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Acoustic Characteristics of Caregiver Speech to Children with Autism and Typically Developing Children

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Abstract

This study compares acoustic properties of mean pitch, pitch range, and duration in maternal speech to children with autism spectrum disorder (ASD) or typically developing children (TD) with a focus on the extent of the production of child-directed (CD) speech modification relative to their adult-directed (AD) speech. Twenty-five caregivers with a typically developing child (M = 23.45 months) and fifteen caregivers with a child with autism (M = 55.21 months), matched on their child's receptive language ability, were enrolled in the study. CD speech samples were collected during a 10-minute storybook session where caregivers read two storybooks to their child. AD speech samples were collected via a 5-10 minute semi-structured interview with the primary caregiver in order to elicit the same words spoken in both CD and AD contexts. Difference scores were calculated for each word appearing in both contexts for each acoustic property in order to examine CD speech modification. The results of an independent samples t-test showed no significant differences in CD speech modification between groups across these three acoustic properties. However, CD speech modification was negatively correlated with chronological age, indicating that caregivers produced less CD speech modification the older the child was. Finally, for children who showed less growth in their receptive language abilities between time 1 and time 3, caregivers demonstrated greater pitch range modification. Findings are discussed in relation to caregivers responding to characteristics of the child.

Résumé

La présente étude compare les propriétés acoustiques de hauteur moyenne, la tessiture et la durée du discours maternel envers son enfant présentant soit un trouble du spectre autistique (TSA) soit un développement typique (DT), avec une attention particulière allouée à la production du discours dirigé vers l'enfant (DE) par rapport au discours dirigé vers l'adulte (DA). Vingt-cinq familles avec un enfant DT et quinze familles avec un enfant TSA, appariés sur les habiletés en langage réceptif de l'enfant, ont été recrutées pour cette étude. Les échantillons de discours DE ont été recueillis lors d'une session de lecture d'un livre de 10 minutes, pendant laquelle les mères lisaient deux histoires à leur enfant. Les discours DA ont été recueillis lors d'entretiens semi-structurés de 5-10 minutes avec un des parents afin d'obtenir les mêmes mots prononcés dans les contextes de discours DE et DA. Les différences entre les scores ont été calculées pour chaque mot prononcé dans les deux types de contexte et pour chaque propriété acoustique, dans le but d'étudier les modifications dans le discours DE. Les résultats des tests t pour échantillons indépendants ne montre aucune différence significative au niveau des discours DE entre les deux groupes, et ce pour tous les types de propriétés acoustiques. Cependant, les modifications du discours DE sont négativement corrélées à l'âge chronologique, c'est-à-dire que plus l'enfant est âgé, moins les parents produisent de modifications de discours DE. Enfin, pour les enfants qui montrent un moindre développement de leurs capacités langagières entre les temps 1 et 3 de l’étude, les parents démontrent quant à eux le plus de modifications de tessiture. Ces résultats sont discutés en relation avec les réponses apportées par les parents en fonction des caractéristiques de l'enfant.

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Acoustic Characteristics of Caregiver Speech to Children with Autism and Typically Developing Children

Autism spectrum disorder (ASD) is a neurodevelopmental condition characterized by deficits in the domains of social interaction (e.g. eye gaze, shared enjoyment, social reciprocity) and communication (e.g. spoken language, pretend play), and by restricted and repetitive behaviors and fixated interests (e.g. motor mannerisms, preoccupation with parts of objects) (American Psychiatric Association, 2000), with prevalence rates in Canada being roughly one in 165 children (Fombonne et al., 2006). The presence of symptoms within these domains is present from infancy or early childhood but, in some cases, may not be detected until later in childhood (Gray, Tonge, & Brereton, 2006). With a high risk for delays and lifelong impairments in aspects of language competence (Lewis, Murdoch, & Woodyatt, 2007; Loucas et al., 2008; Mawhood, Howlin, & Rutter, 2000), lack of speech or language development is most often the first symptom noticed by parents and the most common concern, which leads them to seek professional consultation (DeGiacomo & Fombonne 1998). As early language abilities are one of the strongest predictors of level of overall functioning later in life (Luyster, Qiu, Lopez, & Lord, 2007; Mawhood, Howlin, & Rutter, 2000; Smith, Goddard, & Fluck, 2004; Szatmari, Bryson, Boyle, Streiner, & Duku, 2003), an improved understanding of prelinguistic factors that predict pre-school language development in children with autism could lead to better assessment of communication and strategies that could be focused upon when implementing early intervention programs (Watson, Baranek, Roberts, David, & Perryman, 2010).

Theories focused on how language is acquired in infancy suggest that the ways in which caregivers address their infants play an essential role in the process of acquiring language (Kuhl, Tsao, Liu, Zhang, & de Boer, 2001). Across cultures, caregivers address their children using child-directed speech (Kuhl, 2000), and this form of speech has been shown to assist infants in learning language. In the present study, speech input and the relationship between speech input and child language development was compared between caregivers of children with ASD and caregivers of typically developing children. This link between speech input and language development is essential since strong relationships have been found between this and later language learning. Our study is a novel contribution to this field in that it was longitudinal and carried out in a naturalistic setting with a focus on real single words spoken by the caregivers rather than phonemes (e.g. Tsao, Liu, & Kuhl, 2004) or artificial languages (Thiessen, Hill & Saffran, 2005), thereby making the analyses of speech more realistic, targeted, and focused. Additionally, we were not only able to examine the relationship between the use of child-directed speech and child language development in typically developing children but for the first time, have been able to examine this relationship directly in children with autism.

Child-Directed Versus Adult-Directed Speech

The speaking style of child-directed speech differs from adult-directed speech both syntactically and semantically, allowing this form of speech to be considered as more simplified. For example, in comparison to adult-directed speech, child-directed speech contains fewer different word types, the use of baby words (i.e. “bunny” or “tummy” instead of “rabbit” and “stomach”), one-word sentences (Brent & Siskind, 2001; Christiansen, Allen, & Seidenberg, 1998), content words in utterance final position

(Fernald & Mazzie, 1991), and increased emphasis on the immediate here and now context (Soderstrom, 2007). In addition to syntactic and semantic differences, child-directed speech differs from adult-directed speech in how it sounds acoustically. Child-directed speech is characterized by acoustic properties of speech which includes higher pitch, greater pitch range, shorter sentences, elongated vowels, increased repetition, less diversity in vocabulary, slower tempo, exaggerated intonation, and positive affect (Andruski & Kuhl, 1996; Snow & Ferguson, 1977; Stern, Spieker, Barnett, & MacKain, 1983). Consistent with previous studies on child-directed speech (e.g. Fernald, 1987; Fernald, 1989; Fernald & Mazzie, 1991), the most common acoustic properties differentiating child-directed from adult-directed speech are that of mean pitch, pitch range, and duration. Therefore, these acoustic properties are focused upon in the current study. The concept of pitch is related to the fundamental frequency of the sound that can vary as in the case of speaking in a high voice, characterized by high pitch, compared to speaking in a low voice, characterized by low pitch. Pitch range refers to the difference between the highest pitch point and the lowest pitch point in a sample of speech. The acoustic property of duration refers to the length of the sound being produced. In relation to these specific acoustic properties, child-directed speech would be expected to have higher pitch, greater pitch range, and longer duration.

Age related changes in child-directed speech. As children proceed through infancy into the first few years of life, caregivers modify the patterns and rhythm of child-directed speech directed towards them (Cooper & Aslin, 1990). Moreover, they tend to modify their speech in relation to different communicative functions (Stern et al., 1983). In studies of characteristics of child-directed speech, mothers differentially adjust

their mean pitch and pitch range to express various means of communicative intent and this varies across infancy and the first few years of life. At the newborn stage, the comfort aspect of speech is highest (Kitamura & Burnham, 2003). However, at 3-months of age, a decrease in comfort is seen in child-directed speech along with an increase in characteristics of positive affect, expressing affection, encouraging attention and direct behavior (Kitamura & Burnham, 2003) in response to increased social responsivity displayed by the infants. Furthermore, accompanying these properties of communicative intent are changes in acoustic characteristics of pitch. At 6-months of age, a period in which infants are most interactive, mothers tended to initiate more interaction (Cohn & Tronick, 1987) and hence higher levels of pitch are found along with increased characteristics of positive affect, encouraging attention, expressing affection and comfort (Kitamura et al., 2002). By 9-months of age, a decrease in pitch and characteristics of positive affect are accompanied by an increase in pitch range and characteristics of direct behavior in response to infants becoming more selective in perceiving native speech sounds (Jusczyk et al., 1993; Lalonde & Werker, 1995; Polka & Werker, 1994; Werker & Tees, 1984) and more able to follow simple instructions (Hubley & Trevarthen, 1979) and pointing gestures (Murphy & Messer, 1977). At 12-months of age, an increase in the affective qualities of child-directed speech is accompanied by an increase in pitch (Kitamura et al., 2002), as caregivers offer encouragement to infants who have begun to understand properties of speech segmentation and who also are starting to produce language (Polka & Werker, 1994; Werker & Tess, 1984). Beyond the first year of life, especially between 2 and 5 years of age, pitch and pitch range decrease (Garnica, 1977; Stern et al., 1983; Warren-Leubecker & Bohannon, 1984). Overall, the findings suggest

that mothers alter their use of pitch with communicative intent in response to developmental changes occurring with their child (Kitamura & Burnham, 2003).

Preference or Reduced Preference for Child-Directed Speech

Child-directed speech is attractive to young typically developing newborns and infants, and therefore they show preferences for listening to child-directed speech compared to adult-directed speech. However, this preference is less prominent at birth and rather evolves during the first year of life (Cooper & Aslin, 1990). Speech preference is often measured with a fixation-based auditory preference paradigm (e.g. Colombo & Bundy, 1981) or something of similar form in which infants activate a synthetic recording of child-directed or adult-directed speech by focusing on a visual stimulus. For example, Cooper and colleagues (Cooper, Abraham, Berman and Staska, 1997; Cooper & Aslin, 1990) examined preference for maternal versus non-maternal recordings of child-directed versus adult-directed speech. Newborn and 1-month-old infants showed significantly longer looking times for non-maternal recordings of child-directed versus adult-directed speech with longer looking times seen for 1-month-old infants compared to newborns. However, strong preferences were seen for non-maternal child-directed speech compared to maternal child-directed speech in 1-month-old infants (Cooper et al., 1997) with preference for maternal speech emerging only in 4-month-old infants (Cooper et al., 1997; also, see Fernald, 1985). These findings imply that preference for child-directed speech is evident in newborns and preference from non-maternal to maternal child-directed speech shifts in the first few months of life as infants begin to recognize and attend to their mother's voice. (Cooper et al., 1997).

Child-directed speech preference across different languages. Infant preference for child-directed speech appears to be consistent across all languages that use this form of speech. For example, Werker, Pegg, and McLeod (1994) found that both Cantonese and English-exposed 4.5- and 9-month-old infants were more attentionally and affectively responsive when listening to Cantonese child-directed speech than adult-directed speech. Similarly, Fernald (1993) showed appropriate affective responses to approving and disapproving child-directed speech contours in English, German, Japanese and Italian among English-language exposed 5 month olds (Fernald, 1993).

Characteristics of child-directed speech responsible for preference. These findings of preference to child-directed speech imply that the specific characteristics of this speech make it more appealing for the infants to listen to and therefore, attracts their attention compared to listening to their own mother's voice or listening to a voice in their own native language. Some suggest that intonation directed towards infants, characterized by exaggerated pitch level and range, slower rhythm and tempo and smooth and simple pitch contours accounts for this infant preference for child-directed speech (Fernald & Simon, 1984; Stern et al., 1983). Fernald and Kuhl (1987) examined the acoustic determinants of this preference for child-directed speech and hypothesized that the intonation aspect (i.e. pitch contours, amplitude, and duration) of child-directed speech was sufficient to cause such a preference. After isolating each acoustic characteristic of intonation, they found that when given the choice between pitch contours of child-directed versus adult-directed speech, infants showed a strong listening preference for the pitch contours of child-directed speech. However, child-directed speech pitch contours had both a high mean pitch and wide pitch range. Therefore, it is

possible that both or only one of these characteristics is responsible for infant preference in child-directed speech. No preferences for amplitude and duration characteristics were found for either child-directed or adult-directed speech. In another study in which a preference paradigm was used to examine these acoustic features of child-directed speech and their stability across development, Cooper and Aslin (1994) found that 1-month-old infants preferred child-directed over adult-directed speech. However, when characteristics of pitch were isolated, 1-month-old infants did not show preference for this characteristic as compared to older infants. This implies that preference for child-directed speech due to features of pitch does not emerge until later in infancy.

Reduced preference in children with autism. The clear preference of typically developing children for child-directed speech is evident in newborns and increases in strength during the first few months of life. Due to this strong preference, researchers (i.e. Klin, 1991; Kuhl, Coffey-Corina, Padden, & Dawson, 2005; Nadig, Ozonoff, Singh, Young, & Rogers, 2007; Paul, Chawarska, Fowler, Cicchetti, & Volkmar, 2007) have explored whether similar preferences for child-directed speech are seen in children with ASD or at-risk for autism, a population at risk for delays in language development. For example, Klin (1991) used a preferential listening task in a naturalistic setting in order to compare children with autism (M = 63.5 months), typically developing children (M =40.9 months), and children with mental retardation (M =66.3 months) in their preference for their mother's voice in speaking to them compared to an alternative continuous and monotonous sound made up of superimposed voices (sound effects taken from noises of a busy canteen) (Klin, 1991). Both samples of speech were recorded onto an audio feedback device resembling a toy on which the children were able to push

buttons in order to trigger one of the speech samples to play aloud. Klin found that the children with autism either preferred to listen to the superimposed voices (approximately 40% of the group) or showed no preference for either the superimposed voices or their mother's voice (approximately 60% of the group), whereas the entire group of typically developing children and children with mental retardation preferred to listen to their mother's voice.

In an examination of a younger sample of children with ASD, Kuhl, Coffey-Corina, Padden and Dawson (2005) studied pre-school aged children with and without ASD in their preference for child-directed speech samples compared to non-speech analog signals, matching on frequency and amplitude to the child-directed speech sample. As predicted, a strong preference for the non-speech analogs was seen among the children with ASD (Kuhl et al., 2005). However, when separating the children with ASD by those who preferred child-directed speech versus those who preferred non-speech signals, differing neural patterns were found. The brain waves of the children with ASD who showed a preference for child-directed speech resembled those of typically developing children implying that the children with autism who showed a reduced preference for child-directed speech lacked a particular neural signal found among typically developing children. To further examine the lack of preference for child-directed speech in autism, Paul et al. (2007) compared toddlers with autism in their preference for electronically manipulated speech signals versus child-directed speech. In contrast to Kuhl et al. (2005), Paul et al. failed to find this preference for the non child-directed speech sample (in the case of this study, electronically distorted speech) but rather found a significantly reduced preference for the naturalistic child-directed speech

sample as compared to typically developing children. Additionally, they found that child language level was highly linked to speech preference. For example, the toddlers who were at the level of learning single words appeared to show a preference for words or vocabulary that represented the language they were adopting, whereas toddlers who were at the level of learning multi-words showed preferences for sentences with grammatical pauses. This implies that preferences may change as children focus on different aspects of the speech directed toward them that corresponds to the elements of language that they are in the process of acquiring.

According to the child-directed speech studies conducted with typically developing children, preference for this speech style appear to be strongest at 6-months of age (Newman & Hussain, 2006). In order to examine whether a similar preference may be present at this age in children with autism, Nadig et al. (2007) conducted a study with 6-month old infants at-risk for autism. Using a form of the sequential looking paradigm developed by Cooper and Aslin (1990), infant preference for child-directed (defined as having positive affect) versus adult-directed speech (defined as having neutral affect) was measured. Infants with no known risk for autism showed the expected preference for child-directed speech whereas those infants at risk for autism preferred listening to adult-directed speech. However, Nadig et al. also found that the group of infants at risk had lower expressive language levels and hence, the lack of attending to the child-directed speech sample may be linked to these lower levels of language (Nadig et al., 2007). The preference for child-directed speech clearly differs between typically developing children and children with autism, with a reduced preference for child-directed speech and an atypical preference for non child-directed speech samples such as adult-directed speech

(Nadig et al., 2007), background noise (Klin, 1991), and non-speech analogs (Kuhl et al., 2005) seen in children with autism. However, this was not found in all children with autism or at-risk for autism, which implies that it may only be a subgroup of children with autism who show this atypical preference. Although the reason why some children with autism show a reduced preference for child-directed speech is unclear, perhaps these factors such as the child's language level and neurological differences need to be further explored.

The Role of Child-Directed Speech in Development

Child-directed speech is thought to play several important roles when used during caregiver-child interactions. One, its features promote affective relationships and facilitate social interactions between adults and young children (Fernald, 1989, 1992; Trevarthen & Aitken, 2001; Werker & McLeod, 1989), as infants show more positive affect in response to child-directed speech compared to adult-directed speech (Fernald, 1993; Werker & McLeod, 1989). Two, child-directed speech attracts the attention of typically developing children who prefer child-directed speech to adult-directed speech as early as 1 month of age (Cooper & Aslin, 1990; Fernald & Simon, 1984; Papousek, Bornstein, Nuzzo, Papousek, & Symmes, 1990; Stern, Spieker, & MacKain, 1982) and continuing into the toddler (Kuhl, Conboy, Padden, Nelson, & Pruitt, 2005; Paul et al., 2007) and preschool (Klin, 1991) years. Patterns of pitch in child-directed speech have shown to be attractive and also responsible for maintaining the attention of children (Cooper & Aslin, 1994; Fernald & Kuhl, 1987). Three, child-directed speech appears to enhance children's language learning (Fernald & Mazzie, 1991; Hirsh-Pasek et al., 1987; Kemler Nelson, Hirsh-Pasek, Juscyzk, & Wright Cassidy, 1989) in areas such as

detecting word boundaries (Thiessen et al., 2005) and learning language-specific phonetic categories (Werker et al., 2007).

Facilitating language learning. Several researchers have provided evidence that infants benefit from enhancements provided by child-directed speech in terms of language learning as a whole and specifically in terms of language acquisition (e.g. Fernald & Mazzie, 1991; Kuhl et al., 1997; Liu, Kuhl & Tsao, 2003; Thiessen et al., 2005; Tsao et al., 2004). For example, Thiessen et al. (2005) measured infant looking times in order to examine whether child-directed speech facilitates word segmentation by assisting infants to use statistical cues that allow for the differentiation between syllable sequences and the discovery of which syllables are highly predictive of one another. Child-directed and adult-directed speech recordings were composed of sentences with nonsense words spoken by a natural speaker and the recordings differed in their pitch range and intonational structure. Thiessen et al. found that the prosody, specifically intonation and pitch, facilitated infants in segmenting words. Additionally, the infants were able to differentiate between words and part words after the exposure to the child-directed speech recording, but not after the exposure to the adult-directed speech recording as evidenced by differences in looking times between words and part words when exposed to child-directed speech and not adult-directed speech. Neither acoustic property marked the word boundaries for infants and the only cues that allowed them to recognize word boundaries were the statistical properties of speech. Accordingly, the implications for Thiessen et al.'s study are that child-directed speech allows for faster and more efficient learning. In other studies, Fernald and Mazzie (1991) and Kuhl et al. (1997) found that longer pauses at phrase boundaries, another characteristic of child-

directed speech, allows infants to recognize when a word ends and another word begins in order to better discover and hence, use information in speech.

Child-directed speech and language development. In one longitudinal study of actual language growth in children and its link to the use of child-directed speech, Liu et al. (2003) examined the child-directed speech characteristic of vowel space and its relation to infant speech perception among 6-8 month old as well as 10-12 month old typically developing infants. Speech perception was measured using a head-turn conditioning procedure in which the infants were required to discriminate between two types of syllables. Vowel space, defined as the acoustic space that encompasses the exaggerated articulations of vowels, is said to be an extremely reliable measure of speech clarity (Liu et al., 2003). Maternal speech was recorded in a naturalistic setting in which mothers were told to talk as naturally as possible to the experimenter that was present and also to her infant in face-to-face interactions. Bisyllabic mandarin words containing the vowels /i/, /a/, and /u/ in the first syllable were extracted from the speech samples and used as target words. A highly significant positive correlation between speech clarity in mothers and infant speech perception performance among both 6-8 month old infants and 10-12 month old infants was found. Tsao et al. (2004) further explored this link between maternal speech clarity and infant speech performance by examining whether early infant speech perception plays an important role in later language development, specifically at 13, 16, and 24 months of age. Also using the head-turn conditioning procedure, infants were tested at 6 months of age in their ability to differentiate between two computer-synthesized vowels where /u/ served as the background sound and /y/ as the target sound. Language production and comprehension were measured longitudinally at 13, 16 and 24

months using the MacArthur-Bates Communicative Development Inventory, 2nd edition (Fenson et al., 2004), a highly valid and reliable tool for assessing language and communication development from 8 to 30 months of age. Significant correlations were found between early speech perception skills (in particular, the ability to discriminate between two vowels) and later infant language abilities across a time span of 18 months (Tsao et al., 2004) indicating that early speech perception skills predict later language development.

Child-directed speech appears to enhance language learning by increasing infants ability to segment words (Thiessen et al., 2005), differentiate between words and part words (Thiessen et al., 2005), and recognize the end of one word and the beginning of another (Fernald & Mazzie, 1991; Kuhl et al., 1997). Additionally, relationships between maternal speech clarity, a characteristic of child-directed speech, and early speech perception skills have been found and this, in turn, has been shown to predict later language development.

Child-directed speech and language development in ASD. Although children with autism show a reduced preference to child-directed speech, the use of child-directed speech has shown to have great benefits in language learning for these children. Paul et al. (2007) examined whether a relationship existed between preference for child-directed speech and current language ability as well as language ability one year later, and found that the amount of time children with ASD spent listening to child-directed speech was correlated with current receptive language abilities. Correlations were also found between the amount of time that the children with ASD spent listening to child-directed speech and receptive language abilities one year later as measured by the Mullen Receptive

Language subscale (Mullen, 1995). This suggests that early attention to parental speech input may play an important role in the language development of children with ASD. However, one should observe caution when interpreting these findings as the analyses were correlational and hence, do not imply causality since it is making the assumption that certain variables are not correlated among each other which may not be the case.

The Present Study

The purpose of this study was to compare the acoustic properties of pitch, pitch range, and duration in caregiver speech to children with ASD to those in caregiver speech to typically developing children. Additionally, the modification of speech in a child-directed manner by caregivers was examined in relation to the child's language development over a one-year period.

Aim 1: Child-directed speech modification between groups. Our first aim was to examine whether or not the caregivers of the children with ASD and the caregivers of the typically developing children modified their speech in a child-directed (higher pitch, greater pitch range, and longer duration) manner. We examined how acoustic properties of caregiver speech to young children compare in families with a child with ASD as opposed to those with a typically developing child. Also, we studied whether child-directed speech modification was evidenced to the same degree in both groups. If differences in child-directed speech modification were found between the groups, we were to evaluate two possible exploratory predictions against one another. One prediction was that the caregivers of the children with autism would be expected to use more child-directed speech modification in order to attract their child's attention (Nadig et al., 2007). Alternatively, the second prediction was that the caregivers of the children with ASD

would be expected to produce less child-directed speech if it is driven by child responsiveness, which is consistent with evidence from Lam and Kitamura (2010) who examined child-directed speech to typically developing infants with normal hearing, moderate hearing loss, and profound hearing loss. Hearing loss was simulated meaning that experimenters controlled the sound infants heard from their mother. In order to control for mothers being aware of the fact that their child could either hear or not hear them, they were told for half of the session that their baby could hear them and for the other half of the session that their baby could not hear them. Lam and Kitamura found that significant decreases in the child-directed speech characteristic of vowel hyperarticulation produced by mothers corresponded to the degree with which infants could hear their mothers. However, this was not due to the mothers awareness of whether or not they knew their child could hear them but rather mothers were responding to subtle cues their infants were providing them with during the face-to-face interaction. Since Lam and Kitamura only focused on the child-directed speech characteristic of vowel hyperarticulation and also only conducted the study with mothers of typically developing infants, we further explored this hypothesis with other acoustic characteristics of child-directed speech (e.g. mean pitch, pitch range, duration) in both caregivers of typically developing children and caregivers of children with ASD. In the development of this study, it was never our intention to place blame on any particular caregiver group (e.g. caregivers of children with ASD; caregivers of typically developing children) for their use or lack of use of child-directed speech. Rather, we intended for this study to allow us to better understand the relationship between parent speech behaviours and overall change in child language. As the statistical analyses conducted in this study were

correlations or partial correlations, we were not implying causality but rather, we were trying to determine whether any relationship exists between these two factors.

Aim 2: Child-directed speech and child characteristics. Our second aim was to examine whether the caregiver modification of speech in a child-directed manner was related to child characteristics of expressive language, receptive language and chronological age. We examined whether the caregiver modification of the acoustic properties of mean pitch, pitch range, and duration in child-directed speech, controlling for the child's attention to the caregiver speech during the task, was related to child expressive and receptive language development across a 1-year period. Additionally, we examined whether age-related changes existed in caregiver speech modification. Consistent with previous findings (e.g. Garnica, 1977; Warren-Leubecker & Bohannon, 1984), we would expect child-directed speech modification to increase with younger children and decrease with older children.

It would be unlikely for us to find a relationship between caregiver speech modification and the child's expressive and receptive language since our task and the standardized measures we chose were very different from the study conducted by Tsao et al. (2004), who examined speech perception rather than expressive and receptive language growth in children. The study conducted by Tsao et al. examined two constructs that had a clear conceptual link whereas our current study on acoustic properties of caregiver speech was not linked in any conceptual way to overall language development.

Method

Participants

The study population included 25 caregivers (1 father; 24 mothers) with a typically developing child (M = 23.45 months; SD = 5.45; 16 male) and 15 caregivers (2 fathers; 13 mothers) with a child with ASD (M = 55.21 months; SD = 11.02; 13 male) who were matched on receptive language ability (p = .14). See Table 1 for means and standard deviations of receptive language scores in both groups.

Table 1

Mean and Standard Deviation of Mullen's Receptive Language Raw Scores

Group	*M*	*SD*	*n*
ASD	31.53	14.42	15
Typically Developing	25.32	7.43	25

A separate analysis was conducted with fathers on each of the acoustic properties being examined and values fell within the range of values for mothers for mean pitch, pitch range, and duration. Given that difference scores were being measured to examine overall speech modification, fathers were included in the same group as mothers. Participants with autism were recruited through the Montreal Children's Hospital (MCH) ASD program where clinic staff distributed flyers to families who met inclusion criteria. Typically developing participants were recruited through the McGill Infant Research Group. Children received a small toy at the end of each session and caregivers were given parking passes for any visit that took place in the laboratory. Also, caregivers who

requested a brief report on their child's language level were provided with one by the supervisor of this project.

Inclusion and exclusion criteria for the ASD group. Clinical diagnosis of ASD was determined by the MCH clinic. The children with ASD met criteria on the Modified Checklist for Autism in Toddlers (M-CHAT; Robins, Fein, & Barton, 1999) and the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 1999). They did not have any medical conditions associated with ASD (e.g. fragile X syndrome, tuberous sclerosis) or any physical disability that would interfere with completing the study procedures. They also had some ability to sit and work at a table.

Inclusion criteria for the typically developing group. The typically developing children did not have symptoms of autism, as suggested by M-CHAT results. They had no developmental, learning or behavioral disorders as seen by parent report. The typically developing children showed no history of significant medical complications or conditions. They did not have a 1st or 2nd degree relative with an ASD. They also did not have a physical disability that would interfere with completing the study procedures.

Measures

MacArthur-Bates Communicative Development Inventory, 2nd edition (CDI-2; Fenson et al., 2004). This standardized parent-report measure of early receptive and expressive vocabulary as well as non-verbal social communication is intended for typically developing children between the ages of 8 and 30 months. Only the infant version of the checklist, "Words and Gestures" was given in order to measure change scores on the same items.

Mullen Scales of Early Development (MSEL; Mullen, 1995). This scale is a comprehensive, standardized measure of development from birth through 68 months. Five subscales provide an assessment of skills in the areas of receptive language, expressive language, visual reception, gross motor and fine motor skills. The assessment provided norms for T scores as well as age equivalent scores. The assessment lasted 20 to 45 minutes, depending on the child's level of ability. This measure was only used to match children with ASD and typically developing children on receptive language abilities at the beginning of the study. For matching purposes, consistent with other studies, receptive language raw scores were used as they have been shown to be more informative than using T scores.

Modified Checklist for Autism in Toddlers (M-CHAT; Robins et al., 1999). This instrument, administered to parents, consists of 23 yes/no (or pass/fail) questions that touch on behaviours parents observed in their child (e.g. "Does your child imitate you?", "Does your child look at things you are looking at?"). This questionnaire is validated for screening toddlers between 16 and 30 months of age in order to assess risk for ASD. Children who fail more than 3 items total or 2 (out of 6) items, which are considered to be critical items, are generally referred for diagnostic evaluation of ASD.

Autism Diagnostic Observation Scale (ADOS; Lord et al., 1999). This is a structured observational assessment that provides a number of opportunities for interaction and measures social and communicative behaviours diagnostic of ASD. Each item is scored from 0 (typical for age or not autistic in quality) to 3 (unquestionably abnormal and autistic in quality). Inclusion criteria require that subjects with ASD obtain a combined Communication and Social Interaction score of 7 or above.

Study Procedures

Time 1. During a 60 to 75 minute lab visit, participants were administered the MSEL (Mullen, 1995) while the primary caregiver completed the CDI-2 (Fenson et al., 2004). Results from the CDI-2 were used to match the groups on language ability.

Time 2. Six months later (+/- Two weeks), experimenters scheduled a visit to the family's home, or in the lab if preferred. Two samples of speech, a child-directed and an adult-directed speech sample were collected using audio and video recording. The child-directed speech sample consisted of a 5-10 minute session during which the primary caregiver was asked to read two storybooks to their child. One storybook entitled "Summer" by Anne Thlades was a picture book, appropriate for 2-4 year olds, where the caregiver was asked to generate a story based on the pictures in the book. The second storybook, which we entitled "The Mushroom Man", was a slightly modified version of the book "Fast Food" by Saxton Freymann. It was modified because it initially was a story where the last words of the sentence rhymed and in order to avoid any confound associated with differences in rhyming, the rhyming words were replaced with words that did not rhyme. The caregivers were asked to read the story as they normally would to their child. Following the storybook reading session, the adult-directed speech sample was collected where the experimenter conducted a 5-10 minute semi-structured interview with the primary caregiver using pre-selected questions relating to the topic addressed by the storybook. Caregivers were given the two storybooks and told that they could look through the books should they need to recall anything. These questions were used to elicit some of the same words spoken in both the child-directed context (book reading) and the adult-directed context (speaking with the experimenter). Appendix A provides the list of

questions used for each storybook. Data processing of words spoken in both contexts are described in more detail below.

Time 3. Twelve months (+/- Two weeks) after the first visit, participants returned to the lab to complete the MSEL (Mullen, 1995). During this visit, the primary caregiver completed another CDI (Fenson et al., 2004). Additionally, information about intervention programs the child attended during the 12-month period was recorded to investigate potential interactions with language development. This visit lasted approximately 75-90 minutes.

Data Processing

All storybook reading and parent interview sessions that took place at time 2 were transcribed and common words appearing in both the CD and AD contexts were highlighted and placed in an excel sheet, with the word and the number of times it appeared in both contexts. Also recorded were positions of where the word was located within a sentence (i.e. anywhere or last word) as well as the type of sentence (i.e. statement or question). In the child-directed speech sample, a total of 477 tokens were extracted with 204 anywhere in a statement, 205 last words in a statement, 39 anywhere in a question and 29 last words in a question. In the adult-directed speech sample, a total of 294 tokens were extracted with 208 anywhere in a statement, 81 last words in a statement, 2 anywhere in a question, and 3 last words in a question. A characteristic commonly seen in child-directed speech is the placement of object names at the end of a statement (Fernald & Mazzie, 1991), hence, all last words or words anywhere in a statement remained in the analysis. The examination of the proportion of words that fell at the end of a statement in our child-directed speech samples further supports this

evidence as these words account for nearly half of all tokens extracted from the child-directed speech samples. All words that were found in a question, regardless of whether they were last words or anywhere, were removed from analysis as pitch contours differ when a question is being posed rather than a statement. Using Final Cut Express 4 Software for Macintosh, individual tokens for all words appearing in both child-directed and adult-directed contexts were extracted from the speech samples. Audio files were played back and any files with too much background noise or overlapping speech were removed from analysis. Tokens with clear sound quality were further cropped using PRAAT (Boersma & Weenink, 2001), a software program for the acoustic analysis of speech. This secondary process for cropping words was performed in order to eliminate any white noise before or after the cropped word, so that only the word remains in the token. Another way we ensured that all white noise was eliminated was to examine the sound wave and re-listen to segments at the beginning and end of the word. Text grids were then created for each token cropped providing a platform for analysis of each of the acoustic properties of mean pitch in Hertz (Hz), pitch range in Hz, and duration in seconds (s). With the text grid, boundaries were marked indicating the start point and end point for analysis and tiers were created to specify what was being analyzed which, in the case of our study, were individual words (as opposed to a sentence or tone). Each subject included in the study had a maximum difference of five between the total number of child-directed tokens and the total number of adult-directed tokens. Therefore, for each word that appeared in both the child-directed and adult-directed contexts, if that particular word was spoken in one context more times than the other, only the first X number of tokens were included in order to keep the context difference of five. For words

that contained a high number of tokens spoken, the first ten tokens were considered for analysis. Upon determining the number of tokens included in each context for all words, the average scores were calculated for mean pitch, pitch range, and duration over all included tokens of a word for both the child-directed and the adult-directed contexts. A difference score was then calculated by subtracting, for example, the adult-directed speech average pitch value from the child-directed speech average pitch value for that same word in order to examine the degree of child-directed speech modification by caregivers. A positive value indicated caregivers modified their speech in a child-directed manner (e.g. higher mean pitch, higher pitch range, longer duration) whereas a negative value indicated a lack of child-directed speech modification (e.g. lower mean pitch, lower pitch range, and shorter duration). After completing all the steps of data processing, two caregivers of typically developing children and one caregiver of a child with ASD were excluded from the study due to insufficient number of tokens spoken. Hence, the final population for the study included 23 caregivers with typically developing children and 14 caregivers with children with ASD. Next, receptive (number of words understood) and expressive (number of words produced) language raw scores from the CDI-2 (Fenson et al., 2004) were compared at time 1 and time 3 and a difference score was calculated measuring change in receptive and expressive language ability across the one-year period. The relationship between the amount of child-directed speech modification of mean pitch, pitch range, and duration by caregivers at time 2 and the child's language growth scores was examined.

Coding of Attention

All time 2 video recordings were viewed by research assistants and coded for the child's attention level during the storybook reading session. 83% reliability was achieved among the three research assistants in coding the same three videos. Videos were muted while being viewed in order to eliminate judgments based on the quality of interaction during the storybook reading session. Every 30-second interval was coded on a scale of one to four (1=not attending; 4=highly attending). Appendix B provides the coding scheme used by research assistants. For intervals that were not the full 30 seconds in duration, in order to be coded, the interval must have lasted for a minimum of 15 seconds. An average score was calculated across all intervals for each participant as a measure of the child's level of attention during the storybook reading session.

Results

Descriptive Statistics

The participants of the study were matched on receptive language raw scores of the Mullen's at T1. An independent samples t-test was conducted in order to determine whether the groups of children differed in terms of their receptive language scores. Children with ASD (M = 31.53; SD = 14.42) and typically developing children (M = 25.32; SD = 7.43) were not significantly different in terms of their receptive language raw scores on the Mullen's at time 1, $t(18.54) = -1.55$, $p = .14$. Chi-squared tests were performed in order to test for effects of gender. No significant differences in gender were found, $\chi^2(1, 40) = 2.60$, $p = .11$.

An independent samples t-test was conducted to compare differences in chronological age of each group. Children with ASD (M =55.21 months; SD = 11.02)

and typically developing children (M = 23.45 months; SD = 5.45) were significantly different in terms of their chronological age, $t(18.18) = -10.42$, $p = 0.00$.

Aim 1: Child-directed speech modification

An independent samples t-test was conducted to compare differences in child-directed speech modification on acoustic characteristics of mean pitch, pitch range and duration in caregivers of children with autism and caregivers of typically developing children. For mean pitch, caregivers of typically developing children had increased pitch in the child-directed versus adult-directed contexts (M = 48.47Hz; SD = 34.74) compared to caregivers of children with ASD (M = 29.59Hz; SD = 27.77), however the difference was not statistically different, $t(35) = 1.72$, $p = .09$. See Figure 1 for a box and whisker plot showing difference scores of mean pitch values produced in child-directed vs. adult-directed contexts in both groups.

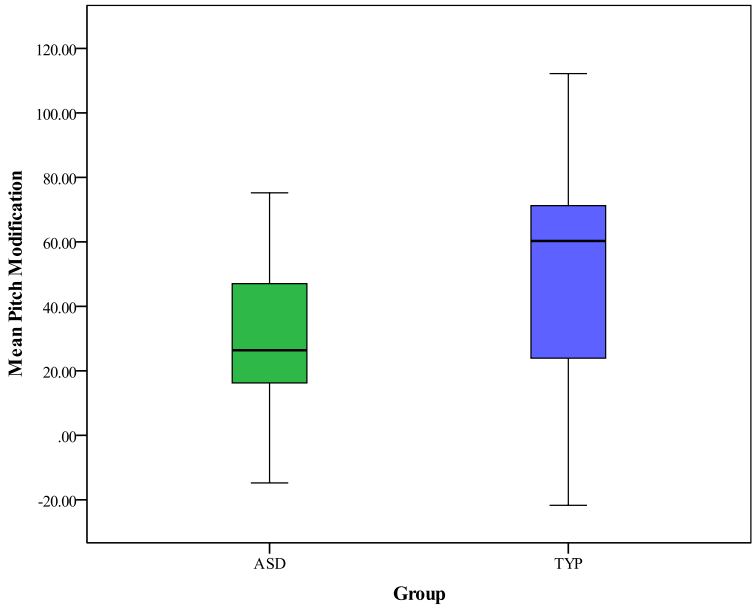

Figure 1. Difference scores of mean pitch values (Hz) produced in child-directed vs. adult-directed contexts (Note: Values greater than zero indicate expected child-directed speech modification)

For pitch range, caregivers of typically developing children had increased pitch range in the child-directed versus the adult-directed contexts (M = 55.66Hz; SD = 56.98) compared to caregivers of children with ASD (M = 28.11Hz; SD = 57.04), however the difference was not statistically different, $t(35) = 1.42$, $p = .16$. See Figure 2 for a box and whisker plot showing difference scores of pitch range values produced in child-directed vs. adult-directed contexts in both groups.

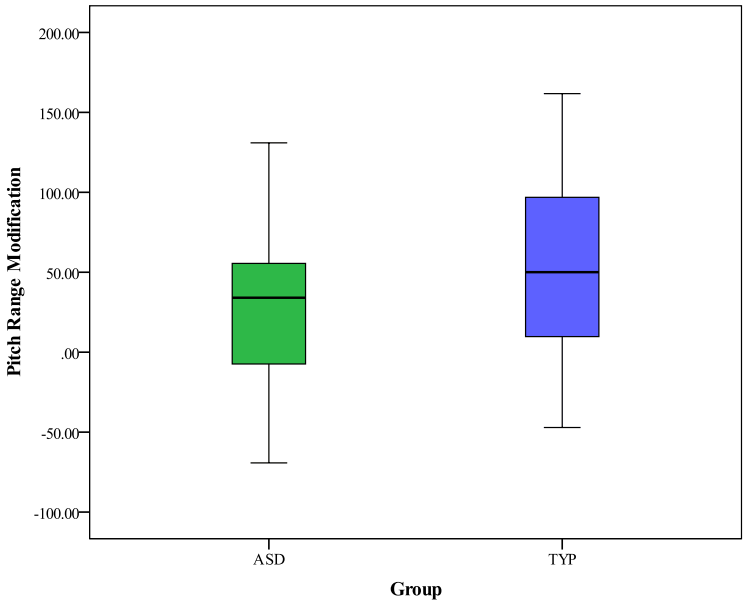

Figure 2. Difference scores of pitch range values (Hz) produced in child-directed vs. adult-directed contexts (Note: Values greater than zero indicate expected child-directed speech modification)

For duration, caregivers of typically developing children had increased duration in the child-directed versus the adult-directed context (M = .13s; SD = .18) compared to caregivers of children with ASD (M = .11s; SD = .18), however the difference was not statistically different, $t(35) = .37$, $p = .72$. See Figure 3 for a box and whisker plot showing difference scores of duration values produced in child-directed vs. adult-directed contexts in both groups.

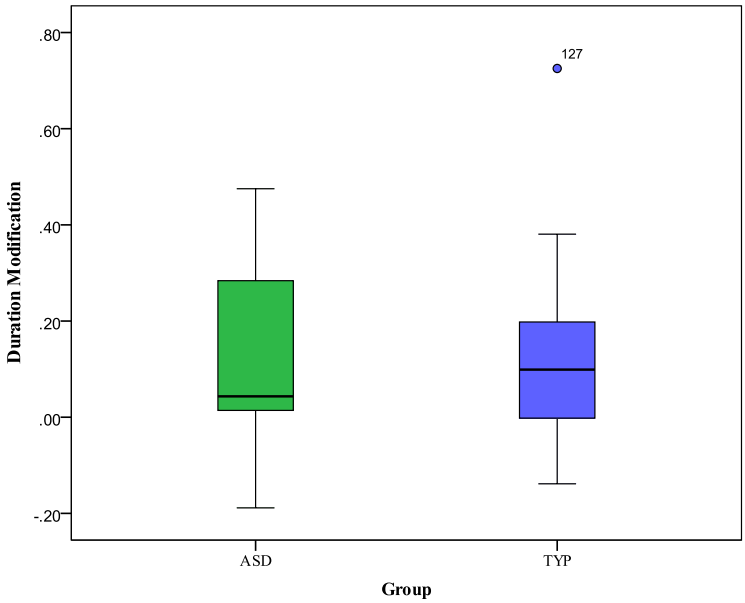

Figure 3. Difference scores of duration values (s) produced in child-directed vs. adult-directed contexts

Correlations were conducted in order to examine whether any relationships were found between the use of acoustic characteristics of mean pitch, pitch range and duration in combination. In caregivers of typically developing children, significant correlations were found between pitch and pitch range, $r(23) = .46$, $p = .03$, as well as between pitch range and duration, $r(23) = .47$, $p = .02$. In caregivers of children with ASD, significant correlations were only found between pitch and pitch range, $r(14) = .64$, $p = .01$.

Aim 2: Child-directed speech and child characteristics

Correlations were conducted on the full sample (combining caregivers of children with ASD and caregivers of typically developing children) in order to examine whether a relationship exists between the acoustic characteristics of mean pitch, pitch range, and duration and child's chronological age at time 1. A significant negative correlation was found between child's chronological age and mean pitch, $r(37) = -.36$, $p = .03$. See Figure 4 for a scatterplot graph showing relationships between mean pitch modification and

child's chronological age at time 1. No significant correlation was found with pitch range (p = .21) or duration (p = .63) and child's chronological age.

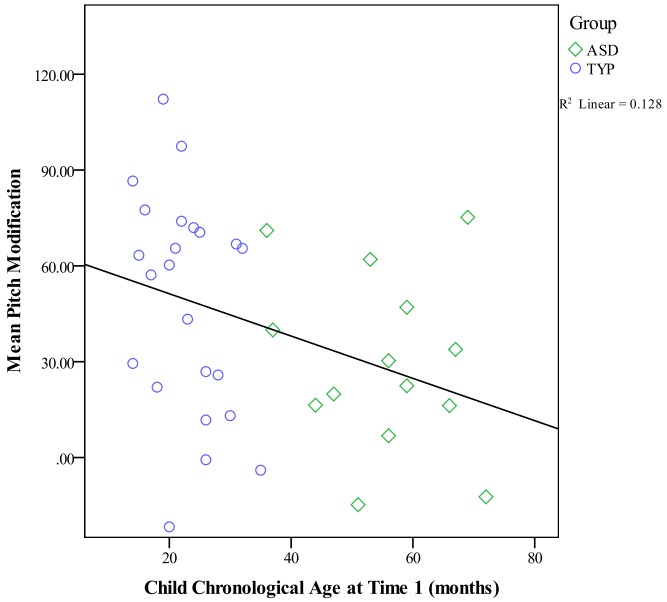

Figure 4. Scatterplot graph showing relationship between mean pitch modification and child's chronological age at Time 1.

A correlation was conducted in order to examine whether a relationship exists between speech modification of the acoustic characteristics of mean pitch, pitch range, and duration and receptive (number of words understood) and expressive (number of words produced) language at time 1 as measured using the CDI-2 (Fenson et al., 2004). No significant correlations were found between modification of mean pitch (p = .78), pitch range (p = .93), duration (p = .83) and time 1 number of words produced. Also, no significant correlations were found between modification of mean pitch (p = .81), pitch range (p = .93), duration (p = .84) and time 1 number of words understood. A partial correlation was conducted in order to examine the relationship between speech modification of acoustics characteristics of mean pitch, pitch range, and duration and

receptive (number of words understood) and expressive (number of words understood) language at time 3 controlling for receptive and expressive language scores at time 1 as well as the child's attention during the storybook reading task. Only a small group of participants had outcome data for time 3 (21 typically developing children; 4 children with ASD) as the study is still in progress. No significant correlations were found between mean pitch (p = .90), pitch range (p = .65), duration (p = .83) and time 3 words produced. However, a significant negative correlation was found between pitch range modification and number of words understood at time 3 controlling for the number of words understood at time 1 and child's attention during the storybook reading task, $r(23) = -.41$, p = .04. No significant correlations were found with pitch (p = .32) or duration (p = .62).

Discussion

The foci of this study were the key acoustic indicators of caregiver child-directed speech such as mean pitch, pitch range, and duration, to children with ASD and typically developing children matched on receptive language levels. The first aim of the study was to examine whether the caregivers of children with ASD and the caregivers of typically developing children modified their speech in a child-directed manner during a short interaction and whether these modifications were the same in the two groups. The second aim of the study was to examine whether child-directed speech modification was related to characteristics such as the chronological age of the child and the child's expressive and receptive language growth.

Several similarities were found between the caregivers of the children with ASD and the caregivers of the typically developing children in the use of child-directed speech.

One, they modified their speech in a child-directed manner with higher mean pitch, higher pitch range, and longer duration. Two, those with older children decreased their mean pitch modification. Three, those with children who showed less change in receptive language over the course of the study increased their modification of pitch range. Conversely, the caregivers of the children with ASD differed from the caregivers of the typically developing children in the combination of the acoustic properties of mean pitch, pitch range, and duration in their use of child-directed speech. Thus, both groups modified their speech in a child-directed manner but differed in terms of how the speech sounded acoustically.

Group Similarities and Differences in Child-Directed Speech Modification

The caregivers of the children with ASD and the caregivers of the typically developing children spoke with higher mean pitch, higher pitch range and longer duration in the child-directed context compared to the adult-directed context. This implies that the caregivers of both groups modified their speech in similar ways when interacting with their children. This is consistent with evidence that the caregivers of children with ASD provide similar language environments as the caregivers of typically developing children (Warren et al., 2010; Wolchik, 1983).

Although the caregivers of the two groups did not differ in overall mean pitch, pitch range and duration modification, they differed in their tendencies to use child-directed acoustic features in combination when speaking to their child. The caregivers of the children with ASD and of the typically developing children both used the acoustic features of mean pitch and pitch range in combination which indicates that higher mean pitch in child-directed speech spoken by the caregivers is related to higher pitch range

and vice versa. This demonstrates that the caregivers who spoke in a higher pitched voice, also showed greater variation in their pitch which is consistent with evidence that the acoustic properties of pitch and pitch range occur together and are linearly related beyond the first year of life (Garnica, 1997; Warren-Leubecker & Bohannon, 1984). However, in addition to the use of acoustic properties of mean pitch and pitch range in combination, the caregivers of the typically developing children, but not those of the children with ASD, also used pitch range and duration in combination when speaking to their child. This indicates that the use of higher pitch range in child-directed speech spoken by the caregivers is related to longer durations of words spoken and vice versa. Therefore, the caregivers of the typically developing children who spoke with greater variation in their pitch also tended to speak at a slower pace. Since the acoustic property of duration was only found to be related to other acoustic characteristics of child-directed speech in the caregivers of the typically developing children, although the caregivers of the children with ASD modified the duration of their speech consistent with that of child-directed speech, their use of this acoustic property was not related to their use of other acoustic properties such as mean pitch and pitch range. Thus, one of the ways in which the caregivers of the children with ASD modified their speech in a child-directed manner was by speaking at a slower pace but unlike the caregivers of the typically developing children, the duration of their speech was not related to the other acoustic modifications of child-directed speech.

Characteristics of the Child Affect Child-Directed Speech Modification

The decrease in caregiver pitch modification seen with older children is consistent with evidence that the caregiver's use of acoustic properties of pitch in speech directed to

their child decreases beyond the child's first year of life (Garnica, 1977; Warren-Leubecker & Bohannon, 1984). Therefore, one explanation of this finding is that the caregivers of an older child, regardless of whether they have a child with ASD or a typically developing child, are simply responding to their child's lack of response. These caregivers recognize that their child may not be as responsive to child-directed speech and therefore begin to alter their speech to more closely resemble that of adult-directed speech. This is consistent with evidence that children provide subtle cues during face-to-face interactions which caregivers respond to (Lam & Kitamura, 2010). Alternatively, the caregivers may also be responding to the needs of their child with a specific purpose in mind. For example, since the language abilities of younger children are less developed than those of older children, the caregivers might modify their speech to encourage their child whose language is still initially developing (Polka & Werker, 1994; Werker & Tess, 1984) or to facilitate language learning for their child (Fernald & Mazzie, 1991; Hirsh-Pasek et al., 1987; Kemler Nelson, Hirsh-Pasek, Juscyzk, & Wright Cassidy, 1989).

The examination of other child characteristics, such as expressive and receptive language and child-directed speech modification, were not related to expressive language ability (i.e. number of words produced). However, children who showed less change in receptive language ability (i.e. number of words understood) had caregivers who produced higher modification of pitch range, which is consistent with speaking in a child-directed manner. Thus, for children who showed less growth in their receptive language abilities between time 1 and time 3, the caregivers spoke with greater pitch range modification when interacting with their child.

The inverse relationship found between receptive language and pitch range modification is not consistent with previous evidence that acoustic characteristic of child-directed speech are related to early language learning (Tsao et al., 2004). In one example of benefits of child-directed speech characteristics for language development, an increase in vowel space area, a strategy consistent with child-directed speech, is related to an infant's ability to discriminate speech (Liu et al., 2003) which, has been show to predict later language development (Tsao et al., 2004). The failure to find a relationship between language growth and child-directed speech modification in this study may be due to the use of specific measures and tasks that were quite different from those used in the study by Tsao et al. who examined the clarity aspect of child-directed speech at the phonetic level using vowel space and speech discrimination in infants in the form of their ability to perceive phonemes. In this study, the focus was on global acoustic characteristics of child-directed speech (specifically mean pitch, pitch range, and duration) and overall child receptive and expressive language. Accordingly, the task and measures used in examining child-directed speech characteristics and its relation to language development in both experiments were very different from one another. In the studies by Liu et al., and Tsao et al., the factors being examined in both studies showed a clear conceptual link whereas in our study, acoustic properties of child-directed speech are not closely linked in any conceptual way to overall language development. Another possible reason to explain why no relationship was found between language growth and child-directed speech modification in the predicted direction is that the children in this study were older in comparison to those in other studies on child-directed speech. By time 3, the children had reached ceiling levels in their expressive and receptive language scores. Therefore,

the children who began with higher overall initial language scores, showed less change in language scores over the course of the study.

Rather than examining possible reasons why this study failed to show relationships between child-directed speech and overall language growth, perhaps there is an alternate explanation for these results. Consistent with evidence that the use of child-directed speech is driven by certain cues provided by the child (Lam & Kitamura, 2010), a more probable interpretation of these findings is that the child's receptive language ability drives the way in which their caregivers interact with them. This relationship between child-directed speech and receptive language suggests that caregivers are sensitive to their child's behaviours and adapt themselves accordingly. Moreover, they respond to their child's delay in language growth and are driven to communicate with their child in a manner similar than that of child-directed speech.

Limitations and Future Directions

The essential findings relating to the use of child-directed speech by caregivers and child characteristics must be considered within certain limitations in data processing, contributing factors and methodology. In order to enhance the strength of the results, these gaps need to be addressed in future studies extending from this project.

The data was processed by isolating single words in child-directed and adult-directed speech with the intention of creating a more targeted analysis. However, a potentially more informative approach would be to examine the entire speech sample in terms of overall mean pitch, pitch range and duration rather than isolating individual words. Acoustics of speech vary across a sentence and are influenced by factors such as whether a question is being posed or whether the word being emphasized is positioned at

the end of a sentence or somewhere in the middle. In this way, the entire speech sample would be more representative of how a caregiver modifies their speech in a child-directed versus adult-directed manner. However, in order to maximize the accuracy of results being produced, the analysis of the same speech passage spoken in both contexts would be beneficial. However, the issue with this is that it would be very difficult to measure in a naturalistic setting, which is one factor we tried to preserve with the present study.

The lack of consideration of other factors may also play a role in impacting the results. One concern is whether the children with autism are first born or whether they already have a sibling and, whether their sibling has also been diagnosed with ASD. This may impact caregiver interaction behaviours if they already have experience with another child who has already been previously diagnosed. The same is also true for caregivers who already have a child but with no previous diagnosis. This idea of previous exposure in either case could impact the findings of this study. Another aspect that may be a contributing factor is whether the child's family is accustomed to storybook reading. Storybook reading may be an activity that is not necessarily a part of a family's daily routine. Hence, these caregivers who are not familiar with storybook reading may sound acoustically different when telling the story compared to those caregivers who engage in this type of activity regularly. Perhaps, a questionnaire examining storybook reading behaviours at home would be beneficial for future studies. Also, families were given the option to have time 2 sessions in the lab or at their home and this could potentially have an affect on the speech recordings. For future studies, it would be beneficial to keep the testing setting consistent to avoid the affect this may have on the overall results.

There are also some minor aspects in the methodology relating to the age of the participants and the measures used in the study that may be of concern. The MSEL (Mullen, 1995) was used to match the typically developing children and the children with ASD on receptive language abilities and scores of the CDI-2 (Fenson et al., 2004) were used to measure changes in expressive and receptive language. Since the children with ASD were older as compared to the typically developing children, language growth was difficult to measure as the children who began the study with higher language scores (as was the case for the older children), had less room for improvement. Hence, many participants reached ceiling levels of performance thereby, limiting the ability to measure language growth precisely. In order to address this issue, the study of even younger participants would have yielded a clearer measure of language growth. Findings regarding the use of acoustic characteristics of mean pitch, pitch range and duration in a younger population would also be more beneficial since evidence has shown acoustics, particularly average pitch and pitch range, in child-directed speech to decrease beyond the first year of life (Garnica, 1997; Warren-Leubecker & Bohannon, 1984). Alternatively, rather than using the CDI-2 (Fenson et al., 2004) to measure language growth, a measure which allows for the examination of language in older children might be more informative as the CDI-2 is only to be used for children ranging from 8 to 30 months of age. Another potential issue with younger children belonging to the typically developing group and older children belonging to the ASD group is we cannot confirm that our findings of a negative relationship between child chronological age and mean pitch are accurate as it could also be interpreted that caregivers of children with ASD (the older children) have decreased mean pitch modification. Therefore, in order to ensure the

accuracy of this result, it would be beneficial to add older typically developing children and younger children with ASD and then examine these groups separately to see if the findings are replicated.

Conclusion

Delays in language development in children are often primary concerns for caregivers due to evidence of its strong relationship with later functioning (Luyster, Qiu, Lopez, & Lord, 2007; Mawhood, Howlin, & Rutter, 2000; Smith, Goddard, & Fluck, 2004; Szatmari, Bryson, Boyle, Streiner, & Duku, 2003). The findings from this study are evidence that caregivers, regardless of whether they have a child with ASD or a typically developing child, respond to characteristics of their child, specifically chronological age and receptive language levels, during periods of interaction. The use of child-directed speech diminishes with age as seen in a decrease in their overall pitch modification, with older children. However, when caregivers recognize poor language comprehension among their children, they tend to modify their speech in a child-directed manner as manifested in an increase in their pitch range. These findings have both theoretical and practical implications. From a theoretical view, these findings are consistent with the idea that caregiver speech is driven by child responsiveness (Lam & Kitamura, 2010) and thus, parents are sensitive to their child's behaviours. From an applied perspective, the findings are informative about trends in caregiver speech as an early indicator of language difficulties. An increase in the use of caregiver child-directed speech might be an early indicator that caregivers feel that they need to simplify their speech resembling a more child-directed manner for their children to further progress in the language domain.

Accordingly, caregiver behaviours provide us with indicators of complex developmental changes that the children undergo in their own interaction with the world around them.

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Appendix A

Caregiver Interview Questions

Storybook 1: "Summer".

1) How do you feel about the season discussed in the book? What are your favorite things about the season?
2) Have you and your family ever seen any of the animals you saw in this story up close? Which ones? If not, which ones do you hope to see up close one day?
3) Have you and your family ever participated in any of the activities seen in the book? Which ones? If not, are there any of the activities that you hope to take part in one day?
4) As a child, did you play outside a lot? Did you have a lot of contact with nature? Of the activities you saw in the book, which ones did you take part in?
5) Does you family have any summer plans? Do you see yourselves doing any of the activities you saw in this book in the summer? If so, which ones?

Storybook 2: "The Mushroom Man".

1) Of the modes of transportation you saw in the book, which ones have you used? Which ones do you hope to use one day?
2) Has your family done any of the outdoor activities you saw in this book? Which ones?
3) Of the food shown in this book, which ones are your favorite to eat? Which ones do you dislike?
4) Of the food shown in this book, which ones are you child's favorite to eat? Which ones does he/she dislike?
5) Do you cook on a regular basis with the food shown in the book? Which fruits and vegetables do you use?

Appendix B

Attention Coding Descriptors

Code	Description
4	Child is doing 3 out of 3 behaviours for more than half of the interval and out of the child's own volition -sitting/standing in contact with (close proximity to) the parent; -attending to the caregiver and/or book with book in front of them* -sitting still and/or staying in one place
3	Child is doing 2 out of 3 behaviours above for more than half of the interval
2	Child is doing 1 out of 3 behaviours above for more than half of the interval
1	Child is not: -in contact with caregiver and/or book -not looking at the book and/or caregiver -not sitting still for more than half of the interval and looks clearly disruptive and actively fighting the activity

*for the purpose of the shared book activity

Appendix C

How I Learn Words: ***Early word learning in autism***

Research project conducted by Aparna Nadig, Ph.D.
School of Communication Sciences and Disorders, McGill University
Funded by Fonds Quebecois de Recherche sur la Société et la Culture

INFORMATION AND CONSENT FORM

We invite you to have your child participate in a research project that involves a language study with your child. Before you agree to participate in this research project, please take time to understand and to consider the following information. This consent form explains the goal of the study, the procedures, advantages, risks and inconvenience, as well as listing people to contact should the need arise.

We encourage you to ask the investigator or other members of the research team any questions or concerns you may have. Please ask them to explain any wording or information that is not fully clear to you.

GOAL OF THE STUDY

We are studying how children with autism spectrum disorders learn words, compared to children who are developing typically. Our goal is to better understand the processes of word learning and individual differences in these processes. In particular, we are investigating the strategies children use to learn new words, and how they generalize the new words they have learned to other objects. We are also examining vocabulary growth over time, and how this might be related to how children learn and extend words. Finally, we are investigating parent behaviors during interaction (e.g., using child-directed speech or "motherese", pointing and showing, labeling of objects) and how they may be related to child vocabulary growth. In the future, knowledge gained from this study may be used to help children with autism communicate better.

STUDY PROCEDURES

Participants in this study will be children with autism spectrum disorders, aged 2 to 6 years, and children who are typically developing, aged 14 months to 3 years at the beginning of the study. Participants will have home and family language exposure that is primarily French or English. In other words, they will have either French or English as a first language.

The study involves 3 visits over one year.

1. Today is the first lab visit and will last an hour to an hour and 15 minutes.
2. The second visit will be in 6 months, and involves
   - a free play session between you and your child (20 minutes)
   - a book reading task, where we will ask you to read a picture book to your child (5 minutes)
   - a brief interview and demographic questionnaire we will ask you to fill out (5 minutes)
   - a task where we will ask you to label objects for your child (5 minutes)

We can come to your home for this session if that is more convenient, or you can come back to the lab.

3. The last visit will take place in one year, at the lab. It will take approximately an hour and a half.

During the sessions you can stay with your child at all times. We will take breaks and have snacks and toys on hand. You can stop at any time if you or your child is uncomfortable in any way.

These are the things we will do in the lab on visits 1 and 3:

- We will do a developmental test with your child, which should last half an hour to 45 minutes. The major part of this test involves sitting at a table and doing activities with objects such as blocks.
- We will do an activity where we bring out new objects and name one, and then ask your child to show us the object we named.
- In a second activity you and your child will be seated in front of a large screen. We will show events or pictures on the screen while playing audio of words or phrases. A hidden camera will record where your child is looking. During this time you will be listening to music on headphones.
- You will be asked to complete two questionnaires. One is about your child's use of gestures and words. Another is about social and communication skills.
- At the last lab visit, your child will be asked to repeat a list of nonsense words like "nibe."
- If your child has an autism spectrum disorder we will ask you to complete a survey on intervention services received at the end of the study.

All sessions will be audio and videotaped for scoring. The tapes will be used for research purposes only and will not be shown publicly unless you sign the separate video consent section below.

BENEFITS

By participating in this research project, you and your child will contribute to science. In the future, knowledge gained from this study may be used to help children with autism communicate better.

RISKS

The study does not use any procedures that cause discomfort or create a risk of injury. However, your child may become frustrated or bored during the lab sessions. We will be ready to take breaks and have snacks or play time as necessary.

CONFIDENTIALITY

All of the information collected as part of this study will be kept confidential. Original records with personal information will be kept in a locked file cabinet in the research laboratory. In all files and analyses of the data, participants' names will be replaced by ID numbers. Data will be kept for a period of 25 years after which time it will be shredded or deleted. Access to data will be limited to study personnel, and to The Institutional Review Board of the Faculty of Medicine and the McGill hospital Research Ethics Board, should they need to review management of the data.

Results of the project will be published and presented at conferences. However, identifying information which would allow readers to know who the participating children were or how individual children performed on the tasks will not be disclosed at any time

COMPENSATION

Children will receive a small gift upon completion of each visit as a small token of our appreciation for your time and efforts. We will also provide you with a parking pass if you come to the lab by car, or reimburse your metro tickets.

PARTICIPANT RIGHTS AND WITHDRAWAL FROM STUDY

Participation in this project is voluntary. You have the right to ask questions at anytime, and to discontinue participation for any reason and at any point during the study. Refusal or stopping to participate involves no penalty. You will be given a copy of this form for your records. If you agree to

participate in this study, please sign this form below.

CONTACT INFORMATION

For any questions that may arise at any time during the project regarding the scientific aspects of the study, scheduling, or the children's results, please contact the Principal Investigator, Dr. Aparna Nadig (514-398-4141, Aparna.Nadig@mcgill.ca), or the research assistants at our lab (514-398-6895). For any questions on participant rights, or should any problems arise, please contact Ms. Ilde Lepore, Senior Ethics Administrator, Institutional Review Board of the Faculty of Medicine, McGill University (514-398-8302) or Patricia Boyer, Ombudsman for the Montreal Children's Hospital (514-412-4400 x22223). By participating in this study, you do not renounce any of your rights nor do you release the researchers or the participating institutions from their legal and professional obligations.

SIGNATURE FOR STUDY CONSENT

The study has been explained to me and my questions have been answered to my satisfaction. I agree to have my child participate in this study. I have been informed that I will be given a copy of this form for my records. I do not waive mine or my child's legal rights by signing this consent form.

Child's Name	Child's Date of Birth	
Parent's Name	Signature	Date
Researcher	Signature	Date

VIDEO CONSENT

At times, the investigators may find it useful to use videotapes of the study sessions for educational purposes with students and other professionals. Please indicate below with your initials whether or not you will allow the video to be replayed at teaching or professional activities. At no time will the participant's name be revealed. Your participation in the study will not be affected by your decision.

☐ **I will allow** videos to be replayed at teaching or professional conferences

☐ **I will not allow** videos to be replayed at teaching or professional conferences

Appendix D

Consent For Sharing of Language Transcriptions

During your second visit with us, you and your child engaged in activities where you played with toys, read books, and taught your child names for objects. These sessions were recorded by audio and video, and transcriptions (written records of speech) of the language will be examined in our study to look at how words are learned by children. These transcriptions are a valuable resource to understanding how children use and learn words.

If you accept, we would like to contribute the language transcriptions obtained through our study to a database called TALK BANK. This would make these transcripts available (free of charge) to other researchers who are interested in studying child language development.

These transcripts do NOT include any personal information such as addresses, birthdates, or telephone numbers. They only consist of speech produced during the interaction between you and your child.

Please INITIAL your preference for the contribution of these transcripts to the language transcript database:

___ **Yes**, I would like to contribute the transcript from my study session.

If Yes:

___ I allow the transcripts to be available WITHOUT pseudonyms (keep all names as they were spoken)

OR

___ I allow the transcripts to be uploaded WITH pseudonyms (replace all names in transcript with "NAME")

If, at any time in the future, you would like to remove your data from TalkBank, please contact us and we will do so.

___ **No**, I prefer not to contribute the transcript from my study session.

Thank you again for your participation in our study!