Published in final edited form as:

Clin Linguist Phon. 2016 ; 30(6): 470–488. doi:10.3109/02699206.2016.1147082.

Volubility of the human infant: Effects of parental interaction (or lack of it)

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Abstract

Although parental volubility, or amount of talk, has received considerable recent attention, infant volubility has received comparatively little attention despite its potential significance for communicative risk status and later linguistic and cognitive outcomes. Volubility of 16 typically developing infants from 2 to 11 months of age was longitudinally investigated in the present study across three social circumstances: parent talking to infant, parent not talking to infant and parent talking to interviewer while the infant was in the room. Results indicated that volubility was least in the Interview circumstance. There were no significant differences in volubility between the parent Talk and No Talk circumstances. Volubility was found to reduce with age. These results suggest that infants vocalise in a variety of circumstances, even when no one talks to or interacts with them. The presence of a stranger or perhaps overhearing adults speaking to each other, however, may significantly reduce infant volubility.

Keywords

Infant volubility; parental interview; parental talk; parent-infant interaction; prelinguistic vocalisation

Introduction

Volubility refers to the amount or rate of talk. In infancy research, this is typically calculated as the number of speech-like vocalisations within a specified time period, for example, per minute, per 30 minutes or as the percentage of time vocalised. Effects of varying amounts of parental interaction and age on infant volubility are the focus of the present study.

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Portions of this work were presented at the 2013 American Speech-Language-Hearing Association Convention.

Declaration of interest

The authors note no conflicts of interest.

Considerable recent attention has focused on parent volubility because it has been shown that parents from low socioeconomic status (SES) backgrounds talk less to their children than parents from middle to high SES backgrounds (Hart & Risley, 1995; Gilkerson & Richards, 2009). It has been suggested that this paucity of parental talk is responsible for the vocabulary and language deficits often reported in children from impoverished backgrounds. In addition, these early deficits have been shown to predict deficits in children's later academic and literacy at ages 9 and 10 (e.g. Hart & Risley, 1995). Several public initiatives have been launched to combat this 'word gap' (e.g. Providence Talks; <http://www.providencetalks.org>)

Infant volubility, on the other hand, has received comparatively less attention despite results from early investigations which suggest that prelinguistic volubility may be linked to later IQ and language scores (e.g. Camp, Burgess, Morgan, & Zerbe, 1987; Roe, 1975). Similar to parental volubility, infants of low SES have been also found to vocalise less than their mid SES counterparts (Oller, Eilers, Steffens, Lynch, & Urbano, 1994). Anecdotal reports also frequently suggest that children with disorders are 'quieter' in infancy. Low volubility was indeed observed in infants with autism (Patten et al., 2014). A reduction in volubility also was reported for premature infants at some points in their development (Törölä, Lehtihalmes, Hikkinen, Olsén, and Yliherva, 2012a, 2012b) although other investigations on premature infants have not observed this reduction (Oller et al., 1994). In addition, Berger and Cunningham (1983) showed strong volubility differences between typically developing infants and infants with Down syndrome but not always in the direction of low volubility for infants with Down syndrome. Thiemann-Bourque, Warren, Brady, Gilkerson and Richards (2014) found no significant differences in volubility between typically developing infants and infants with Down syndrome at 9–11 months, but typically developing infants had higher volubility than infants with Down syndrome after 2 years of age. Investigations on other infants with disorders, however, did not show a reduction in volubility. For example, there were no differences in overall volubility between children with cleft palate (Chapman, Hardin-Jones, Schulte, & Halter, 2001), children with severe-to-profound hearing loss (e.g. Iyer & Oller, 2008) and children with childhood apraxia of speech (Overby & Caspari, 2015), when compared to typically developing infants. Given the mixed evidence and the potential significance of volubility, it is clear that we need more complete, better differentiated data on volubility to help develop clinically useful measures. Key matters in the clinical utility of such a measure are how volubility may be affected by circumstance and age. The present investigation focused on prelinguistic volubility across varying circumstances of parental interaction in the laboratory across 2–11 months of life.

Relatively few investigations (e.g. Delack, 1976¹, Jones & Moss, 1971, Yang, 2005) have examined the effects of circumstance on volubility. Findings showed that infants vocalised most when they were alone, less when interacting with their primary caregiver and least in the presence of a stranger. Based on these findings, Locke and colleagues (Locke & Pearson, 1992; Locke, 2002) hypothesised that infants might vocalise more when alone to provide stimulation to their brains. In both Delack (1976) and Jones and Moss (1971), however,

¹An additional publication, Delack & Fowlow (1978), also reported effects of circumstance on volubility, but this article is merely a condensed version of Delack (1976) rather than a separate study – the data are the same.

actual time in each circumstance was *not* provided, so ‘true’ volubility across circumstances was difficult to determine for these widely cited works. Thus, the claim that infants vocalise most when alone cannot be supported based on the available data; further study is needed. Furthermore, in Delack (1976), no meaningful separation of volubility data across ages was provided. So, any interaction effects between ages and social circumstances are also difficult to determine from this study.

Other available evidence offers mixed predictions regarding the effects of social circumstance on volubility. If child volubility is indeed adversely affected by lack of parental interaction and input, as parent volubility studies (e.g. Hart & Risley, 1995) appear to suggest, then one might expect that infants should vocalise *least* when parents are not actively interacting with their infants. This expectation is indirectly supported by results from a host of conditioning studies that show that vocal reinforcement by an adult significantly increases infant volubility (e.g. Goldstein, King, & West, 2003; Nathani & Stark, 1996). On the other hand, 5–6-month-olds’ volubility was found to substantially increase from a face-to-face episode to a still-face episode (Goldstein, Schwade, & Bornstein, 2009; Delgado, Messinger, & Yale, 2002; Franklin et al., 2014). In the still-face episode, the parent does not interact or respond with the infant but still looks directly at the infant. It was hypothesised that infants vocalised more in this episode in order to gain back the attention of the adult. Based on these results, it might be expected that infants would vocalise most in the circumstance where their parents were not actively interacting with them. Given still-face conflicting predictions, further investigation of the matter is clearly warranted.

Rationale for the present study

Though the data from prior research suggesting influences of circumstances on infant volubility are seemingly contradictory, the issues at stake are theoretically and practically important. We propose that there are at least three important ways that circumstances can affect vocalisation of infants. a) It seems likely that infant vocalisation provides an opportunity for parents to shape infant sounds in the direction of communication and speech. If so, it seems there should be a tendency for infants to be responsive to Infant Directed Speech (IDS), becoming more voluble. b) At the same time, it would make sense that infants should have a naturally selected endogenous tendency to produce the kinds of vocalisations that parents might be inclined to interact with. If so, we should expect that infants would not only be able to be responsive vocally to IDS, but that they should also be inclined to explore vocally in the absence of IDS or of any kind of social interaction. c) We reason further that circumstances unlikely to produce high infant volubility (aside from sleep and circumstances of discomfort) might be those where the infant has something else to focus on (e.g. listening to interesting sounds, playing with noisy toys, learning to turn over or to locomote). Our study is based on recordings designed to evaluate infant vocalisation in three such circumstances.

The volubility issue is also important for clinical purposes because in spite of considerable past research, there still appears to be much to be learned about how adult talk influences infant vocalisation rates. For example, it is important to know which circumstances of adult

talk are more (or less) optimal to the production of prelinguistic vocalisations in the first year of life. Age-related changes in relationships between circumstance and volubility would also be useful to know for constructing developmentally appropriate assessment and intervention procedures. Results from the present study would serve as a backdrop against which to evaluate clinical populations. For example, if no differences are found across circumstances for typically developing infants in the present study, it would suggest that prelinguistic vocalisations are robust with regard to varying social circumstances. Infants with disorders, on the other hand, may turn out to be more susceptible to the effects of parental talk (or lack of it) than typically developing infants.

Plan for the present study

The present investigation examined prelinguistic vocalisations from typically developing infants recorded under three circumstances of social interaction in the laboratory where (a) the parent actively interacted with and talked with the child, (b) the infant was provided with the opportunity to entertain himself/herself, for example, by playing with age-appropriate toys and/or by playfully vocalising, but the parent was instructed not to interact or talk with the child unless required by infant discomfort and (c) the experimenter interviewed the parent while the infant played with age-appropriate toys, and had the opportunity to listen to the talk between the adults.

In addition to effects of social circumstance, age effects on volubility were also examined. Infants' volubility has been shown to considerably change across the first year of life (e.g. Nathani & Stark, 1996; Iyer & Oller, 2008). Age-related changes in volubility across varying social circumstances have, however, not been studied. Because infants are known to become more communicative as they grow older (e.g. Stark, Bernstein, & Demorest, 1993), age-related changes in volubility across different social circumstances also may be expected. The present study examined how volubility changes across different social circumstances from 2 to 11 months of age.

Volubility was examined here in several different ways. Overall utterance rate, or number of utterances per minute, was calculated as one measure of volubility. The number of non-fussy utterances was separately computed because it is possible that fussiness varies across circumstances and ages, even though the overall utterance rate may be similar. In addition, the percentage of time an infant vocalised in each session was computed as another measure of volubility. Percentage of time may yield a different perspective on volubility because it is possible that even though infants in one circumstance may vocalise more than the other circumstance in terms of utterance rate, their utterances may be shorter, and therefore, percentage of time vocalised could be similar between the two circumstances even though utterance rate might differ. Similarly, utterance rate might be similar across two circumstances, but the percentage of time vocalised might vary across the two circumstances if the utterances in one circumstance are longer than the utterances in the other circumstance.

The goals of the present study were therefore to

- evaluate infant volubility (as assessed by total utterances produced per minute, percentage of time vocalised and number of non-fussy utterances produced per minute) across three circumstances (Talk, No Talk and Interview);
- evaluate infant volubility (assessed as described above) across three ages (2–5.5 months, 5.5–7.5 months and 7.5–11 months).

We hypothesised that infants might vocalise more in the Talk circumstance than in either of the other two and further that the No Talk circumstance would correspond to higher volubility than the Interview.

Methods

Participants

The present study used data from a larger longitudinal data set in which infants were recorded from 2 months to 5 years of age in the three social circumstances. The purpose of the broader study was to provide a deeper understanding of the emergence of the speech capacity, to illuminate the circumstances that correspond to high vocal activity and to provide clues to the potential risk status of infants who show aberrations from typical patterns of communication.

In the present study, data from 16 infants from the broader study, recorded between 2 and 11 months of age, were used. There were seven females and nine males. Twelve infants were from monolingual English families and four infants were from bilingual families. Eight of the 16 infants were first-born, seven were second-born and one of the infants was third-born. Included in the sample were one set of identical twins and one set of siblings. Except for one infant, who was born 4.5 weeks prematurely, the remaining 15 infants were full term. Each of the infants was determined to be typically developing based on parent questionnaires completed at each visit and results from various tests (e.g. cognitive, motor, hearing) done at scheduled intervals. All infants in the study had passed their newborn hearing screening and had been deemed normally developing at their regular well-baby check-ups conducted by their paediatricians in the first year of life.

All of the infants were determined to be of middle to high SES, using criteria developed by Eilers et al. (1993). According to results found by Oller et al. (1994), infants from higher SES homes vocalised more than those from lower SES homes. This finding was not expected to affect the results of the present study because no infants from lower SES homes were included. However, it will limit the generalisation of the results to infants from middle to high SES homes.

Recording procedures

Infants were concurrently audio- and video-recorded for approximately 30 minutes in a sound-treated laboratory at each visit. During the recording, each infant was fitted with a customised vest that had a pocket in which a wireless microphone was placed which permitted the infant to freely move around the room. The primary caregiver was also outfitted with a wireless microphone. Audio signals from both microphones were recorded onto separate channels. The recording booth was equipped with three remote-controlled

digital video cameras to record the infant and primary caregiver as they moved across the room. These cameras were controlled by an experimenter outside the booth, who switched the cameras around to obtain the best view of the infant and caregiver. These recordings were then digitised for analysis. Audio and video tracks were overlaid and synchronised during this process.

Within each 30-minute recording session, infants were recorded under three different circumstances:

1. **No Talk:** Typically, a parent was present in the room but did not actively talk or interact with the infant unless the infant was in distress or unsafe in any way. The parent was instructed to sit quietly or to read a magazine. The infant was provided with age-appropriate toys. On occasion, parents left the room during this circumstance and the infant was truly alone in the room. However, only mothers of eight babies were willing to attempt this ‘true’ alone circumstance. Given the small number of true alone observations, data from the true alone sessions were combined with data with the parent in the room but sitting quietly and considered as the ‘No Talk’ circumstance.
2. **Talk:** The parent was instructed to talk and interact naturally with the infant.
3. **Interview:** The infant was in the room while an experimenter interviewed the parent regarding developmental and vocal milestones of their infant. The infant had toys to play with during this period.

As part of the broader study, the experimenters had attempted to record the circumstances in a random order, but because we needed to cater to infant state, this did not always happen. The Interview circumstance was most likely to be recorded first (50% of all Interview circumstances), the Talk circumstance was most likely to be recorded first or second (45% and 44%, respectively, of all Talk circumstances) and the No Talk circumstance was split evenly across all three possible orders (first, second or third circumstance). This non-randomisation occurred because it was observed that when infants were recorded in the No Talk circumstance first, they sometimes became uncontrollably fussy which led to the session ending before other circumstances could be recorded. Thus, the Talk and Interview circumstances were more likely to be recorded earlier in the session. Experimenter oversight also contributed to this lack of randomisation.

Data organisation

Approximately 10 minutes were planned to be recorded in each of the three circumstances. However, we found that a third of the circumstances (31%) were either missing or did not have the full 10 minutes recorded for a variety of reasons, for example, developmental testing being conducted during the session, scheduling and technical issues, experimenter oversight, or other factors such as the infant becoming uncontrollably upset and the session being cut short. Available sessions for each infant were, therefore, organised into three approximate age ranges: (a) 2–5.5 months, (b) 5.5–7.5 months and (c) 7.5–11 months, in the attempt to have a total of at least 10 minutes of recorded data for an infant within each circumstance for each age range. This organisation resulted in a planned total of 144 cells

for analysis (16 infants X 3 circumstances X 3 age groups), although as will be explained below, 12 cells could not be filled. Each of the three cells (Talk, No Talk or Interview) for any infant within any age range (2–5.5 months, 5.5–7.5 months or 7.5–11 months), therefore, represents summed data across more than one session of recording. Across all infants, a mean of 28 minutes within an age range was analysed in the No Talk circumstance (range 12–71 minutes), a mean of 48 minutes was analysed in the Talk circumstance (range 16–81 minutes) and a mean of 33 minutes was analysed in the Interview circumstance (range 12–82 minutes).

The three age ranges were chosen in part because prior still-face research (e.g. Delgado et al., 2002) had shown that the volubility of infants within the age range of 6–7 months is especially sensitive to changes in parental interaction patterns. Furthermore, most typically developing children produce canonical babbling, a key vocal developmental milestone, at the earliest, after 5 months of age (e.g. Oller, 1980, 2000; Nathani, Ertmer, & Stark, 2006). It, therefore, made sense to separate out infants younger than 5.5 months and infants older than 7.5 months into different age groups. We restricted our analysis to a maximum of 11 months of age because it is well known that typically developing children produce their first words around 12 months of age and our focus was on prelinguistic vocal development. These age cut-offs are approximate – sessions closer to 5 months of age (e.g. 5 months, 1 week) were typically included in the youngest age group whereas sessions closer to 5.5 months of age (e.g. 5 months, 2 weeks) were typically included in the next age group and so on.

To explain why 12 cells were unfilled among the 144 cells of the analysis, we reiterate that each cell represents summed data across more than one session of recording. However, six of the 144 cells still did not have a combined total of at least 10 minutes of recording even after including all available recorded sessions in that age range and were, therefore, considered to be missing data points. The other six of those missing points were associated with the identical twins, for whom we used no data from any Interview circumstance at any age range because both infants were recorded in this circumstance together. Their voices were so hard to distinguish that we deemed it inappropriate to estimate their individual utterance rates.

Computation of volubility

Speech-like vocalisations, or protophones, were first identified using criteria specified in the infraphonological model of vocal development (Oller, 2000). According to this model, speech-like vocalisations are presumed to be precursors to speech and include vocalisation types, such as cooing and babbling. Non speech-like vocalisations, on the other hand, are not presumed to be precursors to speech and include two main types: fixed signals and vegetative sounds. Fixed signals (e.g. cry, laugh) typically have obvious social functions, while vegetative sounds (e.g. hiccup, burp) typically have obvious physiological functions.

Once speech-like vocalisations were identified, they were bounded with cursors on a spectrographic display. Utterances were generally defined as speech-like vocalisation(s) separated from all others by judges' (see below) intuitions about utterance boundaries. The utterance boundaries were typically indicated by either audible ingressive breaths or by a second or longer of silence (Lynch, Oller, & Steffens, 1989). Following procedures used in

Nathani et al. (2006), speech-like utterances that were fussy, that is, utterances that were not full-blown cries but had a distressed vocal quality based on judges' (see below) determinations, were noted. The number of utterances per minute, that is, total utterance rate, and the rate of non-fussy utterances² were computed to determine volubility. The percentage of time infants vocalised within a session was computed as another measure of volubility.

Training and observer drift checks

A total of 15 different undergraduate and graduate students in the field of speech-language pathology served as judges for the present study. Each judge received half a semester of training before coding the actual data. This training included learning the criteria to identify utterances and how to use the customised Action Analysis Coding and Training system (AACT; Delgado, 2006), the primary software used to identify utterances in the present study. This software allows for simultaneous analysis of audio and video data. Because tf32 software (Milenkovic, 2001) is incorporated within AACT, both spectrographic and waveform displays of the audio signal are available along with the video displays of sessions. This allowed the listener precision in placing utterance boundaries when viewing the sessions.

In order to minimise observer drift, 20% of each session was checked by an expert (first author with over 20 years of experience in coding infant vocalisations). In order for the session to be considered acceptable, the primary judge and the expert had to have at least 80% agreement regarding number of utterances and the duration of each utterance. Utterance durations were considered in agreement if the beginning or end boundaries for each utterance did not vary by greater than 25 msec between the primary judge and the expert. If agreement was less than 80%, the session was recoded and checked again. No more than two recodes were permitted for each session before it would be discarded. Out of the 239 analysed sessions, 27 (11%) had to be recoded once, two had to be recoded twice and three sessions had to be discarded or replaced with another session because 80% agreement could not be achieved mostly due to excessive fussiness in the session.

Observer agreement

A second judge (a trained student as described above) determined utterances for a randomly selected 20% subset of the data in order to establish agreement with the primary judge's utterance determinations. The intraclass correlation coefficient for interjudge observer agreement for utterance counts was 0.92. For intrajudge observer agreement, the primary judge determined utterances a second time for a randomly selected 15% subset of the data. The intraclass correlation coefficient for intrajudge observer agreement for utterance determinations was also 0.92.

²The rate of fussy utterance production could not be analyzed because there were many sessions with no or very small numbers of fussy utterances, which affected the stability of the statistical analysis. Non-fussy utterances were therefore the focus of our analysis.

Statistical analysis

Due to the small sample size ($n = 16$) and missing data, standard repeated measures analysis (Kutner, Nachtsheim, Neter, & Li, 2005) could not be performed. Instead, a non-parametric bootstrap analysis (Davison & Hinkley, 1997; Efron & Tibshirani, 1998) was carried out. For the purpose of this analysis, we calculated F -like statistics based on the sums of squares and mean squares of the observed data, with degrees-of-freedom surrogates to take into account the missing observations. This was done for the original data on total number of utterances per minute, total number of non-fussy utterances per minute and percentage of time spent vocalising. Explanatory variables for all three of these were age (2–5.5 months, 5.5–7.5 months, 7.5–11 months) and circumstance (Talk, No talk, Interview); the interaction between age and circumstance was also entered into all three models.

For the bootstrap, we took $B = 1000$ resamples with replacement for the analysis of total number of utterances and percent time vocalising, and $B = 5000$ for total number of non-fussy utterances. For each resample, the original structure of the missingness pattern was preserved, the test statistics F^{*3} were calculated and an empirical distribution was thereby built up. Bootstrap p values were found by comparing the observed F -like statistic in the original data to the bootstrap distribution of F^{*} statistics. For non-fussy utterances, it was found that the results were borderline significant whereas, for both total utterances and percentage time vocalised, the results were clearly on one side of significance or the other. Therefore, we upped the resamples to 5000 for non-fussy utterances in order to obtain a more stable estimate of the empirical distribution. Whenever the main effects were significant, effect sizes were calculated and we conducted post-hoc pairwise comparisons, also with the bootstrap approach.

Results

Total utterance rate analysis

A total of 27,260 utterances were coded and included in the analysis across all infants. Figure 1 shows the mean rate and standard error for overall utterance production across circumstances and ages for all infants. Recall that for each infant within a data point, we summed the data across multiple sessions of recording within that age range for that infant. Volubility values were lowest in the Interview circumstance for all three age groups. In addition, for the No Talk and Talk circumstances, volubility appeared to reduce with age. There was considerable variability in volubility values. For 2–5.5-month-old infants, values for volubility ranged from approximately 4–15 utterances per minute for the No Talk circumstance ($M = 8.38$), to 3–12 utterances per minute for the Talk circumstance ($M = 7.57$) and to 0–7 utterances per minute for the Interview circumstance ($M = 4.52$). For 5.5–7.5-month-old infants, values for volubility ranged from approximately 3–16 utterances per minute for the No Talk circumstance ($M = 7.47$), to 2–14 utterances per minute for the Talk circumstance ($M = 6.2$) and to 2–9 utterances per minute for the Interview circumstance ($M = 4.54$). For 7.5–11-month-old infants, values for volubility ranged from approximately 3–11 utterances per minute for the No Talk circumstance ($M = 5.71$), to 2–15 utterances per

³The asterisks indicate these are bootstrap F -like statistics rather than traditional F -statistics.

minute for the Talk circumstance ($M = 5.3$) and to 2–8 utterances per minute for the Interview circumstance ($M = 4.47$).

Results from the bootstrap analysis showed that the main effects of age, $F^* (1.75, 23.92) = 4.66$, $p^* < 0.05$, $\eta_p^2 = 0.25$, and circumstance, $F^* (1.75, 23.92) = 7.73$, $p < 0.01$, $\eta_p^2 = 0.36$, were significant but not the interaction effect of age and circumstance. Specifically, there was a significant difference in the utterance rate of 2–5.5-month-old infants from 7.5–11-month-old infants, $t^* (13.67) = 1.78$, $p^* < 0.001$, but there was no significant difference between the utterance rates of 5.5–7.5-month-old infants ($M = 6.11$, $SD = 3.21$) from 2–5.5-month-old infants or from 7.5–11-month-olds. Infants, 2–5.5 months of age ($M = 6.93$, $SD = 3.1$), vocalised at higher rates than 7.5–11-month-olds ($M = 5.17$, $SD = 2.55$). With regard to circumstance, utterance rate was significantly lower in the Interview circumstance ($M = 4.51$, $SD = 1.86$) when compared to the Talk or No Talk circumstances, $t^* (13.67) = 1.84$, $p^* < 0.001$ and $t^* (13.67) = 2.74$, $p^* < 0.001$, respectively. There was no significant difference between utterance rates in the Talk ($M = 6.33$, $SD = 3.08$) and No Talk ($M = 7.22$, $SD = 3.31$) circumstances.

Non-fussy utterance rate analysis

The rate of non-fussy utterances production across circumstances and ages is provided in Figure 2. Non-fussy utterance rate showed as much variability as overall utterance rate. For 2–5.5-month-old infants, values ranged from approximately 3–14 non-fussy utterances per minute for the No Talk circumstance ($M = 7.27$), to 3–10 non-fussy utterances per minute for the Talk circumstance ($M = 6.66$) and to 0–7 non-fussy utterances per minute for the Interview circumstance ($M = 4.27$). For 5.5–7.5-month-old infants, values ranged from approximately 3–15 non-fussy utterances per minute for the No Talk circumstance ($M = 6.47$), to 2–11 non-fussy utterances per minute for the Talk circumstance ($M = 5.64$), and to 2–8 non-fussy utterances per minute for the Interview circumstance ($M = 4.34$). For 7.5–11-month-old infants, values ranged from approximately 3–11 non-fussy utterances per minute for the No Talk circumstance ($M = 5.08$), to 1–15 non-fussy utterances per minute for the Talk circumstance ($M = 5.02$), and to 2–8 non-fussy utterances per minute for the Interview circumstance ($M = 4.33$).

Results from the bootstrap analysis mimicked those found for overall utterance rate in that there was no interaction between age and circumstance and there was a significant main effect for circumstance, $F^* (1.75, 23.92) = 5.08$, $p < 0.05$, $\eta_p^2 = 0.27$. Again, similar to the overall utterance rate analysis, utterance rate was significantly lower in the Interview circumstance ($M = 4.32$, $SD = 1.73$) when compared to the Talk or No Talk circumstances, $t^* (13.67) = 1.63$, $p^* < 0.01$ and $t^* (13.67) = 2.25$, $p^* < 0.001$, respectively. There was no significant difference between utterance rates in the Talk ($M = 5.76$, $SD = 2.86$) and No Talk ($M = 6.3$, $SD = 3.04$) circumstances. However, unlike that found for overall utterance rate analysis, there was no significant main effect for age for non-fussy utterances.

Percent time vocalised analysis

Figure 3 shows the percentage of time infants vocalised within a session across circumstances and ages. Percentage time vocalised showed as much variability as utterance

rates. For 2–5.5-month-old infants, values for percentage time vocalised ranged from approximately 3–24% for the No Talk circumstance ($M = 10.48$), to 4–19% for the Talk circumstance ($M = 8.64$) and to 1–10% for the Interview circumstance ($M = 4.86$). For 5.5–7.5-month-old infants, values ranged from approximately 3–23% time vocalised for the No Talk circumstance ($M = 9.93$), to 2–16% for the Talk circumstance ($M = 7.29$) and to 1–11% for the Interview circumstance ($M = 5.43$). For 7.5–11-month-old infants, values ranged from approximately 3–13% time vocalised for the No Talk circumstance ($M = 6.53$), to 2–20% for the Talk circumstance ($M = 6.17$) and to 2–11% for the Interview circumstance ($M = 5.15$).

Results from the bootstrap analysis showed that the main effect of circumstance, F^* (1.75, 23.92) = 5.78, $p < 0.01$, $\eta^2_p = 0.3$, was significant but not the main effect of age. The interaction effect of age and circumstance was also not significant. Post-hoc comparisons showed that percent time vocalised was significantly lower in the Interview circumstance ($M = 5.17$, $SD = 2.59$) when compared to the Talk or No Talk circumstances, t^* (13.67) = 1.38, $p^* < 0.02$, and t^* (13.667) = 2.46, $p^* < 0.001$, respectively. There was no significant difference in percent time vocalised between the Talk ($M = 7.34$, $SD = 4.0$) and No Talk ($M = 9.04$, $SD = 5.47$) circumstances.

Discussion

Infants vocalised least in the interview circumstance

The purpose of the present study was to evaluate infant vocalisation rates in the first year across different ages and different social circumstances. Infants were indeed found to vocalise differently across different social circumstances: The rates were higher when the primary caregivers were talking to the infants and when infants were alone with the primary caregivers but the caregivers were not talking to them; on the other hand, the rates were lower when infants were overhearing a conversation between an experimenter and the primary caregiver.

The results were partially consistent with our hypotheses. We anticipated that infants would vocalise more in the Talk and No Talk circumstances than in the Interview circumstance. This prediction is consistent with the expectation that infants have been naturally selected to be responsive to IDS and also to vocally explore when they are alone and not distracted by other activities. As we expected, results demonstrated that the voices of adults talking to each other nearby may have somehow inhibited the infants from possible activities of their own, in particular inhibiting them from vocal play or exploration.

The results suggest the importance of recognising the infant as both being responsive to speech directed towards them, which was largely absent in the Interview circumstance, and as having an independent inclination to vocalise spontaneously during certain periods. The low rates of vocalisation during the Interview circumstance suggest that those ‘certain periods’ may occur primarily at times when the infant’s attention is not drawn to other auditory stimuli. In particular, we suggest that infants hearing adults talking may orient auditorily to those sounds and remain relatively silent, perhaps even experiencing calm. Nathani and Stark (1996) reported that infants appeared to vocalise less in the presence of

noisy toys, perhaps for the same reason, namely that infants' attention was occupied by the noisy toys, and therefore they did not vocalise as much as in silence. Another possibility is that infants did not have as many opportunities to vocalise as during periods of adult silence. Adults talking to each other presumably do not attempt to give the infant space to vocalise, whereas during periods of parent–infant interaction, we presume parents tend to produce vocalisation in alternation with infants, explicitly making space for them to talk.

To interpret the low volubility in the Interview circumstance, we might also consider Delack's (1976) report that the presence of a *stranger* yielded the lowest rate of infant vocalisations for his recording conditions in the first year of life. However, the present study was longitudinal, and infants were being seen on a weekly basis, thus being relatively familiar with the experimenters during the course of study. Therefore, we doubt that a stranger effect was the reason for low volubility in this circumstance in our study.

The lower volubility in the Interview circumstance could have also been influenced by difficulties in identifying infant vocalisations in that circumstance. Often, parent–experimenter vocalisations were simultaneous with those of the infant, and therefore it was harder to identify infant vocalisations amidst the adult talk. Differing amplitudes in the parent and infant channels and synchronised video made it possible to discriminate infant and parent voices in many instances. Still the proximity of the adults to the infants resulted often in overlapping of the infant's vocalisations, and we cannot rule out the possibility of having missed more infant vocalisations during analysis of the Interview circumstance than during the others.

There were no significant differences in volubility between Talk and No Talk circumstances

Our hypothesis that the stimulation of IDS (the Talk circumstance) would produce higher volubility than the No Talk circumstance was not confirmed. In fact, although the differences were not statistically significant, the No Talk circumstance actually yielded the highest rates of vocalisation of the three circumstances. The lack of a significant difference suggests at least that the infant sometimes vocalises endogenously in the absence of vocal stimulation. Oller (2000) has argued that endogenous vocalisation must be naturally selected, as without it there would be no raw material for the parent to shape into subsequent speech. This presumed duality in the nature of infant vocalisations (endogenous *and* interactive) is supported by both the overall results and those from our non-fussy utterance analysis. Just as in the case of the overall results, no significant difference was found in the rate of non-fussy utterance rate between the Talk and No Talk circumstances. We interpret this finding as suggesting there was no obvious attempt on the infant's part to gain the attention of the caregiver in the No Talk circumstance by vocalisation. Instead, the data are consistent with the interpretation that the infant vocalised endogenously in the No Talk circumstance, perhaps as practice or exploration.

Stark et al. (1993) also proposed a dual – endogenous and interactive – nature of infant vocalisations. Although they did not separate their data according to the circumstances in which the infants were recorded, for example, alone or when parents were playing and talking to the infant, they found that infants vocalised freely when gazing at objects *or* people in their environment, termed Reactive Sound Making, from 0 to 6 months of age. In

addition, Activity Sound Making, which refers to infant vocalisations produced in the context of activity or play with objects without any interaction with an adult, was present from 3 to 21 months of age and was most prominent in the 6–13-month age range. Communicative Sound Making, on the other hand, which refers exclusively to vocalisations made during social interaction with another person, was observed from 6 to 21 months of age and was most prominent from 9 months onward. Thus, infants appear to vocalise for a variety of purposes and under a variety of circumstances in the first year of life.

Other prior studies have obtained results that provide a basis for expanding these interpretations. Mother–infant interaction and reinforcement studies (e.g. Keller & Sch Imerich, 1987; Goldstein et al., 2003) have tended to show the circumstance in which parents contingently talk to their infants to be the most conducive context for the production of vocalisations, and still-face studies (e.g. Goldstein et al., 2009; Franklin et al., 2014) have reported that a context when the primary caregiver withdraws after interaction to not talking or interacting with the infant elicits high rates of vocalisations from infants at least 5 months of age. Note, however, that in these lines of research, interaction and effects of increased interaction or withdrawal from it have been the exclusive focus. It is not possible to isolate a possible role for an endogenous infant inclination to vocalise under these circumstances.

The present study involved more naturalistic observation of parent–infant interactions. While the caregiver was indeed actively interacting and talking with the infant in the Talk circumstance in our study, they were not instructed to contingently respond or reinforce vocalisation attempts on the part of the infant. Similarly, although the caregiver was not actively talking and interacting with the infant in the No Talk circumstance, they maintained a pleasant demeanour unlike in still-face studies where the caregiver assumes a passive expression in still-face and may not even maintain eye contact with the infant. Additionally, when the infant appeared to be distressed or unsafe or misbehaved in the No Talk circumstance, the caregiver soothed, warned or admonished the infant, as needed. Thus, our study offered the opportunity to evaluate rates of infant vocalisation both during caregiver talk and interaction *and* during periods when the infant was comfortably unengaged with the caregiver.

Although we did not formally evaluate the functions of the vocalisations in the present study, it is clear that vocalisations served a variety of functions in both the Talk and No Talk circumstances. In the Talk circumstance, many vocalisations appeared to be directed to the caregiver. However, even in this circumstance, not all vocalisations were directed to the caregiver. Sometimes, they appeared to be directed to a toy or another object of attention. At other times, no obvious referent for the vocalisation could be identified. Similar flexibility of functions was noted in the No Talk circumstance. This concept of functional flexibility in the first year of life has long been advocated by Oller and colleagues (Oller, 2000; Oller et al., 2013) and may also help explain the lack of a difference in vocalisation frequency between the two contexts, simply because the flexibility of functions in both cases was considerable. On the other hand, as developing infants begin to use real words, it may well be that vocalisation frequency differences between the two contexts could be detected. Bates (1976) and Stark et al. (1993) noted that infants shift towards much more intentional communication around 9 months of age. Because our investigation ended at 11 months of

age, vocalisation differences across circumstances may not have been easily detected at these young ages. Vocalisation frequency in infants older than 11 months of age would need to be explored in order to evaluate this possibility.

It seems likely, at some point, that we minimise our talking when no one is talking or interacting with us; exactly when this shift occurs developmentally remains to be determined. Karousou and López-Ornat (2013) observed that infants continued to vocalise when alone and with toys up to 30 months of age when their study ended. This study used parent report and simply recorded the presence or absence of behaviours. Therefore, the frequency of vocalisations in a No Talk circumstance is unknown at these later ages and needs further investigation.

It should be noted that even though we did not find a reduction in vocalisations in the No Talk circumstance, our findings do not contradict previous studies that found low overall parental volubility to be associated with low child volubility (e.g. Hart & Risley, 1996) because we did not directly evaluate this claim in the present study, given our small sample size. Our findings simply revealed no significant differences between the two circumstances. With larger sample sizes, it would be possible to evaluate the combined effects of overall parental volubility and circumstance on infant volubility. The higher rate of vocalisation in the Talk than the Interview circumstance, however, suggests infant responsivity to speech directed to them in an interactive context, presumably revealing an important basis for parental shaping of infant sounds in speech development.

Infant volubility decreased with age

The present results showed a reduction in volubility with age. Some previous studies have shown an increase in vocalisation frequency with age (e.g. Stark et al., 1993). However, one of our previous studies comparing volubility of infants with typical hearing and infants with hearing loss showed a similar although not statistically significant pattern of reduction in volubility with age, as measured in utterances per minute (Iyer & Oller, 2008). In that investigation, we suggested that one possible explanation for reduced volubility with age is that as infants grow older, they produce more syllables per utterance. Therefore, although the utterance rate may be lower, the percentage of time vocalised may actually be similar across ages. Indeed, our results indicated no significant differences in *percentage of time* vocalised across ages thereby bolstering our previous suggestion that as infants grow older, they produce more syllables per utterance. The rate of non-fussy utterance production was also not significantly different across ages.

Other explanations for varying reports on volubility across age may be that the utterance determination criteria have varied across studies. For example, Stark et al. (1993) used a 2-second criterion to separate utterances whereas the present study used the more contemporary intuitive breath group criterion. Clearly, different values for utterance rates would be obtained depending on the criteria chosen to identify utterance boundaries. In addition, technological advances have resulted in better recording quality. Also, because our infants were wearing wireless microphones on customised vests, mouth-to-microphone distances may have been more optimal than in previous studies where microphones were often placed in a static location in the room. Consequently, the microphones may have

picked up greater numbers of soft, brief utterances of younger infants than in previous studies.

A reduction in volubility with age, if it turns out to be real, could also suggest that as human infants get older, they pare down the quantity of vocalisations perhaps in order to enhance the quality of the sounds, to make them more speech-like. The early abundance of infant vocalisations may be pruned out in favour of vocalisations that are more salient as potential communication vehicles (e.g. coos, canonical syllables). Vocalisation types and caregiver responses will need to be analysed in order to evaluate this possibility. It may also be that as infants grow older and start sitting, standing and walking, these events occupy their attention to a greater extent than vocalising. Longitudinal observations of vocalisations in relations to these physical milestones will need to be conducted.

Limitations

A concern in this study is the small sample size. Because this was a longitudinal study, where infants were being seen on a weekly basis for a period of several months, the number of infants we could follow on such an intensive schedule was limited. This intensity and longitudinal nature also limited the pool of participants for our study. Although monetary compensation was provided for each session, most parents tended to be of high to middle SES backgrounds presumably because these families were able to more readily participate in the study on a frequent and long-term basis.

A second concern in this study was possible order effects. The Interview circumstance was most likely to be recorded first, and therefore, it is possible that an infant did not have enough time to warm up in this circumstance, resulting in lower volubility during the Interview circumstance. Order effects of circumstance on volubility would have to be explored in future studies.

Clinical implications

First a caveat: Our study focused on typically developing infants in the first year of life. No infants with disorders were included. But, the groundwork has been laid for studies with disordered populations given the present findings. In particular, our results speak to how one might obtain samples of vocalisation for purposes of clinical assessment. The findings suggest possible improvements in the nature of elicitation strategies for obtaining samples of vocalisation to assess and/or intervene with infant vocal development as well as possible improvements in the interpretation of results obtained in vocalisation sampling.

A common approach to assessing and intervening with infant vocal capability employs face-to-face elicitation. This approach is consistent with a considerable literature suggesting infants (at least beyond 3 months) are responsive to such elicitation. However, the approach does not offer the opportunity to assess the infant's presumable endogenous tendency to vocalise, and our results suggest that tendency is strong enough to produce volubility as high as that occurring during parental talk and interaction. The results hint at the possibility that clinical assessment might profit from directly considering vocalisation produced spontaneously when infants are not being addressed vocally. A circumstance in which there is absence of vocal stimulation may allow the clinician the opportunity to observe the raw

material that the infant brings to the learning context, which can then be shaped by the parent and/or clinician within an interactive context to advance the infant in their vocal development.

In addition, the findings suggest it might be wise for clinicians to limit the amount of time they are present in the room with infants during assessment and not to be talking too much to caregivers when obtaining vocalisation samples from infants. The presence of a somewhat unfamiliar person, such as an experimenter, or alternatively simply the presence of adult-to-adult talk, could have the effect of depressing the quantity of infant vocalisations. Similarly, during intervention, the clinician might consider ‘coaching’ the parent (e.g. Wetherby et al., 2014) to elicit vocalisations from the infant instead of trying to elicit vocalisations themselves. The infant may be more inclined to vocalise with their caregiver rather than a relatively unfamiliar clinician.

These implications should, however, be tempered given the considerable individual variability observed in the present study. We tried to reduce individual variability by collapsing sessions into three age ranges. Values for overall utterance rate still ranged from 0.38 utterances per minute to 16.08 utterances per minute across infants. Also, although group results showed that infants vocalised least in the Interview circumstance, not all infants showed this tendency. Four out of 14 infants (for whom data was available in all circumstances) vocalised least in the Talk circumstance instead. It should be noted, however, that the utterance rate in the Talk circumstance for these four infants was only slightly lower than that in the Interview circumstance. Individual differences will need to be taken into consideration when planning clinical assessment and/or intervention.

Clinical populations may, of course, respond somewhat differently than the typically developing infants in the present study to the varying circumstances. For example, infants at risk for social communication disorders, such as autism, may vocalise differently than typically developing infants when there are variations in the amount of talk and interaction directed towards them. This, we take to be a key question for future research, where the findings on typically developing infants provide a foundation for determining potentially crucial differences in how infants having or being at risk for autism may vocalise in differing social circumstances. In addition, it is worth mentioning that infants at risk for communicative disorders but with strengths in social communication, such as infants with Down syndrome, may show yet a different vocalisation pattern across circumstances than either typically developing infants or infants with autism. These potentially differing patterns may also vary across different levels of SES. Consequently, we propose research to evaluate responsivity and endogenous vocalisation tendencies of infants across a broad range of social circumstances and possible disorders.

Acknowledgments

We would like to thank the parents and infants for their study participation. We would also like to thank the numerous undergraduate and graduate assistants who worked countless hours to collect and analyse this data.

Funding

This research was supported in part by grants R01 DC006099 and DC011027 from the National Institute on Deafness and Other Communication Disorders and by the Plough Foundation, which supports Oller's Chair of Excellence at the University of Memphis.

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Figure 1.

Mean overall utterance rate (and standard error) of infants across three circumstances (No Talk, Talk and Interview) and three ages (2–5.5, 5.5–7.5 and 7.5–11 months).

Figure 2.

Mean non-fussy utterance rate (and standard error) of infants across three circumstances (No Talk, Talk and Interview) and three ages (2–5.5, 5.5–7.5 and 7.5–11 months).

Figure 3.
Mean percentage of time (and standard error) infants vocalized across three circumstances (No Talk, Talk and Interview) and three ages (2–5.5, 5.5–7.5 and 7.5–11 months).