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Children's use of the prosodic characteristics of infant-directed speech

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1. Introduction

As adult speakers, we are constantly taking the listener into account as we speak. For example, we speak more slowly and carefully for young listeners and foreigners than for more experienced listeners (Drach et al. 1969). We also produce individual words more slowly when they are new to the discourse and the listener (Samuel and Troicki, 1998; Fowler and Housum, 1987; Gregory and Jurafsky, 2001). And our speech style changes for people who are colleagues as compared to elders (Nakamura, 1998).

Children also need to learn to adjust their speech and behavior for the listener. Although some distinctions are clearly made at very young ages (e.g. infants may wave bye-bye to their parents but not to strangers), other types of listener distinctions are not made until children are much older (Gleason, 1973), and may need to be learned (Nakamura, 1998).

One particularly obvious form of these listener-dependent speech changes is infant-directed speech (IDS). This form of speech (also known as motherese) often contains a simplified, restricted vocabulary and increased repetition (Drach et al., 1969; Broen, 1972; Snow, 1972; Phillips, 1973; Papousek et al. 1985; but see Ochs and Schieffelin, 1984). IDS is spoken more slowly and with shorter sentences (Drach et al., 1969; Broen, 1972), and pauses tend to be limited to sentence boundaries (Broen, 1972). Important words tend to be placed in salient positions,

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even at the expense of grammar violations (Fernald and Mazzie, 1991; Aslin, 1993), and words (especially function words) tend to be hyperarticulated (Bernstein Ratner, 1984; Andruski and Kuhl, 1996). However, the most obvious speech alterations in IDS are prosodic ones: IDS is usually produced with higher pitch, greater pitch variability and volume variability, and with a small set of highly distinctive melodic contours (Jacobson et al. 1983; Fernald and Simon, 1984; Papousek et al., 1985; Fernald et al., 1989). It is also produced with exaggerated positive affect, even when this violates grammatical principles (Masataka, 1992; Reilly and Bellugi, 1996).

These speech changes appear to have a number of benefits. In particular, infants appear to prefer listening to this style of speech (Fernald, 1985; Fernald and Kuhl, 1987; Shute, 1987; Werker and McLeod, 1989; Pegg et al. 1992; Werker et al. 1994). Thus, this speech style serves to increase infant attention to communication by making speech more interesting (Snow, 1972).

In addition, infant-directed speech seems to facilitate a number of language-learning tasks. Focused words in IDS tend to be placed on pitch peaks (Fernald and Mazzie, 1991) and in salient positions, such as sentence-finally (Aslin, 1993), which may aid learning. Kemler Nelson and colleagues (Kemler Nelson et al. 1989) found that infants are sensitive to segment marking cues in infant-directed but not adult-directed speech, and Golinkoff and Alioto (1995) found that adult listeners learned new words better when spoken in an infant-directed manner (although see Fernald and McRoberts, 1996 for an argument against the idea that IDS may aid learning). IDS can facilitate associative learning even for non-linguistic information (Kaplan et al. 1996). There is also evidence to suggest that IDS may aid listeners in separating speech from background noise (Colombo et al. 1995; Newman and Weppelman, submitted), and that adults judge infants listening to this speech style as more appealing, suggesting it may help establish greater emotional ties between parents and infants (Werker and McLeod, 1989).

For these reasons, infant-directed speech appears to be nearly ubiquitous among both men and women from a variety of cultures (Blount, 1972; Ruke-Dravina, 1977; Grieser and Kuhl, 1988; Warren-Leubecker and Bohannon, 1984; Fernald et al., 1989; Shute and Wheldall, 1989; Werker and McLeod, 1989; Cruttenden, 1994; but see Ochs, 1982; Ochs and Schieffelin, 1984). It is used by both parents and non-parents with approximately the same frequency (Jacobson et al., 1983), and is frequently used by the teachers of young children (Morra Pellegrino and Scopesi, 1990) as well as in children's television shows (Rice and Haight, 1986). Despite this consistency, aspects of it do differ across cultures (Smith-Hefner, 1981; Ochs, 1982; Bernstein Ratner and Pye, 1984; Ochs and Schieffelin, 1984; Crago et al. 1997) and even across towns within the same culture and geographical area (Heath, 1983), suggesting that the way infant-directed speech manifests may be culturally determined.

A number of studies have begun examining children's use of this infant directed speech style (Shatz and Gelman, 1973; Sachs and Devin, 1975; Dunn and Kendrick, 1982; Warren-Leubecker and Bohannon, 1983). For example, Sachs and Devin (1975) showed that children 3–5 years of age tend to use shorter utterances, more endearments, and more usage of name when speaking to an infant than to an adult.

They also tended to ask infants less questions than they did to an adult or peer. Woollett (1986) likewise showed older children using shorter utterances when speaking to infants, and Shatz and Gelman (1973) found that 4-year-olds used larger MLUs and less complex constructions when speaking to 2-year-olds than when speaking to adults. Finally, Warren-Leubecker and Bohannon (1983) found that children as young as 3 will shorten their sentences when faced with signals of non-comprehension from a young listener.

Nwokah (1987) reported that child caregivers (aged 9–11) did not differ from mothers in what they talked about, although they did differ in how they spoke, with the primary differences being structural. For example, child caregivers use more concrete nouns and more imperatives, while mothers use more abstract nouns and more declaratives. Nwokah suggested that a child's age affects how he/she will interact with an infant, while being a sibling does not affect these interactions.

Dunn and Kendrick (1982) found that even children as young as 2 will increase attention-getting and attention-holding utterances, shorten their utterances and increase repetitions when speaking to infant siblings. However, there was much more variability among these young children in terms of their use of the affective and expressive components of IDS, such as the use of endearments and questions. These aspects of IDS were only used by those children who had "particularly warm and affectionate relationships with their siblings" (p. 593).

Despite this large number of studies of IDS in young children, none have focused on the prosodic aspects of IDS, such as pitch variation, despite the fact these prosodic components are often the most salient features in adult IDS. Instead, the studies of IDS in young children have consistently focused on discourse-related variables such as sentence structure, to the exclusion of acoustic changes. Tomasello and Mannle (1985) did find that preschoolers used a motherese-style intonation when speaking to an infant proportionately less often than did adults, but they did not compare the children's speech to infants with their speech to adults. Thus, while their findings suggest that children are not as adept at infant-directed speech as are adults, these results do not answer the question as to whether children use this speech style when speaking to infants in the first place.

The present study was designed to examine these prosodic changes in children. We chose to focus on children 4 years of age as this is an age where children quite consistently show the conversational changes at the level of discourse. Would these children also show prosodic changes when speaking to infants?

There are a number of reasons why speech alterations at the levels of sentence structure and prosody might be disconnected. First, the benefits of shorter sentences to a naïve listener may be more intuitive than the benefits of prosodic changes. If children are deliberately altering their speech with the listener in mind, they may be more likely to make changes that have an obvious linguistic or cognitive benefit. Supporting this argument, Dunn and Kendrick (1982) found that children primarily made simplifying changes to their speech, but did not make more affective or attentional alterations. Since prosodic changes are more likely to fall into the latter category, this argument would predict that children would not make these more acoustic changes.

A second possibility has to do with the limited cognitive resources available to children of this age. Choosing to use shorter sentences is likely to be a relatively simple task, primarily influencing children's sentence planning skills. Intentionally varying pitch throughout a sentence may require more cognitive resources on-line. Furthermore, shorter sentences are, by their very nature, easier to produce than longer sentences. In contrast, there is no reason to believe that highly varying prosodic patterns or increased pitch would be any easier to produce than typical levels. For these reasons, the fact that children are capable of making changes in sentence structure need not be an indication that they would make the prosodic changes typical of infant-directed speech as well.

This paper also examines the role that experience may play in children's speech adjustments. Although research suggests that having a younger sibling does not influence sentence structure or simplification (Shatz and Gelman, 1973), prosodic changes might be different. Sentence shortening and pause lengthening are changes used for a wide variety of less skilled conversational partners, including foreigners, the mentally impaired, and the elderly (Ashburn and Gordon, 1981; Caporael and Culbertson, 1986; DePaulo and Coleman, 1986; Kemper, 1994; Wingfield and Stine-Morrow, 2000). As such, children may have heard adults make these changes more frequently. Pitch modifications tend to be more specifically used for infant listeners, and thus children who do not have frequent infant exposure may not have had the opportunity to observe these changes in adult speech. There may therefore be a role for specific experience in children's use of IDS, such that children with frequent infant exposure (say, those with younger siblings) may be in a better position to learn to make these prosodic speech changes. In fact, work with adults suggests that while parents and non-parents do not differ in their use of simplification (Snow, 1972), or pitch changes (Jacobson et al., 1983), experience with infants does influence speech changes among non-parents (Jacobson et al., 1983). Furthermore, women who themselves have other siblings are more likely to modify their speech than are women who grew up as only children, suggesting that particular experiences can have long-lasting influences on prosodic modifications (Ikeda and Masataka, 1999).

Gender may also play a role in IDS use. Most aspects of IDS are produced similarly by both men and women (Jacobson et al., 1983; Lipscomb and Coon, 1983; Warren-Leubecker and Bohannon, 1984; Papousek et al., 1985). However, some studies suggest that females use more extreme changes in F0 variability (Shute and Wheldall, 1999). Furthermore, they tend to maintain the change in speech style to older children than do males, altering their speech even to children as old as five years (Warren-Leubecker and Bohannon, 1984). Four-year-old children are therefore likely to hear their mothers use this style of speech when speaking to them, but are less likely to hear this style of speech from their fathers, unless there is also an infant present. While there is no clear evidence for when gender differences in speech more generally begin to develop, many changes appear to be based more on culture than on physiology (McConnell-Ginet, 1978). This suggests that the differences could potentially be present even in young children, especially if children attempt to model their own speech after that of their same-gender parent. Although work on

sentence simplification in children has not shown evidence of gender differences (Shatz and Gelman, 1973), adult gender differences have also not been found with these measures.

The present study examines the roles of specific experience (having a younger sibling) and gender on children's use of the prosodic characteristics of IDS. More specifically, we examine the average pitch, average word duration, and pitch and amplitude variability of 4-year-old children when speaking to an infant as compared to when speaking with an adult.

2. Method

2.1. Participants

Children were recruited either from local day cares or via a letter sent to parents of children who had participated in other research studies previously. A total of 24 children participated in this study (12 males, 12 females), with a mean age of 4 years, 3 months (range: 4 years, 3 months–4 years, 11 months). Half of the participants of each gender had younger siblings, and half did not. The children were all healthy with no history of language and/or learning disorders. Data from an additional nine subjects were not included because of fussiness ($n=2$), equipment failure ($n=3$), or experimental error ($n=4$). Children received a small toy in exchange for their participation.

As the experiment required that children speak to an infant, we needed a single infant participant as well as the actual test subjects. Some research has suggested that children aged 4–5 years are more likely to interact with a female infant than a male infant (regardless of the child's own gender; see Melson and Fogel, 1982); for this reason, a female infant was selected as the participant. The same infant was used throughout the study: her age ranged between 4 and 12 months of age during the course of the study.

2.2. Apparatus

A Marantz PMD222 tape recorder was used to record all subjects. Due to equipment failure, we changed microphones partway through the study. Subjects were recorded using either a Shure MX185 lapel microphone or a Sony EMC17 lapel microphone. An equal number of participants in each group used each microphone, such that this did not confound with group membership.

2.3. Procedure

Parents of our participants were asked to complete a short questionnaire asking about their child's interactions with infants as well as their language experience.

The task used here is similar in some ways to that used by Shatz and Gelman (1973). Children were tested in a quiet room either at a local day care that they attended, or in a laboratory. The infant was kept in a separate room from the children

prior to testing. The experimenters refrained from using infant-directed speech when talking to the children, or when talking to the infant in front of the children. The children were first tested without the infant present. They were asked to show the experimenter how to use a Mr. Potato Head toy and to name all of its parts. They were also shown two Winnie-the-Pooh picture books and asked to name the characters and objects on each page. The order of these two tasks was counterbalanced across children. The children's speech during these tasks was recorded onto audio cassette, and this served as the example of the children's adult-directed speech.

When these tasks were complete, the infant was brought into the room and introduced to the child. The child was then asked to show the infant how to use the Mr. Potato Head toy, and to show her the books. The order of these two tasks was the same as in the first part of the study. This speech was recorded as the child's infant-directed speech. The entire procedure took approximately 25 min.

This order of listeners was kept constant. Although counterbalancing of the order would have been preferable, several aspects of the task prevented that. First, the experimenters needed to prompt children into naming objects the first time through; this necessarily results in adult-directed speech from the child. Second, we expected that the children would not be willing to show the pictures or the toy to an infant until they had played with them themselves for a few minutes.

The recordings from each child were digitized at a sampling rate of 44.1 kHz, with 16-bit quantization, and stored on computer disk. The first 10 content words spoken by each child that occurred without background noise in both the infant-directed and adult-directed speech were selected for further analysis. The fundamental frequency, amplitude, and duration of each word were measured using the Cool Edit 96 computer program by Syntrillium. Amplitude and duration measures were taken across the entire target word; fundamental frequency was measured over the largest voiced section of the word. Reliability was measured by having two observers separately analyze the speech from each of the first 12 subjects. For the duration measure, the correlation between the two observers was $r = 0.935$. For the fundamental frequency, the correlation was $r = 0.757$, and the correlation was $r = 0.978$ for the amplitude measure. These correlations suggest that measurements are quite consistent across observers, although the measures of fundamental frequency were more variable. For these 12 subjects, the average of the two coders' measures was used in the later data analysis.

From these calculations, we determined four measures for each child in each condition: average fundamental frequency, standard deviation of fundamental frequency, amplitude standard deviation, and average duration. Each measure was compared across conditions (infant-directed vs. adult-directed) using a within-subjects *t*-test.

3. Results and discussion

We first looked for overall differences in speech to adults versus speech to infants, across all four measures, and found a significant effect of listener. That is, the

children spoke differently to an infant than to an adult [$F(1,21) = 5.12$, $P < 0.05$], although this interacted with the type of measure, suggesting that this difference in speaking style was not equivalent in the four measures [listener $F(3,63) = 7.32$, $P < 0.0005$]. The effect of the listener also interacted with child's gender [$F(1,21) = 5.72$, $P < 0.05$], but not with whether the participant had a younger sibling or not [$F(1,21) = 1.31$, $P > 0.1$].

Given these overall results, we examined each speech production measure separately, beginning with duration. We predicted that children's word durations would be longer in the infant-directed version than in the adult-directed version. This is indeed the case. Children spoke significantly more slowly to the infant than they did to the adult listeners [$F(1, 21) = 6.91$, $P < 0.2$), as shown in Fig. 1.

This effect of listener (adult vs. infant) on duration had a marginal interaction with talker gender [$F(1, 20) = 4.19$, $P < 0.06$], such that this speech slowing was much greater for girls than boys. In contrast, whether the participant had a younger sibling did not influence the results ($F < 1$). On average, girls slowed their speech by 120 ms when speaking to the infant, whereas boys only slowed their speech by 15 ms. This gender difference may be a further example of the fact that girls typically have more advanced verbal skills than do boys of the same age (Galsworthy et al. 2000). Girls may therefore have more cognitive resources available to them to devote to making changes to their typical production style.

We next examined amplitude variability, shown in Fig. 2. We expected that children would vary their amplitude when speaking to young infants as a way of maintaining infant attention. Although there was no overall effect of listener ($F < 1$), there

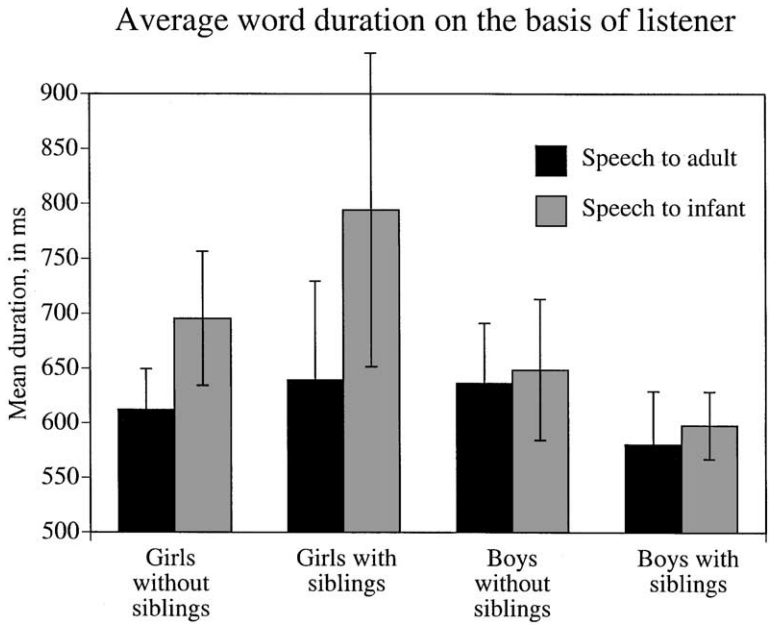

Fig. 1. Average target word duration for adult-directed and infant-directed speech.

was again an interaction between listener and gender [$F(1,21) = 5.11$, $P < 0.05$]. Boys tended to decrease their amplitude variability when speaking to infants (relative to adults), whereas girls tended to increase their variability. This may be an indication of differences in normal amplitudes; although we had not planned on measuring this explicitly, our subjective impression was that boys tended to get very excited at naming pictures, and often shouted out the answer to the adult experimenter. (A post-hoc analysis shows that average amplitude for boys was marginally greater than that for girls [$F(1,21) = 3.55$, $P < 0.10$), although this may have been the result of outside variables such as microphone placement.) The occasional shouting gave the boys a large amount of variability in the adult-directed condition (a range of 14.87 dB, compared to 11.59 dB for the girls). The boys seemed less likely to shout when speaking with infants, resulting in a lower amplitude range (11.09 dB). Girls showed the opposite pattern, having a much lower amplitude range when speaking with adults (11.59 dB) than with children (13.97 dB). Thus, girls again show changes more typical of adults' speech to infants, as might be expected if they were more advanced verbally than were the boys. As with the duration effects, there was no indication that having a younger sibling influenced the degree to which children adjusted their speech to infants ($F < 1$).

Finally, we examined both average fundamental frequency and fundamental frequency standard deviation (Figs. 3 and 4). These two factors are among the most consistent changes that adult speakers make when talking to infants. Prior research has shown that adults increase both their average fundamental frequency and F0

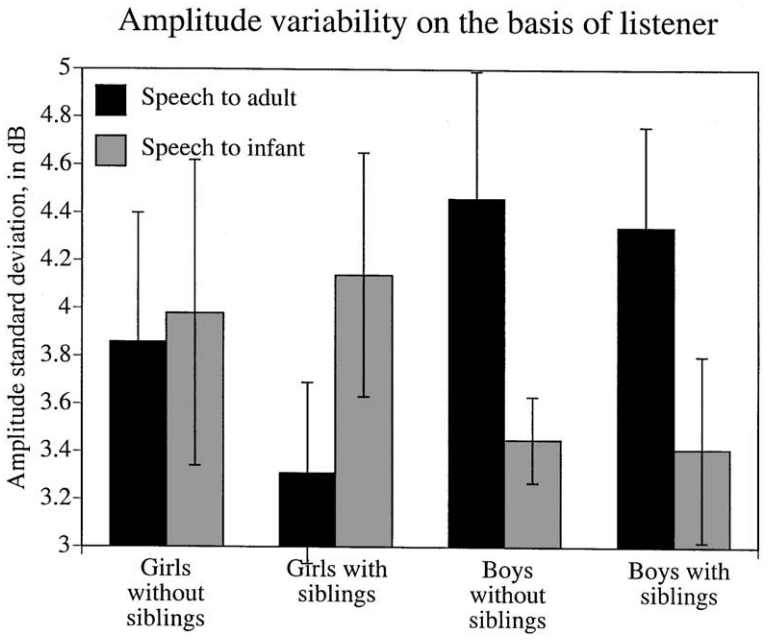

Fig. 2. Average standard deviation of target word amplitude for adult-directed and infant-directed speech.

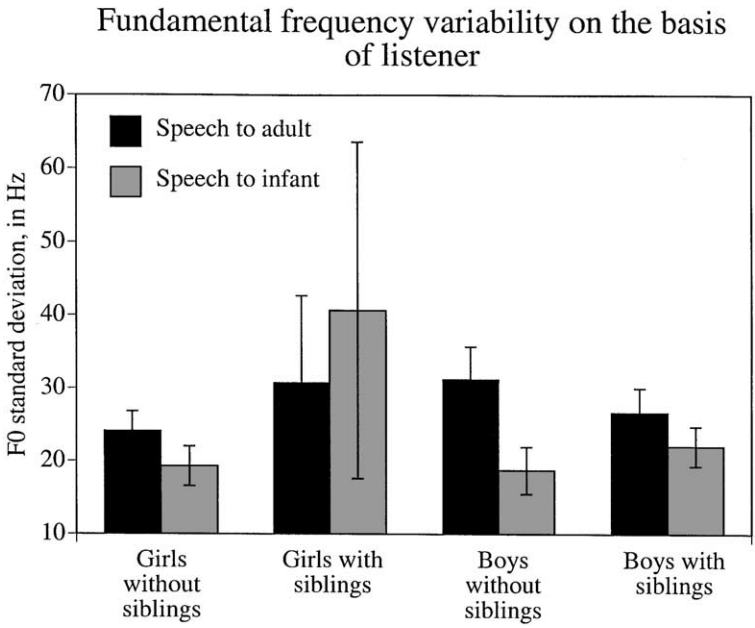

Fig. 3. Average target word fundamental frequency for adult-directed and infant-directed speech.

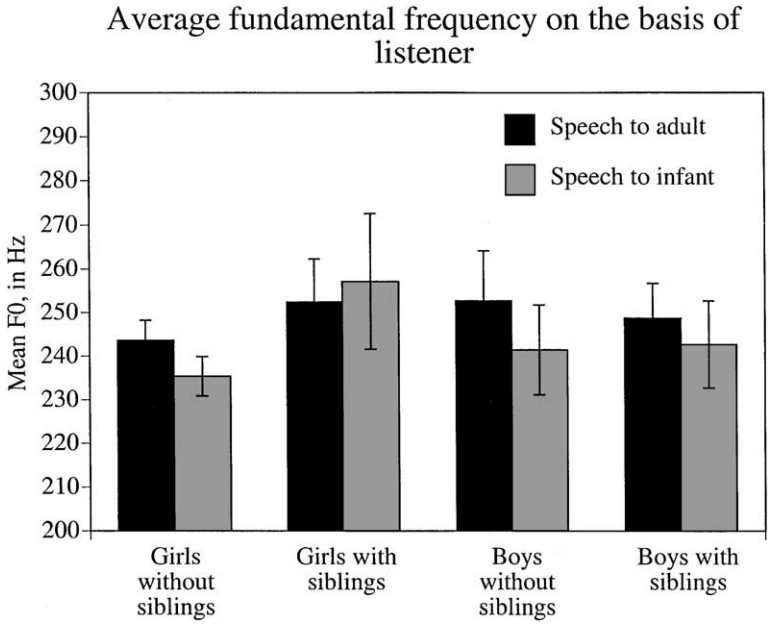

Fig. 4. Average standard deviation of target word fundamental frequency for adult-directed and infant-directed speech.

variability in infant-directed speech (Fernald et al., 1989). Pitch variability appears to be the most important acoustic change in infant's preference for motherese (Fernald and Kuhl, 1987). Surprisingly, we found little evidence of such an effect in children. Children showed only a marginal effect of listener on their average pitch [$F(1,21 = 3.19$, $P < 0.10$], and that was in the opposite direction of that expected from adult research (average pitch to adults, 249 Hz; average pitch to infants 244 Hz). This did not interact with child gender [$F(1,21) = 1.39$, $P > 0.10$] or with experience with younger siblings [$F(1,21) = 2.40$, $P > 0.10$]. There was no overall effect of listener on pitch standard deviation, either ($F < 1$). However, there were marginal interactions of F0 variability with both gender and siblings [for gender, $F(1,21) = 3.02$, $P < 0.10$; for siblings, $F(1,21) = 3.12$, $P < 0.10$]. Girls tend to show an increase in F0 variation when speaking to infants, whereas boys tend to show the reverse. Furthermore, children who have younger siblings tended to show an increase in F0 variation, whereas those without younger siblings did not. However, as Fig. 4 makes clear, these marginal effects are primarily caused by the girls who had younger siblings, who also showed extreme variability.

The lack of overall effects of pitch variability are quite surprising, as this was the property that we most expected to find altered for speech to infants. So too was the lack of an effect for mean F0. It is unclear why children are not adjusting their speech in this manner. One possibility is that they are not themselves sensitive to pitch changes; however, given young infants' strong preferences for higher pitch and pitch variability, it seems unlikely that older children would not notice these changes as well. However, even if children may be aware of these changes perceptually, they may not be sufficiently cognizant of them to attempt to make similar changes themselves.

Another possibility is that children are not sufficiently skilled vocalists to adjust their fundamental frequency on demand. This could take one of two forms: they may not have the necessary muscular control to voluntarily adjust their fundamental frequency, or alternatively, they may not have the cognitive resources available to do so. The former seems unlikely, given research on children's use of lexical tone in tonal languages (Li and Thompson, 1976). Li and Thompson examined tone production of Mandarin-speaking children between ages 1;6 and 3;0. Although rising and dipping tones were more difficult than high or falling tones, the children nonetheless appeared to have mastered the four-way tone distinction quite early. This would suggest that children far younger than those tested here are able to control aspects of their vocal pitch. Thus, it seems more likely that children are lacking in cognitive resources than that they are lacking in muscular control.

The trends towards interactions in the standard deviation data suggest that children of this age are just beginning to learn to make changes in their fundamental frequency variability. As in several of the other measures, girls tended to show the pattern typical in adults, whereas boys did not (for girls, the F0 standard deviations were 27.4 when speaking to an adult, but 30 when speaking to an infant; for boys, the values were 28.9 and 20.4 respectively). Furthermore, those children that had younger siblings were also more likely to show an adult-like pattern than were those that did not have younger siblings (for those with, SD = 27.7 with adults, but 29.0

for infants; for those without younger siblings, variability was 27.7 with adults, but 19.0 with infants).

If children are just beginning to make F0 changes, the 10 words examined here may not have been sufficient to see these changes. We decided to investigate F0 changes further by examining fundamental frequency over the entire experiment. A subset of 12 subjects was selected for this more in-depth analysis on the basis of overall recording quality. The recordings were edited to remove portions in which the experimenter spoke, or in which the infant vocalized. The speech was then downsampled to 10 kHz in order to make the analysis program's memory requirements less severe. A speech analysis program was used to measure the child's fundamental frequency at every 5 ms of the recordings. These measurements were done over a 15 ms window, resulting in overlapping measurements. From these successive measurements, two summary values were obtained: an overall mean pitch across the measures, and the standard deviation of the pitch (a measure of pitch variability). The analysis program indicated whenever it failed to find a pitch in a given time window (which happened during pauses, or voiceless consonants, for example). The pitch summary values were calculated only on those portions where the program successfully found a pitch.

There was a great deal of variability in the amount of voiced speech present. The number of measurements per child per condition ranged from 1,381 for a female with siblings speaking to an infant to 19,525 for a male with siblings speaking to an adult. Although there was no significant difference between the amount of voiced speech spoken to adults versus to infants [$F(1,11) = 1.98$, $P > 0.10$] we were still concerned that these differences in numbers of tokens might influence measures of variability. We therefore computed each pitch measure twice: once using the full amount of speech per child per condition, and a second time matching the number of measures per condition. (Thus, if a child had 8000 measures for adult-directed speech, but 7500 measures for infant-directed speech, we would calculate the statistics over the first 7500 measures in each condition.) In no case did this change the pattern of results, however, and the measure on matched samples is the one reported below.

There was still no effect of pitch variability with these larger speech samples [$F(1,11) = 2.31$, $P > 0.10$]. However, there was a significant effect of listener on average pitch, such that children used higher pitch when speaking to an adult than to a child [by 12 Hz; $F(1,11) = 13.93$, $P < 0.01$]. This pattern had been a trend over the ten target words; that we found it here as well suggests that it is a reliable aspect of these children's speech. Thus it appears that children are modifying their pitch when speaking to infants, but not in an adult-like manner. There was also a three-way interaction, however [$F(1,8) = 10.13$, $P < 0.05$]: boys with siblings did not show this pattern of greater F0 measures when speaking to an adult, although the other three groups did.

In summary, children do seem to change their speech style in some manners when speaking to an infant rather than an adult. However, children do not appear to show the same pattern of these changes as do adult listeners. Children focus primarily on changes to their word duration, rather than to the prosodic changes more typical of adult speech. These pitch changes are just beginning to appear in these children's speech.

In some ways, it may be unsurprising that durational changes appear earlier than frequency ones. Changes in word duration, like changes in sentence length, may be highly pre-planned, and thus may not require much in the way of on-line cognitive resources. Thus, these may be the easiest changes for young children to make to their speech.

Across our various measures, girls tend to show more adult-like patterns of speech style change than do boys, suggesting that this is another domain in which advanced linguistic skills may be important. In contrast, there was only one measure (that of F0 standard deviations) in which we saw even a marginal effect of experience with siblings. This suggests that many of the differences between how children and adults speak to infants may be more based on maturational factors than experiential ones.

4. Conclusions

The present results indicate that 4-year-old children do modify some of the prosodic characteristics of speech when speaking to infants. In particular, they speak slower when talking to infants than when speaking with adults. They also show a slight trend towards lowering their fundamental frequency, and they seem to make some changes to amplitude variability as well.

One possibility is that these duration effects are not actually related to the listener, but instead are caused by the repetition of the information. Adult-directed recordings were consistently taken first, with the infant introduced afterwards. This means that the child was repeating the same information a second time when speaking to the infant, and this repetition itself could influence production. For example, Fowler and Housum (1987) found that repeated words are often reduced in duration when they are repeated. Since the information is no longer novel, less information is presumably needed for the listener to appropriately perceive the words. Speakers take advantage of this by attenuating their production. Furthermore, Fowler et al. (1997) found that talkers reduced the duration of redundant words that are repetitive to them, but not necessarily to their listeners (although see Gregory and Jurafsky, 2001 for an opposing argument). They found that talkers/readers shortened the length of a word based on whether or not they thought it was repetitious, regardless of whether the listeners had heard the word. This suggests that even though the infant was hearing these words for the first time, the children might nonetheless be treating them as repetitions.

Since infant-directed speech always followed the adult-directed speech in the current study, effects of repetition are confounded with effects of IDS, and we cannot be positive that repetition was not influencing our results in some manner. However, the direction of our effect is opposite that expected on the basis of repetition. Fowler and Housum (1987) found that speakers consistently reduced their productions when repeating them. Samuel and Troicki (1998) found similar results for children. Yet the children in our study were lengthening their production when speaking them the second time. This suggests that the effects are more likely due to the age of the listener than to the fact that the words had been previously produced.

There were some indications of an influence of gender on IDS. Girls tended to show greater durational changes than males, and tended to show amplitude variability effects and fundamental frequency variability effects in the expected direction while boys showed effects in the opposite direction. It is possible that these differences are related to the gender of the infant; young children especially are more likely to interact with an infant of the same gender than of opposite gender. However, by the time children reach 4 or 5 years, these patterns seem to change, with both boys and girls of this age being more likely to interact with female infants than male infants (Melson and Fogel, 1982). This suggests that the gender of the infant is unlikely to cause the differences found here. Instead, these gender differences may be a further indication of girls' general tendency for more advanced verbal skills.

Alternatively, these gender differences between children may be related to gender differences in adult speech. Although some researchers report that fathers make many of the same acoustic changes that mothers make (Jacobson et al., 1983), others have reported that fathers fail to show changes in F0 variability, even though this appears to be one of the most salient characteristics in women's speech to infants (Fernald et al., 1989; Shute and Wheldall, 1999; but see Warren-Leubecker and Bohannon, 1984). Furthermore, Shute and Wheldall (1999) found that as many British fathers lowered their mean F0 to children as raised it. Fernald et al. (1989) suggested that women are generally more expressive in speaking to infants than are men. The children in the present study may be picking up on these differences in adult speech, and modeling their own speaking styles on those of their same-gender parents. Mothers and fathers also differ in terms of the age at which they stop using IDS (Warren-Leubecker and Bohannon, 1984). Although both parents tend to speak with a raised pitch and increased pitch range to 2-year-old children, fathers drop these speech patterns by the time children are 5-years old. It is possible that the 4-year-old children in the present study were themselves spoken to in an IDS style by their mothers more than by their fathers.

These gender differences may extend beyond those of speaking style. Melson and Fogel (1982) found that girls aged 2–5 years were more likely to touch female infants than male infants, while boys were more reluctant to touch infants of either gender. Feldman et al. (1977) found that girls were more likely than boys to show interest in infants both in pictures and in person, although the youngest age they tested was 8- to 9-year-olds. The trends towards greater IDS in girls than boys in the present study may be a further indication of girls' interest in infants generally.

There were no differences between children in this study who had younger siblings and those that did not. This seems to argue against the idea that specific experience with infants is crucial to developing infant-directed speaking styles. However, it is possible that having a younger sibling was not the best way to experimentally define exposure to infants. Some of our 4-year-old participants with younger siblings had siblings who were still infants at the time of testing; others had siblings who were only a year younger than themselves, and thus may not have had ongoing infant exposure. Likewise, some of those children who did not have younger siblings may have had infant cousins with whom they interacted frequently, or may have experienced frequent infant interactions in day-care settings.

To investigate this, we examined parental responses to the questionnaire and reclassified the children according to their reported amount of contact with infants. Yet even with this reclassification, we did not find any interactions between experience with infants and the children's speech characteristics. It appears that experience with infants does not play a sizeable role in children's development of an infant-directed speaking style.

We did not find strong effects of listener on the children's fundamental frequency. Changes in mean F0 and F0 variability are among the most salient changes in adult speech to infants (at least in English; see Bernstein Ratner and Pye, 1984), and are the changes more responsible for infants' increased attention to this speech style (Fernald and Kuhl, 1987). It is therefore quite surprising that the children in the present study did not also make these changes. It is unclear whether the children examined here did not have sufficient vocal control to makes these changes, or had not learned to do so. A number of studies suggest that children do reliably increase their pitch when speaking to dolls before the age of three (Sachs, 1977) and one of the three children examined by Weeks used higher pitch when speaking to his younger sibling by the age of five (Weeks, 1971). Furthermore, children have been shown to increase their pitch when singing to infants than to adults (Trehub et al. 1994), which suggests a modicum of vocal control, as well as an understanding of the use of higher pitch. However, the Trehub et al. study examined children of a wide range of ages (from 2;6 to 8;3; mean = 4.9), and it is possible that the significant differences were driven in large part by the older children. (The authors note that when adult listeners were asked to discriminate between infant-directed and adult-directed singing, their performance varied widely across the children, with some children's singing identified at $>90\%$ accuracy and others virtually at chance. However, these variations did not appear to be related to the age of the singer.) These results suggest that children are capable of making pitch changes by the age studied here. Perhaps even more striking, children learning tonal languages master these distinctions productively while still at the one-word stage (Li and Thompson, 1976). This early control over lexical tone makes it quite clear that children have the necessary physiological control of their pitch at a very young age.

One possibility is that children may first learn to use higher pitch when speaking (or singing) to their own sibling, and only later generalize that to other infants. In Trehub et al's study, the infant was always the sibling of the child being tested, and the child studied by Weeks who reliably used baby-talk did so when speaking to his younger sister (1971). In contrast, the infant in our study was always unknown to the children (and most of the children in the present study did not have an infant sibling at the time of testing).

Another possible difference is that of the task itself. Goldstone has reported that children in his study made F0 changes to infants only when facing them. When the children looked down at the book they were reading from, their pitch dropped to normal levels (personal communication). This suggests that children may have difficulty remembering to speak in an infant-directed manner without the constant visual reminder. We did not videotape the children in this study, so we have no way of determining whether the children were looking at the infants at the time that they

spoke the target words. However, since the children's tasks involved flipping through a picture book and putting together a Mr. Potato Head toy, it seems likely that they were often looking at the object or picture being described, rather than looking at the infant.

Yet if the children were forgetting to whom they were speaking, we would not have expected to find changes by any measure. The children here did show durational differences *on the very same words* for which they failed to show significant F0 changes. Furthermore, the overall effect of listener (across measures) was also significant. Assuming that the children were forgetting to whom they were speaking is therefore not a sufficient explanation by itself. Instead, it appears that slowing speech either requires less cognitive resources than does making pitch changes, or is easier to maintain in memory in taxing situations.

One possibility is that IDS is an indication of children's developing "Theory of Mind". Young children often do not seem to recognize that other people are individuals with their own thoughts, feelings, and desires; the development of this understanding is taken to be an indication that children have a theory of other minds. Understanding that infants have special communicative needs could likewise be an indication of this knowledge. However, many of the speech changes made by young children appear to be made without conscious reflection (Gombert, 1987). This suggests that they are not an indication of children's understanding of the addressee's competency. Furthermore, children of the age studied here frequently fail to recognize ambiguities and inconsistencies that can cause communication failures when they are in the role of listener (Pratt and Nesdale, 1984); it thus seems unlikely that changes in speaking style are the result of a conscious evaluation of information needed by the listener.

In conclusion, then, children aged 4 years do understand the necessity of making prosodic changes to their speech when speaking with infants. Yet these changes do not appear to be effortless, or to be equivalent in their cognitive demands. Making durational changes appears to be far easier for children of this age than does making changes to fundamental frequency.

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