising pitch. The structure of questions when combined with rising pitch resulted in maternal utterances that were especially conducive to infant vocal response. Infants may have already learned that questions and declaratives are typically defined by rising and falling pitch, respectively. Therefore, they responded more when utterances had the 'correct' associated pitch contour.

Simply because intonational properties of speech are identifiable beginning in early infancy does not mean pitch based sound patterns are the most effective units around which social interactions are constructed (Stern et al., 1982). However, the vocal responses to rising and falling pitch contours by infants here suggest that early perceptual prowess related to pitch is indeed meaningful. Mothers' tendency to ask questions (specifically, yes/no questions with rising pitch) is reciprocated by a high probability of infant vocal response.

4.3.2   *Relatedness of the pitch contours within contingent mother-infant vocalizations*

Questions with rising pitch elicited infant vocal responses with both rising and falling pitch contours. Infant responses with falling contours were slightly more common, although

any differences were non-significant. There could therefore be multiple processes guiding the intonational aspects of infant vocal responses. For instance, infants may be in effect 'answering' their mothers' questions when they respond with falling pitch contours. When infants responded with rising pitch contours, they may have been imitating the pitch patterns recently heard. Infants may imitate pitch to compliment the arousal level of their mothers or, alternatively, use rising pitch to provoke more stimulating maternal behaviours.

When questions had falling pitch contours, infants' responses were more often characterized by falling pitch than by rising pitch. The use of falling pitch did not reach significance; however, it strengthens the argument that infants generally responded to questions with falling pitch regardless of the pitch contour attributes of questions. It is reasonable to conclude that infants had to some degree learned the question-answer exchange of conversational speech. In these exchanges, questions typically have rising pitch while answers usually have falling pitch.

As evidenced by the current data, infants not only 'answered' questions but declaratives too. Declaratives with rising pitch were more often associated with infant responses with falling pitch. However, this difference only approached statistical significance. Infant vocalizations with falling pitch contours were reliably associated with declaratives that also had falling pitch. Mothers often use falling pitch contours while their infants are engaged as a way to coax positive behaviours. The falling pitch of a mothers voice is comforting to an infant (Papousek & Papousek, 1989; Trainor et al., 2000) and infants' reciprocation of these falling pitch contours may reflect contentment.

The pitch contours of infants' responses did not appear to result from direct imitation even though voluntary imitation develops around 8 months (Piaget, 1951). Matching through direct imitation is well observed among younger preverbal infants (Gratier & Devouche, 2011; Lieberman, 1984; Papousek & Papousek, 1981, 1989). Imitative processes are heavily influenced by mothers' strong intuitive propensity to match their infants' behaviours,

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including those that are vocal (Papousek & Papousek, 1977). Furthermore, mothers use sounds recently acquired by their infants to facilitate opportunities for imitation (Papousek, Papousek, & Haekel, 1987). Sound patterns that infants already know may be the best candidates for vocal matching. Mothers are hardly passive partners in their infants' imitation efforts. Once infants learn basic melodic patterns via direct imitation, they can perhaps use those pitch patterns in more linguistically and socially meaningful ways.

In the current study, direct imitation was not reliably found. However, infants incorporated the pitch patterns of their mothers' utterances. Mothers provide a wealth of pitch contour information in their speech input to infants, which supports the growth of infants' melodic repertoires (Balog, 2010). The melodic patterns evident in maternal speech are simple and highly repetitive (Stern et al., 1982). As infants hear repetitions of the same primary melodic contours, they emerge in their own vocalizations. Infants' representations of these melodic contours may be stored for use in a way that is not necessarily dependent on what infants most recently hear. Kuhl and Meltzoff (1996) hypothesized, for example, that infants store representations of the speech sounds they hear, which in turn influence speech production. It may be too far an extension to claim that infants knowingly select pitch contours based on their communicative merit, but direct imitation does not appear to drive selection either. The process can be considered imitative only in the sense that infants imitate the melodic patterns commonly heard in maternal speech. Infants' use of pitch contour may instead be the outcome of attempts to self-regulate.

4.4   Modelling conversational exchange

Sensitivity to pitch is important to infants' learning about conversational structure. Infants showed an understanding already at 10- and 14-months that yes/no questions with rising pitch require responses. Rising pitch in itself is a salient response cue that, in combination with conversational modelling, helps infants learn when to respond. Mothers often answer

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their own questions, which was noted here and before in the literature (e.g., Bateson, 1975). By modelling a fundamental aspect of human conversation, mothers may promote the development of question-answer exchange within mother-infant interactions.

Mothers often asked questions in succession, which sometimes meant two or three in a row and other times up to ten. The questions succeeding the first were essentially repetitions of the original question. However, each of the subsequent questions had an important function, which was to provide a quasi-answer. For example, a mother would ask, "What is that?" followed by, "Is that a yellow ball?" The answer 'yellow ball' was in effect given by being embedded within the second question. Similar instances occurred frequently. A pattern emerged in which wh-questions were followed with yes/no questions. It was as though mothers were sensitive to the fact that their infants could not yet answer a wh-question in any meaningful way. Infants may have been capable, on the other hand, of indicating vocally or otherwise states of approval (i.e., yes) or disapproval (i.e., no) in a way that was meaningful to their mothers.

Mothers provided answers to their own questions also by using declaratives. In the parallel example to the above, a mother would ask, "What is that?" and respond, "That is a yellow ball." Just as before, the answer 'yellow ball' was encompassed in the response to the initial question. Regardless of whether the 'answer' to a question was contained in a subsequent question or a declarative, these utterances were often repeated. Utterance repetitions occurred in exact form or with slight alterations. Similarly, Bortfeld and Morgan (2010) found that mothers often repeated a single object word within several consecutive utterances. The first of these utterances was spoken the most emphatically while subsequent utterances were less emphatic. This systematic variability of acoustic stress promoted word recognition by infants (Bortfeld & Morgan, 2010). Intonation variability associated with questions and the repetitive utterances that follow them may also contribute to infants' ability to recognize words. Repetitious vocal behaviour reflects mothers' keen efforts to

elicit infant responses or to ensure their infants' understanding of object-word associations. Repetition is commonly observed in mothers' speech, facial expressions, head movements and gestures (Stern, 1977). Snow (1977) proposed that repetition in general plays a critical role in language acquisition.

Mothers were sensitive to their infants' vocal responses and to any indicators of comprehension during the question-answer process. For example, a mother who asked, "Is that an orange fish?" would exclaim after, "Yes, that is right!". When mothers provided vocal rewards, they may have been responding to nonverbal signals indicating their infants' recognition of objects being attended to. A nonverbal signal may have involved eye gaze, pointing, touching or otherwise gesturing toward the relevant object. It is also possible that infant behaviours occurring at random were interpreted by mothers to be meaningful.

Mothers' declarative responses frequently took another form, which was to simply ask about and name an object. For example, "What is that?" was followed by, "That is a lady bug doll". These utterances did not imply any communicative action on the part of the infant. Instead, they appeared to be teaching the infant about word-object associations in a slightly different way. Mothers used question-declarative pairings as a way of modelling question-answer exchange.

Mothers of 14-month-old infants were found to use more consecutive questions than mothers of 10-month-old infants. This could be because mothers of the older infants had developed the expectation that their questions would be 'answered', at least more so than mothers of the younger infants. This expectation may or may not be founded in behavioural differences between 14-month-old and 10-month-old infants. It is possible that by 14 months, infants were to some extent competent in giving interpretable responses to questions. Younger infants may be less capable of giving meaningful responses. By providing 'answers' to their own questions in declarative form, mothers of 10-month-olds took the burden of response off of the infant. Mothers of older infants did not use simple

declarative responses to their own questions as much. The differences noted here suggest that mothers tailor their question use to the developmental stage of the infant.

4.5   Independent infant vocalizations

In the current study, a substantial proportion of infant vocalizations occurred with no immediate response from mothers. Just as mothers responded to their own vocalizations when no response was given, so did infants vocalize independently. However, the rationale was probably quite different. Mothers' primary goal through virtually all vocalization is to elicit infant response (Snow, 1977). Infants are not cognitively advanced enough to be concerned about their mothers' responsiveness in a similar way. A popular view is that infants engage in vocal play while alone (e.g., Hargreaves, 1986). Infants were not alone during the present study, but vocal play may occur in social situations as well. Vocal play may represent a means for phonological development (Stark, 1980), a helpful way to perform tasks (Winsler & Naglieri, 2003), a primitive musical form (Lewis, 1936/1951) or a way to explore the voice and practice making sounds (Hsu et al., 2000; Oller & Ellis, 1998). In any case, playful vocalizations have a purpose that is other than calling for a response. Infants may vocalize simply because they enjoy listening to the sound (Shimada, 2012). Infants have been observed to engage in frequent repetition of the same vocal sounds (Shimada, 2012). By exploring auditory feedback from their vocalizations, infants assist their own learning of speech and language (Koopman-can Beinum, Clement, & van den Dikkenberg-Pot, 2001; Oller & Ellis, 1998). Infant vocalizations that are not intuitively communicative could also be interpreted as self-regulatory behaviours (Shimada, 2012).

4.6   Temporal characteristics of mother-infant vocal interactions

The timing of vocal behaviours is important to the understanding of early social processes (Elias & Broerse, 1996). Information about conversational structure is not limited to verbal features, but includes those features that are non-verbal as well. Bateson (1975) proposed an entire second learned system, which orchestrates the fine-tuned timing parameters of smoothly flowing conversation. Human conversation is just as much about affirming social contact as it is about the exchange of information. Conversational interactions are in place well before infants are verbal participants. The structure of mother-infant interactions is adult-like above the sentence level (Bateson, 1975). Information becomes readily exchanged once differentiation below the sentence level is complete. In the meantime, the quasi-conversations of mothers and infants are already important vehicles for social relatedness (Bateson, 1975).

Social bonding between mother and infant during nonverbal 'conversations' may be related to underlying rhythmic structure. Mothers adopt a regular tempo when interacting with their infants, which is not matched in their interactions with other adults (Stern, 1977). Although, the rhythmic regularities of mothers' speech to infants is not perfect. In fact, rhythm cannot be perfectly structured because infants must evaluate deviations from the norm in order to create expectations about conversational structure (Stern, 1977). A small degree of structural variability is necessary in order to identify the patterns within. The infant perceptual system is able to isolate recurring patterns in the speech stream, which in turn become recognizable (Stern et al., 1982). Familiar patterns in maternal speech are marked with pauses or shifts in direction (Stern et al., 1982). Spoken phrases created this way are much like musical phrases. These phrases are repeated over and over again making them more recognizable and meaningful.

Conversation unfolds across time in a meaningful way. Each conversational partner has the ability to anticipate what the other will do next. This is not so different in adult

conversations. There is a predictable pattern of alternating turns between speakers. The speak-listen pattern of conversations relies on rhythm and time based expectations. Turn-taking also accommodates the limitations of human information processing mechanisms, which do not support the ability to listen and speak simultaneously (Jaffe & Feldstein, 1970). When conversational partners attempt to speak and listen at the same time, comprehension is compromised. Accordingly, each conversational partner must be sensitive to the other in order to avoid overlapping speech. Between speaker turns, there usually is a brief pause that signals the other speaker's turn. (Elias, Hayes, & Broerse, 1986). These short buffers between turns are mutually determined (Elias et al., 1986). The first speaker must offer an opportunity for response while the second speaker must recognize the signal. In this way, conversational exchange relies on speakers' sensitivity to time.

Infants must also learn the temporal regularities of speech that facilitate fluid conversation. Some authors contend that infants are not capable of mutual regulation of vocal turn-taking in the first few months of infancy; instead, smooth turn-taking is managed by the mother (Elias et al., 1986; Schaffer, 1977; Snow, 1977). It is probably true that mothers guide the process, but infants participate in it. One way to evaluate whether infants are sensitive to the conversational pauses that regulate spoken interactions is to quantify the amount of overlapping vocalization. If infants' vocalizations often overlap those of their mothers as observed in early infancy by Ginsburg and Kilbourne (1988) and Owens (1984) for example, then turn-taking cannot be identified as the primary mode of interaction. On the other hand, if infants' vocalizations are temporally coordinated, infants' vocalizations should overlap their mothers' utterances less often.

4.6.1 *Co-vocalization and alternation of vocalization*

In the current study, approximately 10% of all infant vocalizations overlapped mothers' utterances, whereas approximately 6% of mothers' utterances overlapped infant vocaliza-

tions. These findings show that overlapping speech is largely avoided by both mother and infant, which is corroborated elsewhere (Anderson et al., 1977; Bateson, 1975; Elias, Broerse, Hayes, & Jackson, 1984; Jansow & Feldstein, 1986). Infants engaged in a primarily alternating form of vocal exchange, which has been known to occur during the late part of the first year and into the second year of life (Ginsburg & Kilbourne, 1988).

Co-vocalization should not, however, be considered a type of error in the rules governing turn-taking; instead, it holds a function of its own. Instances during which a mother talks over her infant's vocalization may hold a different function than when a buffer silence is allowed beforehand. For instance, a mother may vocalize at the same time as her infant if she is attempting to give comfort, approval or a warning. Such vocalizations are typically short and contain little information (Elias, Hayes, & Broerse, 1987). Therefore, simultaneous vocalization may actually further the interaction (Schaffer, 1977). Maternal utterances that are rich in information may be reserved until after a buffering silence (Elias et al., 1987). The precise timing of maternal utterances suggests that the mother, rather than the infant, is in control of the seamless conversational-like quality of mother-infant vocal exchanges.

Functions of conversational timing are evident in both mother-infant interactions and adult-adult interactions. Mother and infant often vocalize together when arousal is high at either the positive or negative end of the affective spectrum (Stern, Jaffe, Beebe, & Bennett, 1975). For example, mothers soothe their distressed infants by vocalizing to them softly and by making calming utterances such as,"There, there". When infants are happy, mothers and infants laugh in unison and mothers offer utterances of approval and delight. The above examples demonstrate that mothers and infants are well in tune with each another during episodes of co-vocalization. Further, it is evident that turn-taking is not the only way in which vocal behaviour is reciprocally influenced between mother and infant. Instances of simultaneous vocalization are also observed in adult behaviour. For example, interpersonal expressions of anger or love often involve co-vocalization when the alternating

conversational dialogue breaks down out of emotional intensity. Given these observations in adult behaviour, it should not be surprising that mother-infant interactions also contain both vocal coaction and alternation. Each mode of vocalization has a distinct role to play, which are part of human communication from very early on. Vocalizing together is an important mode of social bonding during instances of heightened arousal (Stern et al., 1975). By extension, co-vocalization may represent an important component of early attachment behaviour between mother and infant.

The degree to which mother-infant vocal interactions occur in a coactive versus alternating mode has been discussed by numerous authors. In a recent study by Broerse and Elias (2011), mothers used primarily eliciting acts within an alternating mode of interaction that resembled adult conversational speech. An alternating mode of vocalization predominated over simultaneous vocalization by the time infants were 15 months old while there was a greater presence of co-vocalization during earlier infancy at 3 to 6 months (Broerse & Elias, 2011). Stern et al. (1975) supported the latter claim in their finding that two thirds of 3- and 4-month-old infants' vocalizations occurred simultaneously with their mothers' utterances. Conversely, Bateson (1975) observed that vocalizations by mother and infant very rarely overlapped during the first year of life.

Co-vocalization may be conducive to young infants' learning that their vocal behaviour influences that of their social partners. If vocal feedback occurs instantaneously instead of after a pause, infants may more readily associate their own vocalizations with those of a social partner. Stern et al. (1975) reported that short alternating sequences of vocal turn-taking occurred within the predominant state of co-vocalization and predicted that these alternating episodes would increase as a function of age. Our findings support the notion that changes in the ratio of alternating vocalization to co-vocalization are related to the development of infants' communicative abilities. Mothers and infants engaged in few episodes of covocalization, which suggests that alternating episodes of vocalization already

predominate by 10 months of age and still do at 14 months. By later infancy, alternating vocal exchanges are preferable to co-vocalization, perhaps because infants are learning that their vocal behaviour is communicative (Golinkoff, 1993; Murray & Trevarthen, 1986). Moreover, mothers can hear their infants' first attempts at verbal vocalization more clearly if alternating rather than simultaneous vocalization takes precedence. Given this reasoning, the rate of co-vocalization would be relatively low for the 10-month-old and 14-month-old infants studied here. These infants were on the verge of or just beginning to say their first words. However, the fact that co-vocalization does occur suggests that such episodes hold an important function into mid to late infancy and beyond. In fact, Elias and Broerse (1996) suggested that co-vocalization decreases up until 18 months of age and then increases. The increase is sustained only for a short time before decreasing again (Elias & Broerse, 1996). At that point, the rate of co-vocalization may plateau to an adult-like occurrence rate. These studies together demonstrate that covocalization morphs into an alternating pattern of vocal exchange, but at no point does coaction dissipate altogether.

4.6.2   Timing of vocal turns

In an alternating way of speaking, turn-taking is guided by the pause that occurs between the utterances of two communicative partners. Communication through speech is a continuous process that occurs through moment-to-moment interactions. During this process, a mother influences her infant and vice versa.

The current data showed that when mothers responded to their infants' vocalizations, they did so on average within less than half of a second. By responding quickly to each infant vocalization, mothers bring about episodes of turn-taking (Elias et al., 1986). Maternal vocal behaviour promotes a turn-taking structure in a second way. After mothers vocalize, they prolong vocalizing again to give infants more time in which to respond. Our data showed that mothers' within-speaker pauses exceeded two times the length of the average pause when

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maternal utterances directly followed infant vocalizations. Allowing more time for infant response ultimately results in the increased likelihood that a sequence of conversational turns will occur (Elias et al., 1986). From the precision with which maternal utterances occur emerges the idea that mothers are in control of the fine temporal adjustments during mother-infant interactions. The notion of mutual mother-infant influence may instead exist within a broader communicative framework. Until infants develop the social and language skills necessary to participate as sophisticated conversational partners, mothers compensate for their infants' immature cognitive systems. One way that mothers compensate is by precisely regulating the timing of each utterance, albeit unknowingly.

4.6.3   The inter-utterance pause

The timing and rhythm of spoken exchanges are central to how communicative behaviour is organized (Feldstein et al., 1993). Infants are born with the capacity to perceive time (Lewkowicz, 1989) and can distinguish differences of 25 milliseconds (Jusczyk, 1985). The innate ability to track time prepares infants to perceive temporal sequences, contingencies and expectations during spoken interactions (Allen, Walker, Symonds, & Marcell, 1977; Finkelstein & Ramey, 1977). Possessing sensitivity to how behavioural events are sequenced is a precursor to synchronicity between two speakers, which in turn facilitates social relatedness (Beebe et al., 2000).

The rhythm of a communicative exchange is mutually influenced by both communicative partners (Feldstein et al., 1993). In adult-adult conversation, partners tend to converge on certain temporal parameters of speech by a phenomenon termed vocal congruence (Jaffe & Feldstein, 1970). One example of vocal congruence is the tendency for the pauses separating pairs of utterances by different speakers to become similar in length over time. For instance, Beebe et al. (1988) found a strong positive correlation between the length of pauses separating a mother-infant exchanges and those that separate infant-mother exchanges.

These authors suggest that mothers and infants wait approximately the same amount of time before vocalizing after the other speaker. Further evidence of this effect is noted by Alson (1982) with 4-month-old infants and by Jansow and Feldstein (1986) with 9-month-old infants. Jansow and Feldstein (1986) argued that both adult and infant equally influence pause duration to be more like their own.

The current data provide evidence that mothers and infants do not wait the same amount of time in following their partners' vocalizations. Moreover, this dissimilarity of pause duration is not mutually influenced by mother and infant, rather it is the direct result of maternal behaviour. A moderate negative correlation was found between the average pause length that separated infant-mother vocalizations and mother-infant vocalizations. Generally, mothers responded more quickly if their infants were slower to respond on average. By responding quickly, mothers maintained the proper timing of turn-taking sequences and prevented conversational exchanges from disintegrating.

Although infants' knowledge of timing parameters is impressive, these fine adjustments are more likely to be regulated by the mother as opposed to being the product of mutual regulation. Two primary functions of maternal communicative behaviour are to elicit infant response and to create interactive exchanges that include episodes of turn-taking. Infants' communication is, on the other hand, driven by egocentricity. Infants' concerns are with expressing their needs and desires and less with responding in a sophisticated conversational way. Given that mothers are expert conversational partners, they have to accommodate their infants' immature communication styles to produce fruitful social interactions. Bloom, Russell, and Wassenberg (1987) found, for example, that infants vocalized with more speech-like sounds when adults used a clear turn-taking conversational structure. It is clear that infants' language development benefits from turn-taking, which is managed in large part by adult caregivers.

4.6.4   Convergence of utterance duration

An important aspect of vocal convergence occurs when utterance duration is similar in the speech of two conversational partners. Convergence of utterance duration is a vehicle for social cohesion, which occurs through processes of imitation. Imitation is found in many domains of human behaviour, including gestures, facial expressions and postures (Dijksterhuis & Bargh, 2001). More specifically, imitation has been observed for properties of speech including utterance duration (Feldstein et al., 1993). Others include vocal intensity, speech rate and pitch (Ko, Reimchen, Cristia, Seidl, & Soderstrom, 2013; McRoberts & Best, 1997; Natale, 1975; Street, 1984).

In the current study, relatedness of utterance duration was found in the interactions between mothers and older infants. Mothers whose utterances were longer in comparison to other mothers typically had infants whose vocalizations were longer relative to other infants. A negative correlation was found for mother-infant dyads in the 10-month-old group. Infants whose vocalizations were shorter on average had mothers whose vocalizations were longer. Given that utterance duration is traditionally considered a measure of speech complexity, mothers of infants whose vocalizations were shorter may have compensated for their infants' vocal immaturity. By 14 months, infants produced vocalizations that were well formed enough as to not require the same kind of vocal support. The conversational flow of mother-infant interactions may become more pronounced at this stage of development as the vocalizations of each communicative partner become entrained to that of the other in terms of duration, timing and overarching rhythm.

4.6.5   Convergence of average pitch and pitch range

Vocal pitch matching has garnered a significant amount of attention throughout the literature. The notion that infants are especially attentive to intonation and pitch register is well

supported (McRoberts & Best, 1997). The high and variable pitch of infant-directed speech is important in soliciting infants' attention, but these pitch characteristics perhaps represent more than perceptual salience. There may be mutual entrainment of pitch register between mothers and infants during early social interactions (McRoberts & Best, 1997). Some authors argue that both mothers and infants adjust their pitch to become like the other speaker's (e.g., Papousek & Papousek, 1981; Street, 1984). The role of reciprocal vocal matching is stressed by these authors, whereas others contend that mothers do most of the matching not infants (Fernald et al., 1989; McRoberts & Best, 1997). It is also possible that pitch matching is largely coincidental given that mothers have an inherent tendency to raise the pitch of their voices when talking with their infants (Fernald et al., 1989).

The vocalizations of mothers and infants in the current study converged on measures of mean pitch and pitch range, which may have resulted from mutual entrainment or a biased direction of influence. The matter of who influences whom was not of primary interest here given that true imitation patterns cannot be readily established from interactional data. The average pitch ranges reported for infants in the current study was consistent with those reported by Robb, Saxman, and Grant (1989) who found a range of means spanning 346-430 Hz for 10-month-old infants. For 17-month-olds, the pitch range was 201-423 Hz (Robb et al., 1989). In the current study, the average range of means for 10- and 14-month-old infants was approximately 286-484 Hz, which was slightly higher than that reported by Robb et al. (1989) but reasonably comparable. The average pitch range of infants' vocalizations was similar to that reported by Bateson (1975), which was 260-460 Hz across the first year of life. Fundamental pitch frequency of the voice is typically lower for older infants (Bateson, 1975).

4.7 Various effects of infant age

The amount of speech as it was measured by frequency and duration did not differ between mothers of younger and older infants. One may intuitively believe that mothers talk more to their infants as they grow older because with age they become increasingly socially responsive. On the other hand, mothers of young infants may talk quite continuously as a way to soothe their infants without much regard to speech content. Maternal speech may have a very different function for the very young infant. The infant ages studied here were not broad enough to give an accurate developmental timeline of maternal speech input.

Various other authors have commented on the amount and content of speech infants hear from their mothers. Stern, Spieker, Barnett, and MacKain (1983) found, for example, that speech to 24-month-olds was comprised of much longer utterances on average than speech to 4- or 12-month-olds. In context of these findings, the 10- and 14-month-old infants observed here fell into an intermediate period in which no major shifts occurred in terms of the amount of maternal speech infants were exposed to. In another study by Bornstein et al. (1992), the speech of mothers across cultures was found to increase as infants got older. Differences were instead related to the emphasis of speech, which differed as a function of cultural ideology. Bornstein et al. (1992) studied infants who were 5- and 13-months of age. In light of this work, it may be that an increase in maternal speech occurs between the 5th and 10th months of infancy and remains steady until the 14th month. Together, these results suggest that any increases in the amount of maternal speech input are moderate over the first year to year and a half, whereas the changes approaching the second year are dramatic. A more rapid increase in maternal speech input coincides with the rapid expansion of vocabulary that begins at approximately 18 months and progresses into the 2nd year (e.g., Fernald, Pinto, Swingley, Weinberg, & McRoberts, 1998).

4.8   Gender differences

4.8.1   *Infant vocalization*

No gender differences in vocalization frequency or duration were found between male and female infants. This result is corroborated by the work of Sung, Fausto-Sterling, Coll, and Seifer (2013) who also found that the amount of vocalization by infant boys and infant girls was comparable. These results should not be interpreted to negate the possible influence of gender differences on language, but instead viewed in light of what is known about boys' and girls' language development.

Traditionally, girls are considered to excel on measures of language more than boys. Research pertaining to language related gender differences has flourished since a review by Maccoby and Jacklin (1974) in which gender differences were few to speak of. Early markers of gender differences have since been noted, including those that are involved in language processes. Some authors have reported that girls vocalize more than boys (Feldman et al., 2000; Fenson et al., 1994), while others have found the opposite effect (Brundin, Rodholm, & Larsson, 1988). By mid-way through the second year, gender related differences involve word production and comprehension, which are more advanced in female infants (Fenson et al., 1994). The presence of gender differences in language during the second year is corroborated based on evidence presented by Bornstein, Hahn, and Haynes (2004) who showed that girls out performed boys from the 2nd to 5th years. These gender differences may be mediated in part by differences in maternal vocal behaviours to girls and boys (Sung et al., 2013).

4.8.2   *Maternal speech*

In the current study, mothers of infant boys were found to speak more than mothers of infant girls as measured by utterance frequency. However, this effect was only apparent in the

14-month-old age group. Laflamme, Pomerleau, and Malcuit (2002) found that mothers of 9-month-old boys spoke more to their infants than mothers of same aged infants, but this trend disappeared by age 15 months (Brundin et al., 1988). Our finding that mothers of boys spoke more than mothers of girls could reflect the tail end of the effect reported by Brundin et al. (1988). There is evidence that, by 24 months of age, the trend reverses and mothers of girls talk more than mothers of boys (Cherry & Lewis, 1976).

In addition, there were sex differences in the type of utterances mothers used while talking to their 14-month-old infants. These mothers asked their infant sons more questions as compared to mothers of infant daughters. Mothers of 10-month-olds used a similar proportion of questions regardless of infant gender. Cherry and Lewis (1976) reported that mothers of 24-month-old daughters asked more questions than did mothers of the same aged sons. The age discrepancy between studies makes it difficult to compare effects given numerous developmental shifts in language between the beginning and end of the second year of life.

With respect to declarative use, there was no difference found across age groups or between genders. There are mixed results in the literature concerning declarative use in maternal and paternal speech. Kruper and Uzgiris (1987) found that parents of younger infants (i.e., 3- and 9-month-olds) used a higher proportion of declaratives when speaking to their infant sons relative to parents of infant daughters of comparable age. Conversely, O'brien and Nagle (1987) found that fathers' and mothers' speech to their 24-month-old infants was comparable in structure and those sentence types used. Hummel (1982) also reported essentially no difference between fathers' and mothers' speech while at play with their 24-month-old infants. The current consensus is that maternal and paternal speech are more similar than they are different. Differences in the data reported above may be reflections of methodology, participant age or other confounds. Thus, the profile of maternal and paternal use of questions and declaratives along a continuum of infant development is

unreliable to date.

4.9   Conclusion

The role of intonation in the expression of motive and affect is well-known. However, the use of intonation in maternal speech as it relates to infant vocal behaviour is less clear. The attention of a 6-month-old may be captured by rising pitch, while the same rising pitch may provoke a 1-year-old to contribute in a vocal way (Ryan, 1978). In the present work, robust infant vocalization was hypothesized to occur in response to maternal question use and to rising pitch therein. Infants typically thrive when the maternal speech stream is rich in questions. When mothers' question use was minimized, a reduction of vocal behaviour was predicted accordingly. However, there were no observable differences between infant vocal responses to questions and declaratives. This was found at the global level as well as at the utterance level. Infant vocal behaviour was instead influenced by the intonation patterns contained within maternal utterances. The rising pitch of questions and the falling pitch of declaratives were especially salient in promoting infant vocalization. For infants, questions and declaratives may be distinguishable based on their acoustic features rather than lexical content or grammatical structure.

Infants' perceptual sensitivity to the acoustic regularities of speech allows them to acquire knowledge of intonation patterns. Maternal speech contains a finite number of basic pitch contours that occur systematically and repetitively. Infants become familiarized with these pitch patterns, which are eventually incorporated into their own vocalizations. Infants communicate through vocal melody before they acquire and are able to employ lexical and syntactic knowledge. The current data provide further evidence for the notion put forth by Balog (2010) that maternal intonation patterns are not directly imitated by infants. Instead, the complexity of maternal pitch contours supports the growth of infants' prosodic repertoires.

Infant responsiveness to the particular pitch patterns contained in maternal utterances was dependent upon proper temporal organization of mother-infant interactions. Mothers offered abundant response cues that were accompanied by ample opportunities for infant response. In this way, mothers modelled the speak-listen pattern of adult conversation, which unfolds across a dimension of time. Temporal contingency was paramount in the regulation of mother-infant interactions. For instance, a large proportion of vocalizations by mothers and infants were contingent upon recently occurring utterances by the other speaker. Mothers responded to their infants in a timely way to prolong vocal exchanges and to encourage turn-taking. Infants were sensitive to response cues and exhibited knowledge of appropriate pause duration between their own utterances and those of their mothers. When infants failed to respond, mothers left space in time for the expected response. Mothers and infants took turns with their utterances and rarely vocalized over one another. Mothers emphasized these temporal regularities of social interactions by modelling many aspects of conversation within their own speech. From these observations, it is apparent that conversational modelling and guidance of vocal exchanges are instrumental to maternal scaffolding of infant language development.

The conversational-like exchanges between mothers and infants involved mothers' use of vocal signals (e.g., rising pitch) and infants' response to them. Infants' perceptual sensitivity to rising pitch was reflected in their vocal behaviour, which confirmed the central hypothesis of this work. From the earliest months of life, contingent vocal behaviours are fundamental to mother-infant interactions (e.g., Beebe & Lachmann, 1988; Cohn & Tronick, 1988; Tronick et al., 1978). Turn-taking and mutual coordination of the voice are important examples of these behaviours. Infants learn through contingent experiences that their own behaviour affects that of others in predictable ways (Beebe, Lachmann, & Jaffe, 1997; Bigelow, 1998). This may be how infants first develop an understanding of self.

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