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Autism and the Social Feedback Loop between Infants and Caregivers:

A Case Study

by

Saunja S. Carlson

A thesis

submitted in partial fulfillment

of the requirements for the degree of

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Committee Approval

To the Graduate Faculty:

The members of the committee appointed to examine the thesis of SAUNJA S. CARLSON find it satisfactory and recommend that it be accepted.

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October 10, 2014

Saunja Carlson
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RE: Your application dated 10/9/2014 regarding study number 4168: Infant Vocalization, Caregiver Response, and the Potential for Identifying Prelinguistic Markers for Autism

Dear Ms. Carlson:

I agree that this study qualifies as exempt from review under the following guideline: 4. Analysis of existing data sets. This letter is your approval, please, keep this document in a safe place.

Notify the HSC of any adverse events. Serious, unexpected adverse events must be reported in writing within 10 business days.

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Sincerely,

Ralph Baergen, PhD, ~~MPH,~~ CIP
Human Subjects Chair

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Abstract

Autism spectrum disorder (ASD) is a developmental disorder that clearly impacts a child's ability to communicate and interact with others. A diagnosis of ASD is often not reliable before the age of 2. However, infants who have an older sibling with ASD (ASD-sibs) are at a greater risk for developing speech and language delays, and also ASD themselves. Important to speech and language development is the social feedback loop between a prelinguistic infant and his/her caregiver. Observation of altered development in the social feedback loop may provide cues to early identification. If prelinguistic markers for ASD could be identified, earlier intervention could benefit infants who are at risk. In an attempt to explore potential prelinguistic markers, this case study explored the caregiver/infant social feedback loop dependent upon four variables: 1) infant (an ASD-sib and an infant with a typically developing sibling - TD-sib); 2) infant age; 3) caregiver utterance types; and 4) infant utterance types. The hypothesis, therefore, was fourfold: the number of exchanges in the feedback loop would be greater for the TD-sib, would increase with infant age, and would be contingent upon both the caregiver's directedness and the linguistic quality of the infant's utterance. If results support these hypotheses, further research will be warranted. Clinical implications, study limitations, and future directions will be discussed.

Autism and the Social Feedback Loop between Infants and Caregivers: A Case Study

As children move through the prelinguistic stages of babbling, they learn that there is power in communication, that their attempt to communicate has an effect on others. They begin to engage in joint attention and to be intentional. Early vocalizations lay foundations that children need to establish a firm linguistic base. When infants babble, caregivers will often place intent upon the vocalizations, assuming their child is trying to communicate with them. In turn, caregivers respond to their children, which further encourages the child to vocalize. This social interaction is crucial to speech and language development. The back and forth turn-taking skills that children learn stimulate growth. Warlaumont, Richards, Gilkerson, and Oller (2014) have used the term "social feedback loop" to explain this communicative interaction between infants and caregivers.

Previous research has shown that caregivers respond differentially to their infant's vocalizations (Dunham & Dunham, 1990; Gros-Louis, West, Goldstein, & King, 2006), depending upon any number of variables (e.g., type of vocalization, setting, time of day, etc.). Caregiver responses play an important role in facilitating speech and language development, such that speech directed to an infant will greatly enhance vocabulary growth, whereas mere exposure to overheard speech does not have the same benefit (Goldstein & Schwade, 2008; Goldstein, Schwade, & Bornstein, 2009; Gros-Louis et al., 2006; Weisleder & Fernald, 2013). In addition, infant prelinguistic vocal behaviors are predictors of later language abilities (Heimann, Strid, Smith, Tjus, Ulvund, & Meltzoff, 2006; Watt, Wetherby, &

Shumway, 2006; Wetherby, Allen, Cleary, Kublin, & Goldstein, 2002; Wetherby, Goldstein, Cleary, Allen, & Kublin, 2003), but it is challenging to correctly identify infants and toddlers who may be at risk for future speech and language difficulties (Määttä, Laakso, Tovanen, Ahonen, & Aro, 2012). Identification of *atypical* development is difficult because *normal* vocal development is variable and unstable (Bates, Dale, & Thal, 1995; Darrah, Hodge, Magill-Evans, & Kembhavi, 2003; Fenson, Bates, Dale, Goodman, Reznick, & Thal, 2000; Thal, Bates, Goodman, & Jahn-Samilo, 1997).

One way to prospectively study potential predictors of future speech and language development is to work with infants who present with certain risk factors. For example, previous research has shown that infants who have siblings with autism spectrum disorder (ASD) are at risk for developing speech and language delays (Iverson & Wozniak, 2007; Paul, Fuerst, Ramsay, Chawarska, & Klin, 2011). Accordingly, we wished to explore differences in caregiver/infant communicative interaction (i.e., the social feedback loop), dependent upon a variety of variables discussed in detail below.

Caregiver/Infant Interaction

Social interaction between infants and their caregivers is important for speech and language development (Weisleder & Fernald, 2013). Interaction behaviors include joint attention, imitation, and using objects to pretend. Warlaumont and colleagues (2014) discuss the social feedback loop for speech vocalizations between a child and caregiver as containing two sensitive elements. First, when a child vocalizes, an adult is more likely to immediately respond to that child if the

vocalization contains speech-like content. Second, if an adult immediately responds to a child positively, the child is more likely to produce a second speech-like vocalization. This positive social feedback loop enhances and encourages proper speech and language development. Warlaumont and colleagues (2014) retrospectively investigated the social feedback loop with children who were TD (typically developing), and also with children who had ASD. Using previously gathered 12-hour recordings from a study conducted by Oller and colleagues (2010), utilizing LENA (Language Environment Analysis) software, Warlaumont and colleagues (2014) were able to examine 1,153 recordings (totaling 13,836 hours) of infant/caregiver interaction for 183 infants. Several 12-hour recordings were examined for each infant, in a variety of settings (e.g., in the car, at preschool, at home, etc). The infants ranged in ages from 8 to 48 months and had variability in socio-economic status (SES). Of the 183 infants, 106 were TD, and 77 had ASD. In this study, infant vocalizations were classified as either speech-like (including speech, singing, and babbling), or non-speech-like (including burping, crying, laughing, and coughing). Adult responses were defined as "any adult vocal behavior occurring within 1 second after the child vocalization" (Warlaumont et al., 2014, p. 1317). The researchers hypothesized that social feedback loops between infants and caregivers enhanced vocal development in infants.

Results showed that the social feedback loop was different between adults and children with ASD than it was between adults and children who were TD. First of all, the children with ASD produced less vocalizations, which were overall less speech-like than the children who were TD. Second, adult responses to the speech-like

vocalizations of children with ASD were not as immediate or consistently produced; the contingency between vocalizations and responses did not exist to the same degree as with adults and children who were TD. Accordingly, it was suggested that children with ASD have fewer opportunities to learn about social interaction. In this way, Warlaumont and colleagues (2014) found that the social feedback loop impacts a child's speech and language development.

Likewise, Dunham and Dunham (1990) found that the more vocal interactions between babies and mothers, the more babies smile, and the less babies avert their gaze from mothers. This further supports the idea that the more social interaction babies receive; the more the interaction will generalize and positively impact other areas of their lives.

Goldstein and Schwade (2008) explored how caregiver feedback to babbling infants helps children develop vocally in the prelinguistic stage. They provide evidence that vocal skills develop dramatically during the first year of life, and suggest that caregiver response is a sensitive component of this development. Their study included 60 mother/infant pairs. The infants were between 8 to 10 months of age, and were all TD. Each of the mother/infant pairs interacted in the laboratory for two 30-minute sessions, 1 day apart. The first day was merely for the pair to become familiar with the room and the toys. On the second day, during the first 10 minutes and the last 10 minutes, the mothers were instructed to play and interact with their child as they typically would at home. During the middle 10-minute segment of the session, data was gathered. The pairs participated in one of four different scenarios. Two of the scenarios consisted of contingent responses from 30 of the mothers, where

the researchers instructed the mothers through headphones how and when to respond to their infants. The remaining 30 pairs made up the control group, interacting without instruction from the researchers.

The mothers' responses were coded when they occurred within 2 seconds of their infants' babbling. The infants' babbling sounds were coded into one of four categories, which was based on a categorization system of acoustic qualities developed by Oller (2000). The four categories were "quasi-resonant nucleus, fully resonant nucleus, marginal syllable, and canonical syllable" (Goldstein and Schwade, 2008, p. 517). The researchers also looked at the possibility of infants changing their babbling in imitative response to what their mothers had produced.

Findings showed that infants changed their babbling responses in relation to how mothers produced a sound. For example, in the two contingent groups, the mothers were instructed to respond to the infants' babbling sounds by speaking to their infants *while* moving towards, touching, and smiling at them. Some of the mothers were instructed to respond with consonant-vowel (CV) alternating syllables, while others were told to speak fully-resonant vowels. In both cases, the infants increased their production of CV syllables and fully-resonant vowels. However, in the two control groups, the mothers responded with the same CV syllables and vowels as the two contingent groups, but the timing of moving towards, touching, and smiling at their infants was not in synch with their vocalizations. In these two control groups, the infants exhibited no change in the phonological make-up of their vocalizations. The social interaction helped guide learning different phonological features. These results provide evidence that babies learn the phonological features of sounds in

response to contingent feedback from their mothers, and this interaction has important ramifications for understanding prelinguistic vocal development (Goldstein and Schwade, 2008). The way caregivers respond to babbling helps shape and guide how different phonological features are learned and used.

Caregivers respond to their prelinguistic infants 30 to 50% of the time (Goldstein, King, & West, 2003; Goldstein et al., 2009; Gros-Louis, West, Goldstein, & King, 2006). During the first year of life, infants develop linguistically by producing different pre-linguistic babbling sounds consisting mainly of marginal syllable-like vocalizations at first, and then honing their skills into more canonical speech-like vocalizations containing consonant and vowel combinations with timely transitions between the two segments (Oller, 2000). Goldstein and Schwade (2008) found that when caregivers respond with speech-like sounds, infants are more likely to imitate them and respond back, likewise with speech-like sounds. Goldstein and colleagues (2009) also point out that reinforcement can help a child learn which sound types are most desirable.

In studies conducted by Goldstein and colleagues (2003, 2008), infants demonstrated rapid learning of the social consequence to their vocalizations. Goldstein and colleagues (2009) specifically analyzed data for 38 five-month-old infants, because this is an age when infants are particularly sensitive to differences in the amount of social feedback they receive from caregivers. The researchers also analyzed the 5-month-olds' productions to see if they were good indicators of the infants' language development. Results showed that 5-month-old infants were aware of the social back-and-forth turn taking style of conversations. The infants increased

their vocalizations during caregiver still-faced episodes, to try and increase the responsiveness of adults. They were trying to engage the caregiver in conversational turn taking. Further, the infants significantly decreased their vocal behavior after the still-faced episodes, when natural interaction convened. When typical conversation resumed, the number of infant vocalizations decreased because the caregiver was attentive and interactive. Additionally, the amount of vocalizations infants made during the still-faced episodes was directly related to later language abilities. Goldstein and colleagues (2009) found that five-month-old babies were aware that their prelinguistic vocalizations requested responses from listeners, expecting even an unfamiliar listener to respond. Thus, infants understand communicative interaction.

Gros-Louis and colleagues (2006) explored how caregivers' responses to their infants affect vocal growth and development. The researchers used previously gathered data from a study conducted by Goldstein and colleagues (2003), from which 10 pairs of mothers and babies (ranging in age from 7 to 10 months) were studied. In the Goldstein and colleagues (2003) study, the mothers and infants had participated for 2 days in a play setting. Gros-Louis and colleagues (2006) analyzed recordings from the first 10 minutes of the second day of play. While the researchers' focus was mainly on the mothers' responses to infant vocalizations, both the infant vocalizations and the mothers' responses were coded for type and quality. For the infants, CV productions, as well as vegetative sounds, were coded. For the mothers, responses were coded into one of seven categories: "1) naming; 2) questions; 3) acknowledgements; 4) imitations attributions; 5) attributions; 6) directives; and 7) play vocalizations" (Gros-Louis et al., 2006, p. 114).

The researchers found that the infants produced roughly three times as many vowel sounds as consonant sounds (34 vowels/14 consonants), and that mothers responded vocally to infants 73% of the time. Vocal responses were significantly greater in number than non-vocal responses (such as smiling and making gestures). Mothers were also three times more likely to respond to infants with a vocal response when infants had produced consonant-vowel combinations, rather than just vowel sounds. When infants produced just vowel sounds, mothers tended to respond more in a play-related manner. The conclusion was that vocal feedback from caregivers helps infants develop speech and language skills (Gros-Louis et al., 2006).

Caregiver speech directed to infants will also greatly enhance vocabulary growth, whereas mere exposure to overheard speech does not have the same benefit for children (Weisleder & Fernald, 2013). As children have unequal access to interactions with caregivers, due to different social and home environments, Weisleder and Fernald (2013) examined the language learning effect for infants when speech was directed specifically to them. They conducted a study on 29 infants between the ages of 19 to 24 months, all of whom were from low-SES Hispanic Spanish-speaking families. All of the infants were recorded interacting in their natural home environment at 19 months of age. Each audio recording was an average of 11 hours in length, and was analyzed using LENA software. Standardized tests were administered to each infant at 24 months of age, for measures of expressive and receptive language.

Weisleder and Fernald (2013) found much variability in the amount of words spoken directly to infants in each family; 12,000 words were spoken directly to one

infant, while only 670 words were spoken to another. There was not a correlation between child-directed speech and overheard speech in the home, which suggests that the variability in amount of child-directed speech was not a result of talkativeness in the home. The infants who received less direct vocal interaction at 19 months of age had smaller vocabularies and more difficulty identifying familiar words at 24 months. This study supports a direct link between infant ability to process speech and use vocabulary at age 2 and the amount of child-directed speech provided earlier in his/her development (Weisleder & Fernald, 2013). Thus, talking to infants makes a difference.

Autism Spectrum Disorder

ASD is a developmental disorder that negatively impacts an individual's social, emotional, and communication skills (Cassel et al., 2007). A person with ASD typically exhibits difficulty with social interaction and establishing joint attention. Children with ASD demonstrate significant language delays (Paul et al., 2011). A diagnosis of ASD requires both the absence of, and presence of certain characteristics. Symptoms of ASD include an absence of behaviors such as: eye contact, social gestures, friendships with peers, using objects during social interactions, social and emotional flexibility, vocal communication with others, and pretend play; along with a presence of behaviors such as: repetitive actions, obsessions with certain patterns, and self-stimulating behaviors (American Psychiatric Association, 2013).

When communicating, children with ASD tend to avoid eye contact, often causing a breakdown in communication. Irwin, Tornatore, Brancazio, and Whalen

(2011) express the importance of accurate perception of both auditory and visual information when someone is speaking. Due to aberrant eye contact during interaction, the researchers explored whether children with ASD have an impaired ability to process visual information when someone is speaking to them, or whether they do not receive visual information during communication at all. The study consisted of 26 children ages 5 to 15 years; 13 of these children had a diagnosis of ASD, and 13 were TD. Eye-tracking software and audio-visual speech perception activities were used to determine the relationship between a child looking at a speaker's face and speech perception. The researchers confirmed that children with ASD look at a speaker less often than children who are TD. Eye contact is an important component to successful speech and language development. Children with ASD are likely to grow up with an impaired ability to decipher audiovisual information presented to them because of reduced gazing at a speaker. In turn, they interact less and their communication skills suffer. This negative cyclical pattern continues to impair their language development (Irwin et al., 2011).

Diagnosis of ASD is not reliable before the age of 2 (Iverson & Wozniak, 2007). In order to provide optimal speech and language services, Chawarska and colleagues (2007) suggest the need for diagnostic markers of ASD within the first 12 months of a child's life. If patterns could be identified that would allow a diagnosis before age 2, earlier intervention could provide stimulation and education necessary for the child's speech and language development. While some caregivers notice symptoms of ASD in their children within the first year of life, many symptoms do not become apparent until the second or third year (Chawarska et al., 2007).

ASD-sibs

Infants who have an older sibling with ASD (ASD-sibs) are at risk for developing speech and language delays (Iverson & Wozniak, 2007; Paul et al., 2011). Often manifestations of ASD are found in more than one member of a family (Cassel et al., 2007). Paul and colleagues (2011) explored whether or not ASD-sibs would exemplify pre-linguistic behaviors that could signal they are at risk for developing language delays, as well as ASD and corresponding symptoms. The researchers wanted to determine if these infants who are at risk are indeed delayed, and specifically how vocal behaviors were delayed. The study included 69 infants who participated at 6, 9, 12, and 24 months of age. The infants were assigned to one of two groups: High Risk (HR) if they had a sibling diagnosed with ASD, or Low Risk (LR) if they did not have a sibling with ASD (Paul et al., 2011). Vocalizations were classified as either speech-like or non-speech-like. Speech-like vocalizations included babbling of consonants and vowels that could be identified with typical phonetic symbols; non-speech-like vocalizations included laughing, squealing, crying, yelling, growling, etc.

The researchers found that the infants who were HR produced vocalizations just as often as those who were LR. However, the infants who were HR produced fewer speech-like vocalizations than those who were LR, and produced more non-speech vocalizations at each age (6, 9, 12, and 24 months). The infants who were HR also produced fewer consonants than the infants who were LR, and significantly fewer canonical syllable shapes (CVs) at 9 months of age. The vocal productions from infants who were HR at 12 months demonstrated signs of ASD at 24 months. It

was suggested that the infants who were HR as a whole did not engage in turn taking as often as those who were at LR. Turn taking is a crucial skill that typically emerges in the early stages of language development. Paul and colleagues (2011) suggest that if a child is HR and manifests delays, intervention is vital, especially in the 7 to 12 month age range.

Iverson and Wozniak (2007) studied the relationship between rhythmic motor ability and vocal ability in ASD-sibs, as there is a relationship between motor growth and speech/language growth (Iverson & Wozniak, 2007). The study included 39 infants; 21 were ASD-sibs and 18 were infants with siblings who were typically developing (TD-sibs). Each of the infants were videotaped at home with their caregivers for 45 minutes a month, starting at 5 months and going to 14 months of age, with a follow-up visit at 18 months. The first 15 minutes and third 15-minute segments videotaped consisted of natural interaction between the infant and caregiver. The second 15-minute segment was structured play.

The researchers presented data observed in four different areas. The first area noted the onset of six milestones, including the production of first words, reduplicated babbling, pointing, showing, sitting independently, and walking. The ASD-sibs demonstrated a delay in all measures, except for pointing. The second area noted the duration of the infants maintaining their posture, which included sitting, standing, on hands and knees, etc. The ASD-sibs were not able to maintain their posture as long as the TD-sibs. The third area noted the infants' ability to rhythmically move their arms and legs, and any changes in this rhythmic movement when the infants started babbling. During babbling sequences, both groups of infants showed an increase in

rhythmic arm movement leading up to babbling, an increase during babbling production, and a decrease after the infant stopped babbling. However, the ASD-sibs moved their arms less often than the control group. The fourth area consisted of the 18-month follow-up visit, which noted ASD behaviors and language abilities in the ASD-sibs group only. The researchers found that 9 out of 14 ASD-sibs demonstrated significant receptive and expressive language delays by the age of 18 months. These findings demonstrate that ASD-sibs are at risk for developing delays.

Caregiver Report and Signs of ASD

The later caregivers report signs of ASD in children, the more significant the receptive language delays (Chawarska et al., 2007). The main concerns voiced by caregivers of children with ASD are speech and language delays (Chawarska et al., 2007; De Giacomo & Fombonne, 1998). Caregivers of infants with ASD often report concerns with behaviors such as children not engaging in joint attention, not making eye contact, not imitating, not responding when their names are called, not using gestures and vocalizations, and exhibiting extreme reactive behaviors (Chawarska et al., 2007; Zwaigenbaum et al, 2009).

Chawarska and colleagues (2007) studied the relationship between when caregivers first noticed that their children were delayed (termed "parental age of recognition," or AOR), and the time at which their children received a diagnosis of ASD. They also looked to see if there was a relationship between the timing of AOR and how functional children were later in life, at ages 2 and 4. Chawarska and colleagues (2007) studied 75 children with ASD, with AOR's ranging from birth to 26 months. The average AOR was 14.7 months. The main concerns caregivers

reported first were speech and language delays, as well as social inhibitions. The AOR typically ranged between 12 and 24 months, with 56% being between 12 to 18 months. Most of the children manifested significant *expressive* language delays, and the later the AOR, the more significant the *receptive* language delays. Also, the later the AOR, the less social, playful, and communicative the child was at age 4, as determined by standardized testing. These findings are important for the currently proposed study because an earlier AOR could facilitate earlier intervention on the child's behalf.

De Giacomo and Fombonne (1998) also studied caregiver recognition of delays in their infants. The study included 82 children and caregivers who self-referred to an outpatient clinic for concerns of their child's delayed speech and language development, and more specifically, possible signs of ASD between the years of 1993 to 1996. De Giacomo and Fombonne (1998) sought to determine both the age of the child at which the caregivers first noticed there was a delay, as well as when the caregivers first sought out medical advice. Each of the children included in the study had been given standardized tests and observed. Results showed that the average age caregivers first noticed symptoms of autism in children was 19.1 months, and the average age caregivers first sought medical attention was 24.1 months. It was suggested that possible reasons for this delay in seeking help could be attributed to parental lack of knowledge, denial, or not having any other children on which to base their knowledge of typical child development. When caregivers had older children, the age of noticing symptoms of autism was much lower than when infants were first born. The present study could lead to the development of a means for educating

caregivers to detect possible signs of ASD in their child earlier. The sooner caregivers request intervention, the greater the likelihood could be for the child's successful speech and language development.

Feldman and colleagues (2012) developed a screening tool for ASD in children under the age of 2. The Parent Observation of Early Markers Scale (POEMS) contains 61 social/behavioral measures on items that are appropriate for children under 2 years of age. Some parts of the measure focus specifically on the main core deficits typically seen in a child with ASD, such as repetitive behaviors and delays in social and communicative skills. Other parts of the measure focus on emotional and behavioral issues typically seen in children with ASD, such as low tolerance levels for loud sounds and changes in their environment, activities of daily living, and emotional skills (Feldman et al., 2012).

Feldman and colleagues (2012) found that for ASD-sibs, ASD can be detected at 9 months of age, and possibly even earlier. Infants who later received a diagnosis of ASD demonstrated difficulty with social and communicative skills on the POEMS scale. These items include showing interest in another person's face, being able to shift attention, ability to imitate, and ability to respond to his/her name. The researchers also found that the POEMS scale detected problems in the areas of emotion and behavior for these children. ASD-sibs demonstrated signs of impatience and irritability. As the POEMS scales were based on parental observations, the research conducted by Feldman and colleagues (2012) strengthens the idea that caregivers are reliable reporters of signs and symptoms of ASD observed in children, which is vital to initiate early intervention. The present study supports the idea that

earlier intervention could improve the number of exchanges (to be defined) and quality of the social feedback loop between caregiver and infant.

Purpose

In summary, very important to speech and language development is the social feedback loop between a prelinguistic infant and his/her caregiver. This interaction enhances an infant's vocal development. As well, child-directed speech benefits an infant more than mere overheard speech in the home. Infants who are spoken directly to at an early age have a broader vocabulary base as they get older. One way to prospectively study potential predictors of future speech and language development is to work with infants who present with certain risk factors. For example, ASD-sibs are at a greater risk for developing speech and language delays, and also ASD themselves. ASD is a developmental disorder that clearly impacts a child's ability to communicate and interact with others. A diagnosis of ASD is often not reliable before the age of 2. However, with earlier detection of ASD signs, high-risk infants could receive the intervention they need for proper speech and language development. Caregiver report has been shown to be a reliable measure of various aspects of speech and language development, therefore, with proper education, perhaps caregivers could modify their behaviors with infants who are at risk. If prelinguistic markers for ASD could be identified in a timelier manner, earlier intervention could be developed and implemented.

Given the above information, it is clear that research needs to be conducted on the interaction between caregivers and infants who are at risk for developing speech and/or language disorders. If caregivers respond differently to their infants who are at

risk, it may be possible to develop a means of educating the caregivers to respond in ways that will help facilitate their child's speech and language development. Accordingly, the present case study explores the number of exchanges[1] in the caregiver/infant social feedback loop given four variables: 1) infant; 2) infant age; 3) caregiver utterance type; and 4) infant utterance type.

[1] An *exchange* was one part of a total social feedback loop. For example, if a loop consisted of an infant utterance, followed by a caregiver utterance, followed by another infant utterance, and a final caregiver utterance, there were three exchanges in the loop. One exchange between the initial infant utterance and the initial caregiver utterance, a second between the initial caregiver utterance and second infant utterance, and a third between the second infant utterance and final caregiver utterance.

Method

Participants

This study includes data collected from a previous study directed by the investigator's faculty mentor, Dr. Heather L. Ramsdell-Hudock. The data was originally gathered at East Carolina University (ECU). Prior to study initiation, voluntary informed consent was obtained (approved through the ECU University Medical Center Institutional Review Board). As the present study was conducted at Idaho State University (ISU), exemption was obtained from the ISU Human Subjects Committee, given that the study purpose was covered under the umbrella of the original consent.

The present study is part of a larger ongoing longitudinal study, in cooperation with Ramsdell-Hudock, and focused on two out of 16 participants. The two participants are both infant males, known for these purposes as an ASD-sib and a TD-sib. These two infants were chosen out of convenience because the ASD-sib had an older sibling (male age 3) with ASD, while the TD-sib had an older sibling (male age 3) who was TD. Both infants were determined by an audiologist to have normal hearing abilities, had routine births, and were healthy at the time of data collection. The ASD-sib and TD-sib were both Caucasian, same age, and came from English-speaking homes of similar socio-economic status, with both mother and father present. The infants were matched on a variety of variables (e.g., age, gender, socioeconomic status, etc.) so as to increase the chance of differences in number of exchanges in social feedback loops resulting from developmental status alone. Data was also gathered for the caregivers of the ASD-sib and the TD-sib.

Procedures and Materials

Data collection and analysis. Data collection took place monthly (from 6 to 18 months of infant age) at the ECU Infant Vocal Development Laboratory, which was designed to resemble a home's nursery. Each of the infant/caregiver dyads interacted while they were recorded. For the purposes of this study, 12 recording sessions were chosen at random to analyze, one for each infant at 7, 10, 11, 14, 15, and 18 months of age. Each session was 20 minutes long, and was held in the same room, with the same toys. The caregiver/infant choice of toys and position in the room was not controlled for, as a naturalistic interaction was desired. Action Analysis Coding and Training (AACT) software was utilized for coding, specifically the TF32 interface. This acoustic analysis software program allowed for location of utterances from both infants and caregivers in the selected sessions. Utterances were selected based on a breath-group criterion (also applied by Ramsdell, Oller, Buder, Ethington, & Chorna, 2012). Further, through a coding interface in AACT, all of the caregiver and infant utterance types were classified according to labels defined below.

Feedback loop measurement. The number of exchanges in the feedback loop was measured. Following the criterion set forth by Weisleder and Fernald (2013), Warlaumont and colleagues (2014), and Keller, Lohaus, Volker, Cappenberg, and Chasiotis (1999), a 1 second time window was originally adopted. This was then adapted to a 5 second time window, in order to allow for the possibility of slower processing time often seen in children with developmental delay. Therefore, a 5 second time window between infant and caregiver (or vice versa) utterances was the criterion for inclusion in the social feedback loop. In other words, if a contingent

utterance from either the infant or the caregiver (depending upon the order of the sequence) occurred within 5 seconds from the completion of a preceding utterance, the feedback loop had been initiated. Accordingly, the social feedback loop initiated with an infant utterance, followed within 5 seconds by a caregiver response, followed within 5 seconds by another infant utterance, and so on until the feedback loop ended. The feedback loop terminated when no contingent utterance was produced within 5 seconds after a prior utterance from a communication partner. Each feedback loop contained a minimum of one infant utterance followed by one caregiver response. All infant utterances could possibly initiate a social feedback loop, however, if the infant produced an utterance that was followed by no response from the caregiver, it was not counted in the study as being part of a social feedback loop. Therefore, the no response probabilities listed in the data do not include no response by a caregiver to an initial vocalization by an infant.

Analysis

As the purpose of the present study was to focus on differences in caregiver/infant communicative interaction (social feedback loop), the following questions were asked, all with respect to the number of exchanges in the feedback loop:

1. What is the difference between an ASD-sib and a TD-sib?
2. What is the difference across age groups? Infant age groups were defined as follows:
    a) Early age group (between 7 and 10 months of infant age), containing mostly prelinguistic vocalizations.

b) Middle age group (between 11 and 14 months of infant age), containing a mix of prelinguistic and early linguistic vocalizations.

c) Late age group (between 15 and 18 months of infant age), containing mostly early linguistic vocalizations.

3. What is the difference based on the type of caregiver utterance? Caregiver utterance types were defined as follows:

   a) Directed: an utterance directed to the infant (a response, request, or clarification).

   b) Not directed: an utterance not directed to the infant, but to someone else in the room, or on the phone.

   c) No utterance within 5 seconds after an infant's utterance.

4. What is the difference based on the type of infant utterance? Infant utterance types were defined as follows:

   a) Linguistic: any utterance that would be interpreted as a word by an unfamiliar listener.

   b) Canonical: well-formed babbling (fully-resonant nuclei and well-formed consonants, timely transitions between consonants and vowels, overall mature sounding).

   c) Non-canonical: marginal babbling (growl, squeal, "raspberry" sound, "fuzzy" sounding consonants and vowels with imprecise articulation, slow transitions between consonants and vowels, fussing that the baby has control over, overall immature "mushy" sounding).

   d) Reflexive: crying and laughing (not controlled).

e) Non-linguistic: coughing, burping, hiccups, grunt, sigh, ingress, movement artifact.

f) No utterance within 5 seconds after a caregiver utterance.

Following location of caregiver and infant utterances, utterance type was identified and documented in AACT using a consensus method by two trained listeners. Consensus coding was utilized, with six coders overall who worked on the data set. For consistency between listener judgment, two coders would listen to each utterance a maximum of 4 times, and together would make a determination on what type of utterance was produced. Caregiver utterances were located by two of the six coders in 11 of the 12 sessions (not always the same two coders), and in one instance a single coder located caregiver utterances. Caregiver utterance types were assigned as follows: three of the six coders designated utterances in 2 of 12 sessions, two coders designated utterances in 7 of 12 sessions, and one coder designated utterances in the remaining 3 of 12 sessions. Infant utterance types were assigned as follows: two coders designated utterances in 8 of 12 sessions, and a single coder designated utterances in the remaining 4 of 12 sessions. In all instances where only a single coder located utterances or assigned utterance types, the coder was a senior coder in the Infant Vocal Development Laboratory, having worked with infant/caregiver data for approximately 20 hours per week for 2 years. Each of the coders knew that a random check of their work would later be conducted, for accuracy of judgment to be determined. Accuracy was not determined for this project.

Descriptive statistics are presented to answer research questions of interest. Data was systematically organized into figures representing the number of exchanges

in the feedback loop given the following four variables: infant (ASD-sib or TD-sib), age group (early, middle, or late age group), caregiver utterance type (directed, non-directed, or no utterance within 5 seconds), and infant utterance type (linguistic, canonical, non-canonical, reflexive, non-linguistic, or no utterance within 5 seconds).

The hypothesis for this project was fourfold, always with respect to the number of exchanges in the feedback loop. It was hypothesized that the number of exchanges in the social feedback loop would be greater for the TD-sib with his caregiver, than for the ASD-sib with his caregiver. It was expected that the TD-sib would generate more linguistic utterances, which would in turn prompt caregiver utterances that were directed to the infant. These caregiver responses would in turn prompt further linguistic utterances from the infant. It was hypothesized that the number of exchanges in the social feedback loop would increase between caregiver and infant, as the child grew older. It was likely that in the early age group there would be more non-canonical babbling, with linguistic features increasing as the infant entered the middle and late age groups. It was hypothesized that the number of exchanges in the feedback loop would be contingent upon the directedness of the caregiver's utterance. If the caregiver's utterance was directed to the infant, it was anticipated that the infant would respond with a linguistic utterance more often than if the caregiver's utterance was not directed to the infant, but rather to someone else in the room or on the phone. It was hypothesized that the number of exchanges in the feedback loop would be contingent upon the linguistic quality of the infant's utterance. If the infant produced a linguistic or canonical utterance, a directed response from the caregiver was expected to be elicited more often than if the infant

produced a non-canonical, reflexive, or non-linguistic utterance type.

Results

Results are displayed in table form and discussed below. The tables demonstrate features of the social feedback loop (e.g., the number of loops, the range and average of the number of exchanges in each loop), the total number of infant and caregiver utterances produced, and the proportion of infant and caregiver vocal types within each loop (e.g., linguistic, canonical, non-canonical, etc.)

Question 1. With respect to the number of exchanges in the feedback loop, what is the difference for the ASD-sib and the TD-sib? As demonstrated in Table 1, the TD-sib had a greater number of loops than the ASD-sib (Difference = 8), with a greater average number of exchanges per loop (Difference = 0.25). Additionally, the TD-sib's range in the number of exchanges per loop was greater than the ASD-sib (Difference = 3).

Table 1
Social Feedback Loop

	ASD-sib (age in Months)				TD-sib (age in Months)			
	7 to 10	11 to 14	15 to 18	Total	7 to 10	11 to 14	15 to 18	Total
# of Loops	64	57	45	166	40	71	63	174
# of Exchanges in Loop (Range)	2 to 10	2 to 20	2 to 22	2 to 22	2 to 16	2 to 18	2 to 25	2 to 25
# of Exchanges in Loop (Average)	3.58	3.88	5.02	4.07	4.25	4.06	4.67	4.32

Question 2. With respect to the number of exchanges in the feedback loop, what is the difference across age groups? As also demonstrated in Table 1, the range in the number of exchanges increased for both infants, as age increased. Differences across age groups are as follows. In the *early age group* (between 7 and 10 months), the TD-sib had less loops than the ASD-sib (Difference = 24), but more exchanges

per loop on average (Difference = 0.67). In the *middle age group* (between 11 and 14 months), the TD-sib had more loops than the ASD-sib (Difference = 14), and he also had more exchanges per loop on average (Difference = 0.18). In the *late age group* (between 15 and 18 months), the TD-sib had more loops than the ASD-sib (Difference = 18), and fewer exchanges per loop on average (Difference = 0.35).

Question 3. With respect to the number of exchanges in the feedback loop, what is the difference based on the type of caregiver utterance? In Table 2, the total number of caregiver utterances produced is displayed. The TD-sib caregiver produced fewer utterances overall (Difference = 783) than the ASD-sib caregiver.

Table 2
Total number of Infant and Caregiver Utterances Produced

	ASD-sib (age in Months)				TD-sib (age in Months)			
	7 to 10	11 to 14	15 to 18	Total	7 to 10	11 to 14	15 to 18	Total
Infant	271	181	160	612	195	262	292	749
Caregiver	701	735	646	2082	434	488	377	1299

Table 3 displays the proportion of caregiver vocal types within each social feedback loop, normalized by the total number of caregiver utterances produced. Here, we see that despite the fact that the TD-sib caregiver produced fewer overall utterances than the ASD-sib caregiver, more of the TD-sib caregiver utterances were part of a loop (Difference = 49, or 14%). Further, a greater percentage of the TD-sib caregiver's utterances were directed to the infant (Difference = 9%). Non-directed utterances were very few in number for both caregivers, but the TD-sib caregiver did have a greater percentage of non-directed utterances (Difference = 4%). Additionally,

more of the TD-sib's loops ended with no response from the caregiver within 5 seconds when compared to the ASD-sib's loops (Difference = 2%).

Table 3
Proportion of Caregiver Vocal Types within each Social Feedback Loop (Normalized by Total Number of Caregiver Utterances Produced)

		ASD-sib (age in Months)				TD-sib (age in Months)			
		7 to 10	11 to 14	15 to 18	Total	7 to 10	11 to 14	15 to 18	Total
Caregiver Vocal Types	Directed	13	12	14	13	13	28	24	22
	Not-directed	1	3	3	2	4	7	7	6
	No Response	2	1	1	1	2	4	4	3
	Total	17	16	17	17	19	38	34	31

Question 4. With respect to the number of exchanges in the feedback loop, what is the difference based on the type of infant utterance? In Table 2, the total number of infant utterances produced is displayed. The TD-sib produced more utterances than the ASD-sib across all age groups (Difference = 137). Table 4 displays the proportion of infant vocal types within each social feedback loop, normalized by the total number of infant utterances produced. The TD-sib produced a greater percentage of more advanced utterance types, with more utterances in the linguistic and canonical utterances (Differences = 3% and 16% respectively) than the ASD-sib. The ASD-sib, on the other hand, produced a greater percentage of more immature utterance types, with more non-canonical and non-linguistic utterances (Difference = 11% and 15% respectively) than the TD-sib. The TD-sib displayed a greater percentage of reflexive utterances (Difference = 5%). Finally, more of the ASD-sib's loops ended with no response from the infant within 5 seconds when compared to the TD-sib's loops (Difference = 5%).

Table 4

Proportion of Infant Vocal Types within each Social Feedback Loop (Normalized by Total Number of Infant Utterances Produced)

		ASD-sib (age in Months)				TD-sib (age in Months)			
		7 to 10	11 to 14	15 to 18	Total	7 to 10	11 to 14	15 to 18	Total
Infant Vocal Types	Linguistic	0	0	0	0	0	6	1	3
	Canonical	0	0	1	0	3	22	20	16
	Non-canonical	28	29	57	36	26	29	20	25
	Reflexive	1	2	1	1	9	8	2	6
	Non-linguistic	13	34	12	19	8	5	1	4
	No Response	19	26	24	22	15	20	16	17
	Total	62	90	95	79	62	89	60	70

Discussion

The purpose of this case study was to explore differences in caregiver/infant communicative interaction (i.e., the social feedback loop), dependent upon four variables: 1) whether the infant has an older sibling with ASD (ASD-sib), or an older sibling who is typically developing (TD-sib); 2) infant age; 3) caregiver utterance type; and 4) infant utterance type. In line with terminology from Cassel and colleagues (2007) ASD-sib and TD-sib were used to differentiate between these groups of infants in the present study.

Study Focus

The study hypothesis was fourfold; the number of exchanges in the feedback loop would be greater for the TD-sib, would increase with age, and would be contingent upon both the caregiver's directedness and the linguistic quality of the infant's utterances.

Question 1. With respect to the number of exchanges in the feedback loop, what is the difference between the ASD-sib and the TD-sib? As was hypothesized, the TD-sib had a greater number of loops with his caregiver, than the ASD-sib and his caregiver. It was expected that the TD-sib would generate more linguistic utterances, which would in turn prompt caregiver utterances that were directed to the infant. These caregiver responses would in turn prompt further linguistic utterances from the infant, which is exactly what happened. The TD-sib demonstrated a greater average number of exchanges per loop, and also had a greater range of exchanges per loop, than the ASD-sib. The TD-sib exhibited more joint attention and intentionality with his caregiver, as demonstrated through more frequent interaction. This dyad appeared

to inherently understand and incorporate conversational structure better into the social feedback loop. It was observed that the ASD-sib did not interact as often with his caregiver as the TD-sib did with his. Anecdotally, the ASD-sib generally played on his own, without establishing much joint attention or initiating linguistic interactions.

Question 2. With respect to the number of exchanges in the feedback loop, what is the difference across age groups? It was hypothesized that the number of exchanges in the social feedback loop would increase between caregiver and infant as the child grew older. Indeed, the range in the number of exchanges did increase for both infants, as age increased. In the early age group, the TD-sib had less loops than the ASD-sib, but he had a greater average number of exchanges per loop, meaning that the loops he did have with his caregiver had more turns back and forth between communication partners. In other words, when the TD-sib and his caregiver interacted, they did so for more exchanges than the ASD-sib did with his caregiver. In the middle age group, the TD-sib had more loops than the ASD-sib, and he again had a greater average number of exchanges per loop. In the late age group, the TD-sib once again had more loops than the ASD-sib, but he had a slightly smaller average of exchanges per loop. This phenomenon could be explained in that as the infant got older, he perhaps became more efficient with the interaction process. As his relationship with his caregiver developed, less words were needed to convey meaning in conversation. Additionally, while there were a smaller average of exchanges per loop, possibly the exchanges themselves could have been increasingly longer in duration of time. The present study did not focus on length of time for loops, only on the number of exchanges.

It is interesting to note that the ASD-sib's number of loops *decreased* as he got older. He had 64 loops in the early age group, 57 in the middle age group, and 45 in the late age group. Conversely, the TD-sib started out with 40 loops in the early age group, increasing to 71 and 63 in the middle and late age groups, respectively. Again, this could be due to the reasons listed above, in that as the TD-sib got older, his communication with his caregiver may have become more efficient, and possibly the length of time increased for each exchange. The TD-sib did demonstrate a great increase in loops from the early age group to the middle age group. The decrease in the ASD-sib's number of loops as he got older could be explained by the atypical response of the ASD-sib caregiver. As the ASD-sib caregiver was not responding as directly to the infant as the TD-sib caregiver, the ASD-sib was not receiving sufficient feedback to his vocalizations. Perhaps he realized that although he produced, he did not receive the response he desired, so he gradually started to vocalize less. Another thought could be that given that his caregiver talked a lot, to anybody that was in the room, maybe the ASD-sib knew that it did not really matter if he vocalized or not, his caregiver would continue to talk. Perhaps he just got used to the sound of her voice, and did not understand the importance of his vocalizations in conversational turn taking because it did not matter if he produced vocalizations, his caregiver continued to talk.

Question 3. With respect to the number of exchanges in the feedback loop, what is the difference based on the type of caregiver utterance? It was hypothesized that the number of exchanges in the feedback loop would be contingent upon the directedness of the caregiver's utterance. If the caregiver's utterance was directed to

the infant, it was anticipated that the infant would respond with a linguistic utterance more often than if the caregiver's utterance was not directed to the infant, but rather to someone else in the room or on the phone. The hypothesis was correct. The TD-sib caregiver produced roughly half as many utterances overall when compared to the ASD-sib caregiver, but a larger proportion of the TD-sib caregiver's utterances were part of a social feedback loop. The ASD-sib caregiver may have noticed that something was amiss in the interaction with her infant, and overcompensated by talking more, in an effort to get her child to speak. Perhaps the ASD-sib caregiver felt that since her child was not responding well or interacting with her much, she needed to continually be providing opportunities for him to vocalize. Another possible explanation could be that she just talked a lot, not worried about whether or not her infant was interacting with her. Perhaps she was content with whatever the ASD-sib produced, as he was most likely vocalizing more than his older sibling with severe autism.

However, it is also interesting to note that the TD-sib caregiver's utterances that were involved in loops demonstrated a greater percentage of directedness to the infant when compared to the ASD-sib caregiver's utterances (Difference = 9%). So the TD-sib caregiver did not talk as often, but when she did, it was more directed to the infant. The ASD-sib caregiver talked a lot, but was not as direct with her infant. This could be explained by personality differences. Perhaps she was generally a more talkative person than the TD-sib caregiver was. The ASD-sib caregiver would possibly talk constantly with whoever was in the room, in any instance, while the TD-sib caregiver was perhaps of a more restrained and conservative vocal nature. Since

the TD-sib received more directed interaction, it can be concluded that he would have a larger vocabulary at 2 years than the ASD-sib (Weisleder & Fernald, 2013).

Previous research has found that caregivers respond to their prelinguistic infants 30 to 50% of the time (Goldstein et al., 2003; Goldstein et al., 2009; Gros-Louis et al., 2006). The results of the present study support these findings. The TD-sib caregiver fit into this range, but the ASD-sib caregiver did not. As is referenced in Table 3, 31% of the TD-sib caregiver's utterances were involved in loops, as opposed to only 17% of the ASD-sib caregiver's utterances. The TD-sib caregiver responded to her infant typically, while the ASD-sib caregiver did not.

However, when observing the percentage of utterances involved in loops that ended with "no response" from the caregivers, the ASD-sib caregiver did not respond only 1% of the time, while the TD-sib caregiver did not respond 3% of the time. Both of these percentages are low, and demonstrate that most of the loops did not end with the caregiver not responding, but rather with the infant not responding, as will be discussed in Question 4 below.

Question 4. With respect to the number of exchanges in the feedback loop, what is the difference based on the type of infant utterance? It was hypothesized that the number of exchanges in the feedback loop would be contingent upon the linguistic quality of the infant's utterance. If the infant produced a linguistic or canonical utterance, a directed response from the caregiver was expected to be elicited more often than non-canonical, reflexive, or non-linguistic utterance types. Additionally, it was likely that in the early age group there would be more non-canonical babbling, with linguistic features increasing as the infant entered the middle

and late age groups. The data demonstrates exactly that. First of all, the TD-sib produced more utterances than the ASD-sib overall. Secondly, the TD-sib produced a greater percentage of more advanced utterance types, with significantly more utterances in the linguistic and canonical categories than the ASD-sib. Conversely, the ASD-sib had a greater percentage of more immature utterance types in loops; non-canonical and non-linguistic utterances.

Overall, the TD-sib exhibited more utterances, which were more mature in quality than the ASD-sib's utterances. In the early age group, it would be expected that both infants' speech would contain mostly prelinguistic vocalizations. The data support this claim. It is interesting to note that the TD-sib also had 3% canonical utterances involved in loops at this age, demonstrating an early stage of development for this utterance type, while the ASD-sib had none. Neither infant had linguistic utterances. As the infants moved into the middle age group, it would be anticipated that their speech would contain a mix of prelinguistic and early linguistic vocalizations. This again is demonstrated in our findings, but only by the TD-sib. In the late age group, it would be expected that infant utterances would contain mostly early linguistic vocalizations. The TD-sib demonstrated this, as he had a mix of linguistic, canonical, and non-canonical utterance types, with only minimal non-linguistic and reflexive utterance types. While there were still many non-canonical utterance types in the loops of the TD-sib in the late age group, there were fewer than in his loops from the early and middle age groups. His vocal development was maturing and progressing typically. The ASD-sib's utterances in loops at this age were almost predominantly non-canonical, with far fewer non-linguistic, canonical,

and reflexive utterance types. He again did not demonstrate any linguistic utterances. The ASD-sib's vocal development was not progressing or maturing as it should. In fact, over the course of the study, the ASD-sib only produced one canonical utterance, and he had no linguistic utterances in loops with his caregiver.

Additionally, when observing the percentage of utterances involved in loops that ended with "no response" from the infants, the ASD-sib did not respond more often than the TD-sib. This means that the TD-sib was more engaged in the interactions with his caregiver, and responded more often than the ASD-sib did. The TD-sib seemed to understand better the contingency of back and forth turn-taking in conversation.

Clinical Implications

Through studying typical and atypical development of the social feedback loop, it was possible to determine that the infant who was at high risk for speech and language delays did not interact with his caregiver as often as the infant who was typically developing. Here, the infant who was at risk did vocalize less than his peer who was typically developing, and the vocalizations he produced were less mature. Therefore, it may be that if education on the social feedback loop were provided to pediatricians and caregivers of children at risk, early identification and intervention could be facilitated.

Additionally, since the ASD-sib caregiver in this study appeared to respond differently to her infant who was at risk, it may be possible to educate caregivers to respond more directly, which will help facilitate their child's speech and language development. By implementing training of caregivers, infants at risk could benefit

from more frequent child-directed speech.

Study Limitations

One possible limitation to this study was that it only involved two infant/caregiver dyads, which as a sample cannot be held representative of their two different populations. It is possible that the descriptive differences observed may not be present between the population of infants with typically developing siblings compared to infant with siblings who have ASD. Further understanding of the effects and benefits of the infant/caregiver social feedback loop could be attained through a larger study, which would also facilitate report of statistical significance. A larger study would also be able to observe elements of cause and effect. In the present study, there were no controls, independent variables, or manipulation; this study was absent of intervention, being an observational case study. Another possible limitation is that some of the classification schemes developed for this study have not been used before (the definitions for infant and caregiver utterance types), instead they were based loosely on concepts previously utilized. Furthermore, the 5 second time window used as a measure for inclusion in the feedback loop may have been excessively generous, as utterances may have been included that otherwise would not have, with a smaller time window (e.g., 2, 3, or 4 seconds). Following the criterion set forth by Weisleder and Fernald (2013), Warlaumont and colleagues (2014), and Keller and colleagues (1999), a 1 second time window was originally adopted. This was then adapted to a 5 second time window, in order to allow for the possibility of slower processing time in children with developmental delay.

Future Directions

As the data supports hypotheses set forth, this is a positive indicator that further research needs to be conducted on caregiver response to infants who are at risk for developing speech and/or language disorders. Research could be conducted on a larger scale, which would facilitate greater understanding of benefit of this crucial feedback loop. Future studies could observe the length of time in each exchange in the loop, as well as personality differences in the talkativeness of both caregivers and infants.

Developing and piloting training of caregivers could be implemented, which would ensure that infants at risk receive more frequent child-directed speech. Classes could be taught to caregivers at autism support group meetings, on how best to interact with their child so as to enhance their speech and language development. Pamphlets could be produced and distributed to pediatricians' offices, which could be given to families who already have a child with autism and are planning on having more children. Also, commercials could be created and broadcast on television, emphasizing the importance of frequent child-directed speech, and early intervention for infants who are at-risk for developing speech and language delays.

As the present study is part of an ongoing longitudinal study, future research will incorporate the results and expand on them further. For example, research will include infants who are exposed to two different languages in the home, infants who are hearing impaired, and infants who are more vocal than others.

Overall Conclusion

Overall, the TD-sib engaged more with his caregiver than the ASD-sib, and the TD-sib caregiver's utterances were more directed to the infant than the ASD-sib's. The TD-sib caregiver did not say as much as the ASD-sib caregiver, but her utterances were more directed to the TD-sib. This could be a result of personality differences in the caregivers, with one simply being more talkative than the other. However, it could also be a result of caregiver and infant developing a closer bond as the infant grew, with fewer words needed to convey meaning, and communication becoming more efficient.

Additionally, the TD-sib's utterances were more linguistic and canonical than the ASD-sib's. The TD-sib dyad appeared to inherently understand and incorporate conversational structure better into the social feedback loop. As Warlaumont and colleagues (2014) stated, the general idea of the feedback loop is that when a child vocalizes, an adult is more likely to immediately respond to that child if the vocalization contains speech-like content. Further, if an adult immediately responds to a child positively, the child is more likely to produce a second speech-like vocalization. This positive social feedback loop enhances and encourages proper speech and language development.

The ASD-sib dyad interacted less with each other, and the infant's utterances were overall less mature than the TD-sib's utterances. As research has shown, infants who have siblings with ASD are at risk for developing speech and language delays themselves (Paul et al., 2011). The ASD-sib likely had grown up with a model from his older sibling of reduced eye contact, no joint attention, and reduced social

flexibility. With his caregiver demonstrating less directedness to him in conversation, having atypical social interaction with his sibling, and being a child at risk himself, the ASD-sib's speech and language communication skills appear to have suffered.

Since the beginning of this project, follow-up speech and language testing has been conducted with each child at 3 ½ years of age. Results supported speech and language development within normal limits for the TD-sib, and atypical development for the ASD-sib. More specifically, the ASD-sib demonstrated expressive language and hearing abilities within normal limits for his age, and total language abilities below expected for his age, with significant deficits in receptive language. Additionally, the ASD-sib exhibited delays in speech sound production, likely as a result of articulation, rather than phonology (with the exception of gliding). These test results indicate that findings related to the social feedback loop between caregivers and infants in this study had accurate portrayals of the infants' speech and language developmental trends.

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