THE IMPACT OF AUTISM ON LANGUAGE INPUT:

A COMPARISON OF THE ACOUSTIC CHARACTERISTICS OF MOTHERS' SPEECH TO TODDLERS WITH AUTISM AND TYPICALLY-DEVELOPING CONTROLS

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by

KELSEY M. MCKINNIS

Dr. Judith C. Goodman, Thesis Supervisor

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The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled

THE IMPACT OF AUTISM ON LANGUAGE INPUT:

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presented by Kelsey M. McKinnis,

a candidate for the degree of master of health science,

and hereby certify that, in their opinion, it is worthy of acceptance.

Associate Professor Judith Goodman

Associate Professor Stacy Wagovich

Assistant Professor Shawn Christ

For Brad

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ABSTRACT

Autism spectrum disorders (ASDs) are a group of complex and increasingly common neurodevelopmental disorders characterized by deficits in language and social skills. One factor that could plausibly contribute to language deficits in children with ASDs is language input. Research suggests that the acoustic characteristics of child-directed speech promote language acquisition in typically-developing children, but there is a dearth of information regarding the use and impact of child-directed speech for children with ASDs. In this study, five mothers of children with ASDs and eight mothers of typically-developing toddlers were videotaped in their homes during interactions with their children and the researcher. Child-directed speech and adult-directed speech were transcribed for each mother using the Codes for Human Analysis of Transcripts (CHAT) and then compared using Praat speech analysis software and ProsodyPro, a Praat script for prosody analysis. Our results suggest that mothers modify their speech in similar ways to both children with ASDs and typically-developing controls. These results contribute to our understanding of the language environment for children with ASDs and have implications for the role of child-directed speech in language development.

CHAPTER 1

Introduction

Autism spectrum disorders (ASDs) occur in all racial, ethnic, and socioeconomic groups, with an average male-to-female ratio of 4:1 to 5:1 (Rice, 2007). Estimates of the prevalence of ASDs vary tremendously. Just 45 years ago, the incidence of ASDs was 4 cases per 10,000 births (Rutter, 2005). More recent estimates are considerably higher, ranging from 30 to 60 cases per 10,000 births (Rutter, 2005) to 1 case per 110 births (Rice, 2009). Even the lower range is about 10 times greater than earlier estimates. This increase may be the result of a number of factors, including increased professional and public awareness of ASDs, a broadened diagnostic concept, and/or a true increase in occurrence. Regardless of the reason, current prevalence and incidence rates suggest that ASD diagnoses are becoming increasingly frequent, making this population and its deficits growing areas of concern.

ASDs are characterized by atypical neurological development that manifests symptoms in the following three areas: (a) impaired sociability, empathy, and ability to read other people's moods and intentions, with resulting inadequate or inappropriate social interactions; (b) rigidity and perseveration, including stereotypies (i.e., purposeless repetitive movements and activities), the need for sameness, and resistance to change; and (c) impaired language, communication, and imaginative play (Rapin & Tuchman, 2008). The focus of this study is on impaired language and communication, and in particular, whether differences in language input may contribute to language delays.

Communication deficits associated with ASDs typically include delay or regression of speech abilities and impairments in both receptive and expressive language abilities (Rapin & Tuchman, 2008). Some children are nonverbal or have sparse, poorly articulated, and agrammatical speech, while others are verbose but use atypical vocabulary, echolalia, frequent verbatim scripts, and unusual prosody (Rapin & Tuchman, 2008). The communication deficits experienced by children with ASDs may impact many areas of their lives, including academic performance and family dynamics (Schopler & Mesibov, 1984).

The mechanisms that underlie these communication deficits in children with ASDs are not well understood. Both motor and cognitive variables (i.e., impairments in oral motor skills, imitation abilities, auditory processing abilities, and attentional faculties) have been linked to language deficits in children with ASDs (Tager-Flusberg et al., 2005). These impairments could affect children's ability to glean linguistic information from input. For example, children with ASDs appear to be less likely than typically-developing age- and language-matched children to attend to developmentally relevant aspects of speech input such as lexical stress patterns or syntactic clause boundaries (Paul et al., 2007).

It has also been argued that communication deficits are related to social impairments in understanding nonverbal cues and theory of mind; when these impairments are severe, children with ASDs may be unable to recognize language as an intentional symbolic system (Tager-Flusberg et al., 2005). Social impairments may also impact parents' language input to children with ASDs. Children with ASDs do not reciprocate their caregivers' attempts to initiate communication because their responsiveness to language input is limited (Tiegerman-Farber & Radziewicz, 2008). As a result, caregivers lack feedback from their children, thus limiting the information they receive about the children's language levels, understanding, and interest in the input. This, in turn, may prevent caregivers from appropriately regulating the content and complexity of their input for their individual children (Tiegerman-Farber & Radziewicz, 2008). Thus, not only may the children's impairments prevent them from making effective use of input, but the type of the input that they hear could possibly be less effective for language learning.

Adults typically modify the speech that they direct to young children. Among the most striking modifications are acoustic changes. These changes may convey positive affect, attract a child's attention, and highlight lexical and syntactic boundaries. It is possible that children with ASDs may fail to elicit this type of input. If so, a lack of child-directed speech might be related to the communication deficits these children exhibit. However, no study has systematically examined the acoustic properties of utterances directed to children with ASDs. A brief review of the literature on child-directed speech is presented below.

Characteristics of Child-Directed Speech. Although researchers have not described the acoustic characteristics of speech to children with ASDs, they have studied the acoustic properties of speech directed to typically-developing children for several decades. In contrast to adult-directed speech, child-directed speech is characterized by higher average fundamental frequency, greater pitch excursions, shorter duration, and rising terminal pitch (Fernald et al., 1989; Garnica, 1974). Infants as young as 2-days-old demonstrate a preference for child-directed speech over adult-directed speech (Cooper & Aslin, 1990). At about 3 to 6 months of age, as children become more responsive, the mean frequency and pitch range of mothers' speech to children are greatest (Kitamura, Thanavishuth, Burnham, & Luksaneeyanawin, 2002). As children move through the toddler years and into the preschool years, the use of these acoustic modifications declines (Garnica, 1974). When children reach 5 years of age, the acoustic features of input are more adult-like, with decreased average fundamental frequency and fewer instances of rising terminal pitch (Garnica, 1974).

The acoustic features of child-directed speech are thought to play a role in word learning (Fernald & Mazzie, 1991; Thiessen, Hill, & Saffran, 2005). In speech directed to 14-month-old infants, mothers consistently produce noun labels in utterance-final position with exaggerated pitch peaks; this may facilitate auditory processing of these content words (Fernald & Mazzie, 1991). Child-directed speech may help even prelinguistic infants to isolate words in fluent speech. When exposed to a set of nonsense sentences spoken with the acoustic features of either child-directed speech (i.e., greater pitch excursion and higher average fundamental frequency) or adult-directed speech, infants between the ages of 6.5 and 8.5 months were only able to discriminate words from part-words when sentences were produced using child-directed speech (Thiessen et al., 2005). In both conditions (child-directed speech versus adult-directed speech), the only cues to word boundaries were the acoustic features of the input and the statistical structure of the sentence, or the probabilities with which sequences of sounds co-occur (Thiessen et al., 2005). When a sequence of phonemes is highly likely to co-occur, it is more likely to be a word. Because sound combinations that make up a word occur together more often than those that cross word boundaries, gaining statistical information about speech is important for word segmentation. The findings of Thiessen et al.'s (2005) study suggest that the acoustic modifications present in child-directed speech, namely exaggerated pitch excursion and higher average fundamental frequency, facilitate the acquisition of statistical information about speech, and thus word segmentation.

The acoustic characteristics of child-directed speech may also facilitate the development of syntax (Kemler Nelson, Hirsch-Pasek, Jusczyk, & Wright Cassidy, 1989). Infants between the ages of 7 and 9.6 months orient longer to syntactic units in child-directed speech than in adult-directed speech. Kemler Nelson et al. (1989) inserted 1-second pauses into child-directed and adult-directed speech either at a clause boundary or within a syntactic clause. They found that infants preferred the "intact" syntactic clauses to "interrupted" clauses when listening to child-directed speech, but did not distinguish between intact versus interrupted clauses in adult-directed speech. This suggests that child-directed speech may increase the perceptual salience of grammatical units and could, therefore, contribute to the acquisition of syntax (Kemler Nelson et al., 1989).

Child-Directed Speech and Children with ASDs. As indicated above, it is well known that typically-developing children prefer to listen to child-directed speech over adult-directed speech (Cooper & Aslin, 1990; Fernald, 1985). When given a choice of child-directed speech or adult-directed speech, infants turn to a speaker producing child-directed speech and look toward it for longer (Cooper & Aslin, 1990; Fernald, 1985). Unlike typically-developing infants, however, children diagnosed with ASDs show a reduced preference or no preference at all for child-directed speech (Kuhl, Coffey-Corina, Padden, & Dawson, 2005; Paul, Chawarska, Fowler, Cicchetti, & Volkmar, 2007). Kuhl et al. (2005) found that children with ASDs prefer electronically distorted speech to natural child-directed speech stimuli. While Paul et al. (2007) found that children with ASDs preferred natural child-directed speech to electronically distorted speech, they still reported a reduced preference for child-directed speech when compared to typically-developing age- and language-matched peers. Regardless of whether the preference for child-directed speech is reduced or absent for children with ASDs, language development could be significantly impacted as a result.

Despite the lack of a preference for child-directed speech by children with ASDs, child-directed speech might still facilitate language acquisition in this population. The amount of time children with ASDs attend to child-directed speech is positively correlated with their ability to discriminate phonetic differences in speech sounds (Kuhl et al., 2005) and with receptive language abilities (Paul et al., 2007). Nonetheless, given that children with ASDs do not prefer child-directed speech, parents could plausibly produce less of it in response to their children's preference. If that is the case, it would deprive this population of input that could help them to identify and understand language.

Although it seems that child-directed speech may facilitate language learning in children with ASDs, the use of child-directed speech by mothers of children with ASDs has not been studied. The extent to which mothers of children with ASDs use the modifications present in child-directed speech is unclear. Perhaps children's responsiveness typically elicits the properties of child-directed speech from parents. Therefore, if children with ASDs show a lack of responsiveness to language input (Tiegerman-Farber & Radziewicz, 2008) and little or no preference for child-directed speech (Kuhl et al., 2005; Paul et al., 2007), mothers may be less likely to use child-directed speech with these children. If this is the case, then mothers may produce fewer of the modifications associated with chiId-directed speech when interacting with this population. It is possible that a reduction or lack of these acoustic modifications in the input to children with ASDs contributes to communication deficits.

Alternatively, mothers of children with ASDs might exaggerate the acoustic characteristics of child-directed speech in order to encourage responsiveness. In other words, mothers of children with ASDs may show a larger magnitude of acoustic change between adult-directed speech and child-directed speech than mothers of typically-developing peers. If so, it may suggest that the acoustic features are not as facilitative for these children as they may be for typically-developing children.

This goal of the current study is to examine the extent to which mothers of children with ASDs use child-directed speech compared to mothers of typically-developing age- and language-matched children. Implications for the role of child-directed speech in language development will be discussed based on the findings.

Specific Aims

1) To compare the acoustic features of mothers' child-directed and adult-directed speech in order to determine whether mothers of children with ASDs modify speech to their children in the same way that mothers of typically-developing children modify speech to their children; and
2) To examine whether the acoustic characteristics of child-directed speech appear more related to the children's ages or to the children's language levels.

CHAPTER 2

Method

Participants. Thirteen monolingual English-speaking mother-child dyads participated in the study. These dyads were divided into three groups:

ASD group: Five mother-child pairs in which the children were diagnosed with ASDs

AM (age-matched) group: Five mother-child pairs in which typically-developing children were matched by chronological age and gender with children in the ASD group

LM (language-matched) group: Three mother-child pairs in which typically-developing children were matched by language level and gender with children in the ASD group

Mother-child pairs were excluded from participation in the study if parents reported that children were exposed to more than one language in the home, had a significant medical history, or had a vision or hearing impairment that was not corrected to normal.

Participants in the ASD group were recruited through Missouri First Steps referrals and an announcement distributed to students and faculty at the University of Missouri as a part of a weekly campus email. Children in this group were males between 21 and 32 months of age (mean age = 28 months) who were formally diagnosed with autism or ASD according to *DSM-IV* diagnostic criteria. The diagnoses were made by a physician or psychologist independent of this study. Mothers of children in the ASD group had education levels ranging from high school diploma (two mothers) to bachelor's degree (one mother) to post-baccalaureate work (two mothers).

Participants in the two control groups were recruited through the same weekly University of Missouri email announcement used to recruit participants in the ASD group. All control participants were matched on gender to participants in the ASD group. Children in the AM group were matched to children in the ASD group within 16 days of age on average (range = 6 to 37 days). Mothers of age-matched controls had education levels ranging from bachelor's degree (two mothers) to graduate/professional degree (three mothers). Children in the LM group were matched with three children in the ASD group on the basis of their mean length of utterance (MLU) during the mother-child interactions we observed. The children in the language-matched dyads ranged in age from 8 to 22 months (mean age = 13 months). Mothers of language-matched controls had all attained bachelor's degrees. At this time, we have not recruited language-matched controls for the remaining two children in the ASD group[1].

Data Collection. Participants were visited in their homes at a time that was convenient for the family and when only the mother and child participating in the study were present. Each mother-child pair was visited for 1 hour. Each mother was instructed to engage in typical play activities with her child and to interact with him in a normal fashion. The researcher also provided the mother with a wordless picture book ("Happy Birthday Carl!") with complex scenes and asked her to "read" the book with her child

[1] Using the mother-child interaction that we collected and transcribed, we have calculated the mean length of utterance (MLU) for each of the remaining two children in the ASD group. However, we have not yet recruited typically-developing children with similar MLUs to serve as language-matched controls.

during their interaction. This procedure provided researchers with examples of interaction during spontaneous activities that were typical of each particular mother-child dyad and also of interaction during a planned activity that was consistent across mother-child pairs. All mother-child interactions were recorded using a wireless microphone worn by the mother, a digital video camera, and a digital voice recorder. Following 45 minutes of mother-child interaction, the researcher conducted an interview with each mother to obtain a sample of her adult-directed speech and language (average duration: 7 minutes; range: 2 to 12 minutes). During the interview, mothers were asked to evaluate the level of naturalness of the interaction, describe a typical day for the child, and provide information about her own education and/or profession.

Transcription and Coding. All mother and child utterances and actions, as well as relevant information about context, were transcribed from the videotapes and linked to .mov files using the Codes for the Human Analysis of Transcripts (CHAT) system (MacWhinney, 2000). All videos were divided into 5-minute segments, each of which was transcribed by a single research assistant or pair of research assistants working together. Thirteen different undergraduate and graduate research assistants contributed to transcribing the video segments. As a measure of reliability, 38% of all 5-minute segments were transcribed by a research assistant or pair of research assistants that was not involved in the original transcription. Reliability for utterance division in transcription was 94%. Other discrepancies in transcription did not impact utterance division and thus would not affect extracting utterances for acoustic analysis.

Discrepancies between these transcriptions were then reviewed and resolved by one of two research assistants who were not involved in transcribing the segment.

Selecting Utterances for Acoustic Analysis. For each dyad, we selected 20 child-directed utterances produced by the mother. We selected 10 consecutive child-directed utterances following the first 25 minutes of mother-child interaction. We began our acoustic analyses well into the recorded interaction in order to increase the likelihood that the dyads were engaging in comfortable and natural interaction with reduced self-consciousness about the presence of the researcher and the camera. Another 10 child-directed utterances were chosen at intervals throughout the transcript to ensure a distribution of utterances across a range of activities. For each transcript, the appropriate interval was determined by dividing the total number of lines of transcription by 10 (e.g., if there are 800 total lines, we selected utterance 80, 160, etc.).

We also attempted to select 10 adult-directed utterances produced by each mother during the interview segment of data collection. Utterances that were wholly or partially unintelligible, overlapped any extraneous sound (e.g., child vocalizing or talking, researcher talking, toys banging, music playing, etc.), or contained laughter or whispering were excluded. Because each mother’s adult-directed speech sample was short relative to the child-directed speech sample collected, fewer adult-directed utterances were available for analysis. Furthermore, the child’s presence in the room during data collection resulted in several instances of noise and overlap, making many utterances unusable. For 11 of our 13 subjects, 10 consecutive adult-directed utterances were selected, starting at the beginning of an interview. For the remaining two subjects, fewer than 10 usable adult-directed utterances were produced due to overlap with extraneous noise throughout the interview[2]. For these two mothers, all usable adult-directed utterances collected during the interview segment were analyzed.

Creating Sound Files. Each child-directed and adult-directed utterance that was selected for analysis was imported into the Praat speech analysis software program (Boersma & Weenink, 2008) as a .wav file. The raw sound file for each utterance was modified in the following ways. Silence and noise were removed from the beginning and end of the selected utterance. False starts, filled pauses (e.g., *uh*, *um*), and reformulations were also removed if they were present at the beginning of the selected utterance. When making cuts, the researcher examined the acoustic waveform and the spectrogram to ensure that speech sounds, including aspiration and frication, were not removed from the segment.

To reduce the potential effect of extraneous noise, each sound file was filtered using Praat's pass Hahn band filter, set to include a range of 100 to 5,000 Hertz (Hz) with a 50 Hz smoothing region (de Jong & Wempe, 2009). By using these pass Hahn band filter settings, de Jong and Wempe (2009) suggest that "we attenuate nonspeech frequency components and keep all possible voice-related information about intensity and voicedness, across all formants" (p. 387).

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[2] During the researcher-conducted interview, one mother in the language-matched group produced only four usable adult-directed utterances, and one mother in the age-matched group produced just two usable adult-directed utterances. In both cases, noise made by their children playing in the same room (e.g., vocalizing, talking, banging toys, playing music) was almost constant throughout the interview segment, resulting in few usable utterances for analysis.

Measures. Acoustic properties of mother's speech that are typically associated with child-directed speech were analyzed from the processed sound files using ProsodyPro, a Praat script for prosody analysis (Xu, 2010). ProsodyPro automatically calculated a number of acoustic measures for these sound files, including minimum fundamental frequency, maximum fundamental frequency, mean fundamental frequency, final fundamental frequency, pitch excursion (in semitones per second), and utterance duration (in milliseconds). When analysis of all utterances was complete, averages were calculated for each mother's child-directed and adult-directed speech.

CHAPTER 3

Results

The acoustic analyses of selected utterances yielded data for six measures: minimum fundamental frequency, maximum fundamental frequency, mean fundamental frequency, final fundamental frequency, pitch excursion, and duration. We calculated the average value of each measure for each mother's child-directed speech and her adult-directed speech. These averages are displayed in Table 1. These results were used in tests of significance to address the specific aims of this study. Since this was a small study, we also present several descriptive examinations of the data. For descriptive analyses, we required a minimum of a 5% difference between child-directed speech and adult-directed speech on a dependent measure to argue that mothers modified speech directed to children. This is an arbitrary cutoff, but it gives us a way to quantify the difference and maintain consistency.

Table 1.

Mean acoustic measures for each mother's child-directed (CD) and adult-directed (AD) speech

Subject		minimum F_0 (in Hz)	maximum F_0 (in Hz)	mean F_0 (in Hz)	final F_0 (in Hz)	pitch excursion (in ST/sec)	duration (in ms)
ASD01	CD	158.83	325.43	233.42	234.23	13.23	1038.8
	AD	89.58	283.38	172.48	156.32	8.83	3310.62
ASD02	CD	180.85	325.9	257.06	236.23	12.51	913.48
	AD	127.07	282.82	201.23	184.13	4.37	4023.14
ASD03	CD	182.8	363.62	274.05	237.7	11.6	1434.55
	AD	123.13	288.86	203.8	197.87	5.34	3327.11
ASD04	CD	145.16	326.16	235.98	228.06	15.35	1155.91
	AD	108.42	257.34	196.6	140.52	7.68	3030.07
ASD05	CD	120.96	312.67	203.42	182.93	16.68	1183.68
	AD	134.66	319.89	204.39	238.89	9.03	2210.22
AM01	CD	180.74	335.76	256.66	252.02	12.49	1012.56
	AD	104.04	301.12	206.28	252.64	5.23	4084.6
AM02	CD	139.81	291.73	218.04	217.4	11.28	1571.55
	AD	107.29	310.18	208.85	184.69	9.04	3586.48
AM03	CD	143.18	308.02	229.44	197.77	15.8	950.28
	AD	104.69	270.64	174.91	198.64	8.53	2153.77
AM04	CD	148.45	312.44	227.58	252.44	18.03	785.67
	AD	89.83	298.32	213.66	145.98	26.68	2060.12
AM05	CD	193.13	346.36	272.4	265.25	14.96	772.59
	AD	139.91	301.31	228.11	217.19	8.21	2326.28
LM01	CD	145.93	315.56	237.43	211.34	15.87	1063.43
	AD	100.2	314.21	201.35	171.93	8.36	2452.04
LM02	CD	132.07	337.92	247.93	205.71	16.05	1059.52
	AD	98.86	281.12	190.45	226.72	7.98	4984.36
LM03	CD	181.48	346.32	254.37	256.29	14.53	788.66
	AD	133.82	278.02	220.41	203.57	14.07	1093.44

Do mothers of children with ASDs modify speech to their children in the same way that mothers of typically-developing children modify speech to their children?

Statistical Analyses. To address the question of whether mothers modify their speech to children with ASDs, six separate repeated-measures ANOVAs were run using the SPSS General Linear Model program. For each ANOVA, a within-group factor (type of speech: child-directed and adult-directed) was nested within each of the three groups

(ASD, AM, and LM). These data are presented in Table 2. Main effects for type of speech were found for all six measures. Mothers in each group used higher minimum fundamental frequency, higher maximum fundamental frequency, higher mean fundamental frequency, higher final fundamental frequency, greater pitch excursion, and shorter duration when speaking to their children than when speaking to an adult. The main effect of group type (ASD, AM, LM) was not significant for any of the acoustic measures. Similarly, none of the group by speech type interactions approached significance. We will return to discuss these data when we address our second research question concerning group differences.

Table 2.

Repeated-measures ANOVAs

	Between-Subjects		
		F(2, 10)	*p*
Group Effects	minimum F_0	0.070	.933
	maximum F_0	0.141	.871
	mean F_0	0.228	.800
	final F_0	0.644	.545
	pitch excursion	0.711	.514
	duration	0.230	.798
	duration	0.230	.798
	Within-Subjects		
		F(1, 10)	*p*
Speech Type Effects	minimum F_0	44.072	.001**
	maximum F_0	17.276	.002**
	mean F_0	38.289	.001**
	final F_0	5.823	.036*
	pitch excursion	13.479	.004**
	duration	38.842	.001**
		F(2, 10)	*p*
Group x Speech Type Interactions	minimum F_0	0.294	.752
	maximum F_0	0.724	.508
	mean F_0	0.282	.760
	final F_0	0.114	.894
	pitch excursion	0.808	.473
	duration	0.052	.950

*p<.05. **p<.01.

Eta-squared values were calculated to determine the within-subject effect sizes of acoustic differences between mothers' child-directed speech and adult-directed speech. These eta-squared values are presented in Table 3. Based on Cohen's interpretation guidelines[3], large effect sizes were found for all acoustic features measured. Overall, our statistical findings indicate that mothers alter their speech when speaking to children in predictable ways, even when their children have been diagnosed with ASDs.

Table 3.

Eta-squared values for within-subject acoustic differences between child-directed speech and adult-directed speech

	Sum of Squares Within Groups	Total Sum of Squares	**Eta-squared**
minimum F_0	12473.677	15470.343	**.806**
maximum F_0	8100.087	13467.993	**.601**
mean F_0	10157.278	12959.789	**.784**
final F_0	6974.339	19223.691	**.363**
pitch excursion	156.382	291.161	**.537**
duration	22397097.185	28222706.939	**.794**

Descriptive Analyses. Descriptive inspection of the individual data show tremendous similarities across mothers as well as some variation. All 13 mothers used shorter utterances in child-directed speech than adult-directed speech. All mothers but one (ASD05) used higher minimum fundamental frequency in child-directed speech than adult-directed speech. Eleven of the 13 mothers used significantly greater pitch

[3] Cohen states that eta-squared values of 0.03-0.059 represent a small effect size, values of 0.06-0.139 represent a medium effect size, and values greater than or equal to 0.14 represent a large effect size.

excursion in child-directed speech, while a different eleven mothers used significantly higher mean fundamental frequency in child-directed than adult-directed utterances. There was less consistency on the acoustic measures of maximum and final fundamental frequencies. Six of the 13 participants used higher maximum *and* final fundamental frequencies in their child-directed utterances, while six others used either higher maximum fundamental frequency *or* higher final fundamental frequency during child-directed speech.

Overall, four of the five mothers of children with ASDs showed the commonly reported acoustic differences between child-directed and adult-directed speech for *every* measure. The mothers of the typically-developing children were not as consistent. Of the eight mothers of typically-developing children who participated in this study, one mother (AM05) showed the predicted acoustic differences for every measure, five mothers showed them for five of the six measures (all three mothers in the LM group and two mothers in the AM group), and two mothers only showed them for four of the measures (two mothers in the AM group).

Comparisons of ASD, AM, and LM group means are presented in Table 4. These data are shown graphically in Figures 1 through 6. For every measure, the group mean for child-directed speech differed from the group mean for adult-directed speech by at least 5% in the expected direction, regardless of group. The results of these comparisons indicate that mothers of children with ASDs modify the acoustic features of their child-directed speech in the same way that mothers of typically-developing children do.

Table 4.

Acoustic measure group means for child-directed (CD) and adult-directed (AD) speech

		minimum F_0 (in Hz)	maximum F_0 (in Hz)	mean F_0 (in Hz)	final F_0 (in Hz)	pitch excursion (in ST/sec)	duration (in ms)
ASD Group	CD	157.72	330.76	240.78	223.83	13.87	1145.29
	AD	116.57	286.46	195.7	183.55	7.05	3180.23
	CD-AD	**+41.15**	**+44.3**	**+45.08**	**+40.28**	**+6.82**	**-2034.94**
AM Group	CD	161.06	318.86	240.82	236.97	14.51	1018.53
	AD	109.15	296.31	206.36	199.83	11.54	2842.25
	CD-AD	**+51.91**	**+22.55**	**+34.46**	**+37.14**	**+2.97**	**-1823.72**
LM Group	CD	153.16	333.27	246.58	224.44	15.48	970.53
	AD	110.96	291.12	204.07	200.74	10.14	2843.28
	CD-AD	**+42.2**	**+42.15**	**+42.51**	**+23.7**	**+5.34**	**-1872.75**

Figure 1.

Comparison of group means (+SE) for minimum fundamental frequency in child-directed and adult-directed speech

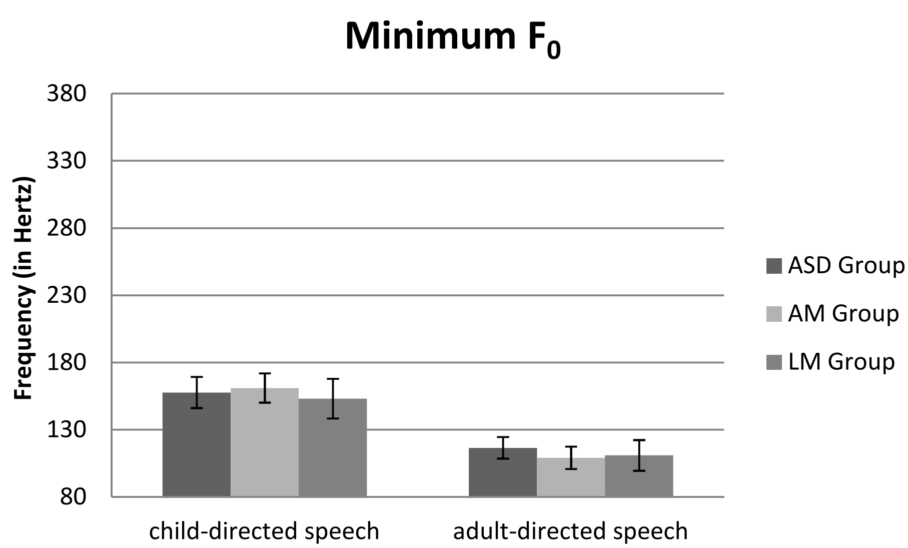


Figure 2.

Comparison of group means (+SE) for maximum fundamental frequency in child-directed and adult-directed speech

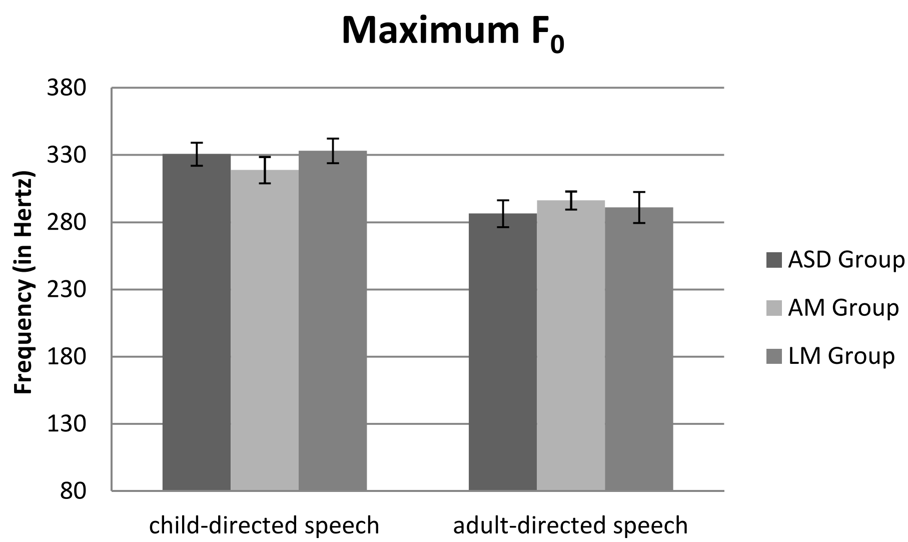


Figure 3.

Comparison of group means (+SE) for mean fundamental frequency in child-directed and adult-directed speech

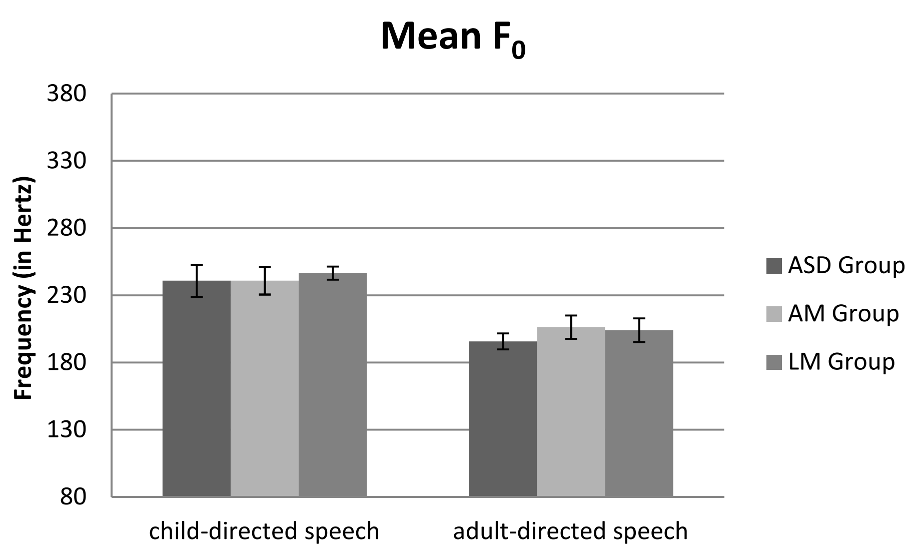


Figure 4.

Comparison of group means (+SE) for final fundamental frequency in child-directed and adult-directed speech

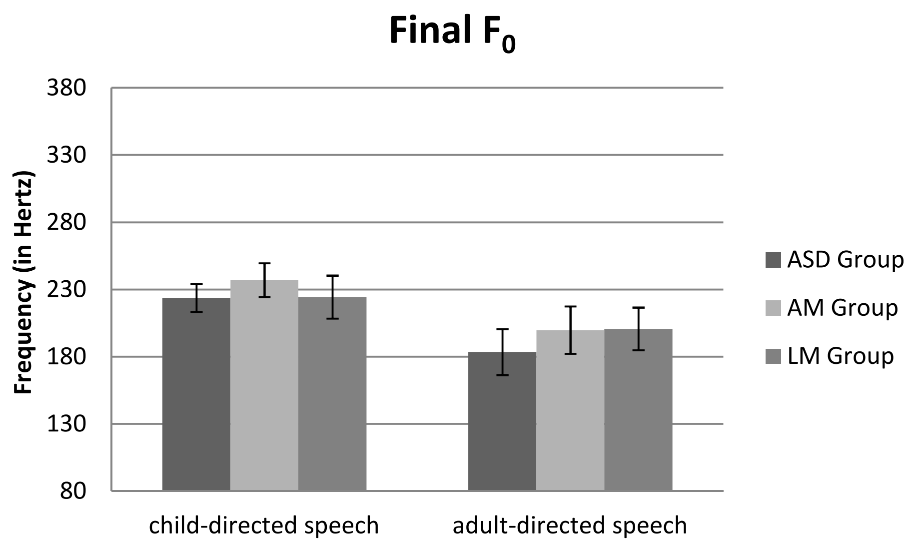


Figure 5.

Comparison of group means (+SE) for pitch excursion in child-directed and adult-directed speech

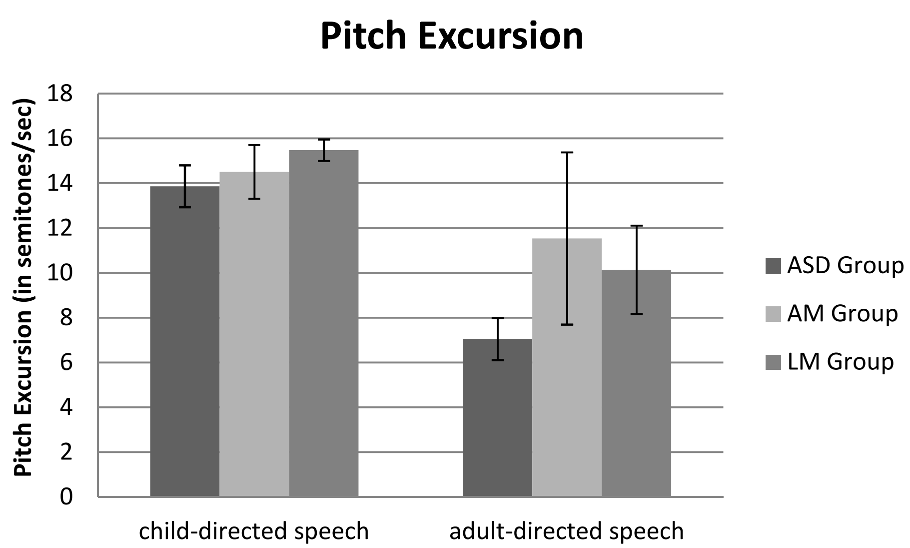
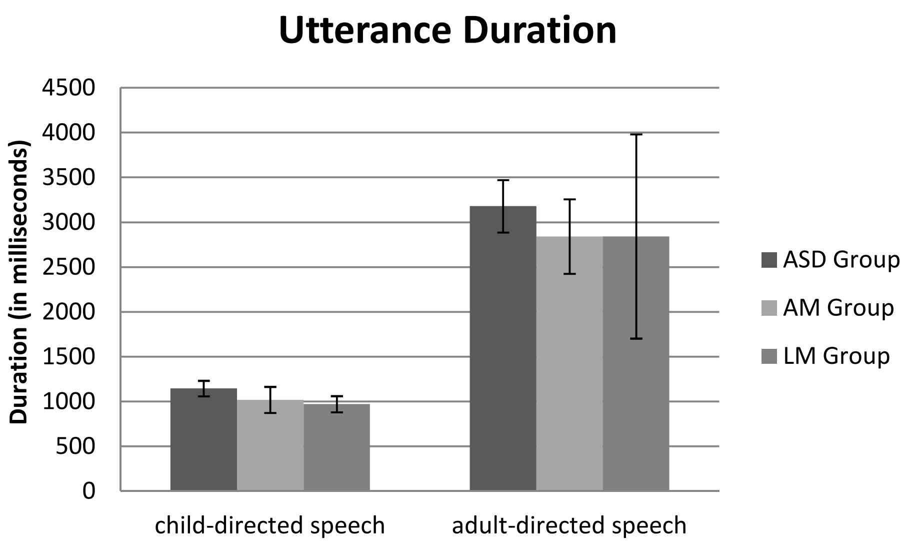


Figure 6.

Comparison of group means (+SE) for utterance duration in child-directed and adult-directed speech



Finally, we calculated the percentage of participants in each group that used the acoustic modifications associated with child-directed speech. These findings are presented in Table 5. All mothers in the ASD group with the exception of one (ASD05) used all measured acoustic modifications associated with child-directed speech. ASD05 behaved quite differently: Analysis of her speech revealed lower minimum, maximum, mean, and final fundamental frequencies in child-directed speech than adult-directed speech.

Table 5.

Percentage of subjects using acoustic modifications associated with child-directed speech (5% cutoff)

	ASD Subjects	AM Subjects	LM Subjects	**Total**
Is minimum F_0 higher in child-directed speech than adult-directed speech?	4/5 (80%)	5/5 (100%)	3/3 (100%)	**12/13 (92%)**
Is maximum F_0 higher in child-directed speech than adult-directed speech?	4/5 (80%)	3/5 (60%)	2/3 (67%)	**9/13 (69%)**
Is mean F_0 higher in child-directed speech than adult-directed speech?	4/5 (80%)	4/5 (80%)	3/3 (100%)	**11/13 (85%)**
Is final F_0 higher in child-directed speech than adult-directed speech?	4/5 (80%)	3/5 (60%)	2/3 (67%)	**9/13 (69%)**
Is pitch excursion greater for child-directed speech than adult-directed speech?	5/5 (100%)	4/5 (80%)	2/3 (67%)	**11/13 (85%)**
Is duration shorter for child-directed speech than adult-directed speech?	5/5 (100%)	5/5 (100%)	3/3 (100%)	**13/13 (100%)**

As noted above, fewer of the LM and AM mothers modified every acoustic measure in speech to their children. Two mothers in the age-matched group (AM01 and AM03) and one mother in the language-matched group (LM02) used lower final fundamental frequency in their child-directed speech than their adult-directed speech. In addition, two other subjects (AM04 and LM01) failed to demonstrate a 5% difference between maximum fundamental frequency in child-directed and adult-directed speech even though results were in the right direction. A fourth mother in the age-matched group (AM02) used lower maximum fundamental frequency in her child-directed speech than her adult-directed speech. This mother modified her speech in the predicted direction for mean fundamental frequency, but the child-directed mean was only 4.4% greater than the adult-directed mean. ASD05 was the only participant who used lower minimum fundamental frequency during child-directed utterances than adult-directed utterances.

Despite these variations, all but one of the mothers modified speech directed to their children for at least four of the six measures. The remaining mother (ASD05) followed the pattern for two of the six measures. We will return to her performance in the discussion. Overall, these findings suggest that mothers modify the acoustic characteristics of their speech to young children regardless of whether the children are developing typically or are diagnosed with an ASD.

Are the acoustic characteristics of child-directed speech more related to the children's ages or to the children's language levels? As noted above, the ASD, AM, and LM groups did not differ in their child-directed speech or adult-directed speech. Although each group's child-directed speech differed significantly from their adult-directed speech for every variable, no significant relationships were found for the main effect of group or any group by speech type interaction (see Table 2). Based on these findings, there is no evidence that mothers of toddlers with ASDs differ from mothers of typically-developing age- or language-matched children.

CHAPTER 4

Discussion

This study was designed to examine the question of whether or not mothers of children with ASDs modify the acoustic features of their child-directed speech. Researchers have established that speech directed to typically-developing children is characterized by higher average fundamental frequency, greater pitch excursions, shorter duration, and rising final pitch (Fernald et al., 1989; Garnica, 1974). These modifications are thought to play a role in the development of word learning and syntax for typically-developing children (Fernald & Mazzie, 1991; Thiessen et al., 2005; Kemler Nelson et al., 1989).

No study to date has addressed the use of these same acoustic modifications by mothers of children with ASDs. Before this study, it was unclear whether mothers of children with ASDs were modifying their speech at all. We thought that these mothers might not modify the acoustic features of their speech to children with ASDs because these children generally have impairments in social responsiveness, and specifically lack social responsiveness to maternal language input. However, our findings suggest that mothers do alter the acoustic features of their speech to toddlers diagnosed with ASDs in the same way that mothers of typically-developing children do. In general, mothers of children with ASDs used higher minimum, maximum, mean, and final fundamental frequencies; greater pitch excursion; and shorter duration when speaking to their children than when speaking to an adult. These findings are consistent with our results for mothers of typically-developing children, as well as the current literature regarding acoustic characteristics of child-directed speech to typically-developing toddlers.

Furthermore, we found more of the mothers of children with ASDs used all of the acoustic modifications associated with typical child-directed speech than did mothers of typically-developing children. Eighty percent of mothers of children with ASDs modified their child-directed speech in the expected way for *every* measure, while only 12.5% of mothers of typically-developing children were as consistent. These findings presented us with an unexpected observation that mothers of toddlers with ASDs appear to use the acoustic modifications expected in child-directed speech with *more* consistency than mothers of typically-developing children do.

Our results fail to reveal significant group differences in magnitude of child-directed speech produced by the mothers. Figures 1 through 6 indicate that the magnitude of modifications for our measures of child-directed speech was very similar for mothers of children with ASDs and mothers of their age- and language-matched peers. However, because mothers of children with ASDs appear to use *all* of the acoustic modifications associated with child-directed speech more consistently than mothers of typically-developing children do, it appears that speech directed to children with ASDs may contain more acoustic modifications overall. It is possible that mothers of toddlers with ASDs are compensating for their children's lack of social responsiveness by consistently using all of the acoustic characteristics associated with child-directed speech in an attempt to draw their children's attention to the input. Thus, although mothers of children with ASDs might not exaggerate the acoustic characteristics of individual components of child-directed speech more than mothers of typically-developing children do, perhaps they more consistently use all of the components together in order to encourage their children to attend.

Implications. Our findings suggest that the acoustic characteristics of input to children with ASDs and typically-developing children are modified in similar ways and that mothers of toddlers with ASDs may use the modifications associated with child-directed speech more consistently than mothers of typically-developing toddlers. Because the current literature suggests that typically-developing children gain important information for language learning from these acoustic modifications, it would be logical to assume that being exposed to these same modifications could facilitate language learning in children with ASDs. Moreover, the time children with ASDs spend attending to child-directed speech has been found to be positively correlated with their ability to discriminate speech sounds (Kuhl et al., 2005) and understand language (Paul et al., 2007). However, children with ASDs continue to demonstrate deficits in language skills, which suggests that the acoustic features of child-directed speech are not sufficient for normal language acquisition.

In our study, children with ASDs were exposed to the same acoustic modifications as their typically-developing peers, but they continued to demonstrate language deficits. For example, two children in the ASD group produced fewer than 50 intelligible utterances during 45 minutes of recorded interaction with their mothers, all of which were single word productions. Their language-matched peers were 12 and 22 months younger. The remaining three children in the ASD group used utterances with an average length of 1.89 morphemes (individual MLUs ranged from 1.57 to 2.51). On average, the mean length of utterance produced by children in our ASD group was 0.9 morphemes less than their age-matched peers. Although many researchers have suggested that the acoustic features of child-directed speech play an important role in facilitating language acquisition for typically-developing children, our results suggest that the acoustic modifications associated with child-directed speech are not sufficient for children with ASDs to develop language at a typical rate. This might be due to social or cognitive deficits associated with ASDs. Because positive correlations have been found between some language abilities (i.e., discrimination of speech sounds and receptive language skills) and the amount of time spent attending to child-directed speech, it seems that children with ASDs are gleaning some linguistic information from the modified input (Kuhl et al., 2005; Paul et al., 2007). However, the children in our study who were diagnosed with ASDs were severely impaired despite hearing child-directed speech. Of course, it is possible that their language skills would be even more impaired if they did not hear child-directed speech. Our study cannot assess this. However, the results of our study do suggest that using acoustic modifications in speech directed to children with ASDs is not sufficient to facilitate typical language acquisition.

Limitations. The results of this study clearly show that mothers use similar acoustic modifications in speech to both typically-developing children and children diagnosed with ASDs. However, we did not find evidence that modifications in speech to children with ASDs differ in magnitude from modifications in speech to age- or language-matched peers. The question as to whether between-group differences would be found in a larger sample remains unanswered. It is also possible that between-group differences would be found if participants with ASDs were older. Currently, no research exists regarding the rate of change in acoustic modification for speech directed to typically-developing children between 2.5 and 5 years of age. However, the literature does suggest that input is more adult-like by the time children reach 5 years of age (Garnica, 1974). Mothers of our age- and language-matched controls were all using the acoustic modifications associated with child-directed speech in similar ways. However, if the children in our ASD group had been older, it is possible that the age difference between their age- and language-matched peers would have been greater, with the age of their language-matched controls failing to rise in proportion to their chronological age. Analyzing speech to older children (3 to 5 years old) with ASDs and their age- and language-matched peers may reveal a difference in the acoustic features of input to children in the LM and AM groups. Between-group comparisons might then be used to determine whether speech directed to children with ASDs is more similar to one control group than the other.

Generalization of the current findings is limited by the small number of participants in this study. With only 13 subjects, it is possible that these findings are not representative of the population. Furthermore, the language-matched group contained only three dyads, two less than both the ASD group and the age-matched group. Because this project began as a pilot study, it was intended to serve as an exploratory look at the acoustic features of mothers' child-directed speech to precede a large-scale study. Therefore, these findings should be replicated with more participants before generalizations are made.

It is also possible that the dyads in our ASD group are not representative of the ASD population. We recruited participants for this group through Missouri First Steps referrals. Because this program's mission is to provide family-centered early intervention services, these mothers may have had some feedback regarding communicative interactions with their children. We initially sought to recruit children who had not yet begun receiving intervention services, but we were unable to find any subjects willing to participate in a research study immediately after receiving an ASD diagnosis.

In addition, our inclusionary criterion for participation in the ASD group was a diagnosis of autism or ASD from a physician or psychologist independent of this study; we did not collect an independent measure of autism severity. All children in the ASD group met our criterion, but one child in particular (ASD05) did not resemble the other children in the group in terms of language skills. Although we do not have severity ratings for any of our participants, we do have language measures based on language equivalent scores on the *MacArthur-Bates Communication Development Inventories* (CDI-II; Fenson et al., 1993) and MLU. The child in question reached the ceiling for expressive vocabulary on the CDI-II (produced 677/680 words, which fell in the 99th percentile) and used a MLU of 2.51 during the speech sample that we collected. For the remaining three children in the ASD group whose mothers returned the CDI-II, expressive vocabulary size averaged 66 words (range = 0 to 195 words). Two of the remaining four children in the ASD group produced fewer than 50 intelligible utterances during our observation, all of which were single word productions. The other two children used MLUs of 1.57 morphemes and 1.59 morphemes. Obviously, the child of ASD05 demonstrates greater expressive language skills than the other children in the ASD group. Interestingly, his mother is the only mother in the ASD group who did not modify her speech in the expected way for every measure. For minimum, maximum, mean, and final fundamental frequencies, her results were actually greater in adult-directed speech than child-directed speech, which is opposite of what would be expected. The differences in this mother's child-directed speech may be related to a number of factors, including differences in language skills or severity in relation to the other children in our ASD group. In fact, this child's MLU was the highest of any participant in our study and 0.62 morphemes greater than his own age-matched control.

Finally, although an attempt was made to analyze 20 child-directed and 10 adult-directed utterances produced by each mother, extraneous noise overlapped parts of many adult-directed utterances because the children were present during the interview segment used to collect adult-directed speech. Due to the limited number of usable utterances in some samples, fewer than 10 adult-directed utterances were analyzed for 2 of the 13 participating mothers (one mother in the language-matched group and one mother in the age-matched group). Specifically, only four adult-directed utterances produced by LM01 and two adult-directed utterances produced by AM04 were analyzed. We examined the acoustic measures for these mothers to see if they differed from the rest of the sample in any notable ways. Each mother differed from the majority of participants on one measure. For LM01, only a small difference (less than 5%) was found between child-directed and adult-directed maximum fundamental frequency, but this difference fell in the same direction as 10 of the other subjects. For AM04, acoustic analysis revealed that average pitch excursion (in semitones per second) was greater in adult-directed than child-directed utterances, the opposite of what we expected. Both mothers mirrored group effects for the remaining five measures.

Future Research. This study is a first attempt to examine the role of child-directed speech in language acquisition for children with ASDs. Regardless of the aforementioned limitations, we found significant differences between the acoustic features of child-directed and adult-direct speech with large effect sizes for all three groups. This indicates that acoustic differences between child-directed speech and adult-directed speech were so consistent that they were apparent despite the small number of participants. Although it will be necessary to conduct a large-scale study to replicate these findings and continue searching for between-group differences, our results clearly suggest that speech to toddlers with ASDs is altered in ways that have been documented in the literature for typically-developing toddlers.

Although speech to children with ASDs is modified *acoustically* in the same ways as speech to typically-developing children, other aspects of the input may differ, and these should be studied. For example, speech to children with ASDs may differ in semantics, syntax, and/or pragmatics from speech to typically-developing children. Differences in any aspect of language input may impact language learning. If differences are found, specific areas of language input could be targeted for intervention. Our study suggests that, for children with ASDs, the acoustic modifications present in child-directed speech are not sufficient to facilitate normal language development, but more research is needed to support this finding and determine what aspect of the input, if any, may support increased language skills for this population.

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