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The effect of telepractice on vocal interaction between provider, deaf and hard-of-hearing pediatric patients, and caregivers.

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THE EFFECT OF TELEPRACTICE ON VOCAL INTERACTION BETWEEN PROVIDER, DEAF AND HARD-OF-HEARING PEDIATRIC PATIENTS, AND CAREGIVERS

By

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ABSTRACT

THE EFFECT OF TELEPRACTICE ON VOCAL INTERACTION BETWEEN PROVIDER, DEAF AND HARD-OF-HEARING PEDIATRIC PATIENTS, AND CAREGIVERS

Abigail Betts

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The purpose of this thesis is to examine how telepractice affects a vocal interaction between a speech-language pathologist (SLP), deaf and hard-of-hearing children who received cochlear implants ($n = 7$), and caregivers as they engage in speech-language interventions conducted in-person and via telepractice (tele). Frequency of vocalizations, vocal turns, pause duration, fundamental frequency (F0) mean and range, utterance duration, syllable rate per utterance duration, and mean length of utterance (MLU) were examined. The SLP vocalized more during in-person than tele-sessions, opposite result for the mother. There were more SLP-child turns during in-person sessions than tele-sessions; opposite result for mother-child turns. Pauses were longer in SLP-child, mother-child turns during tele than in-person sessions. The SLP increased mean F0, SLP and child expanded F0 range in tele-sessions. The mother had longer utterance duration, higher MLU during in-person than tele-sessions. Results suggest vocal interactions between provider, patient, and caregiver are impacted by intervention service modality.

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INTRODUCTION

Telepractice refers to the use of telecommunication technology to deliver speech-language pathology services over a distance by linking clinician to client for assessment, intervention, and/or consultation (ASHA, 2020). Telepractice has been increasingly adopted by clinicians as a result of the COVID-19 pandemic disrupting the provision of in-person services (Fong et al., 2020). Telepractice delivery can be synchronous, asynchronous, or a hybrid model (ASHA, 2005). Speech-language pathology intervention is uniquely suited for telepractice delivery given the audiovisual nature of clinical interactions (Theodoros, 2013). Previous research has indicated telepractice can be used in a variety of speech and language disorders including voice and resonance (Becker & Gillespie, 2021), pediatric feeding (Raatz, 2020) and fluency disorders (McGill et al., 2019). The American Speech-Hearing Association (ASHA) recognizes telepractice as a viable service modality for all health care settings and for patients of all ages (ASHA, 2020).

Telepractice shows the potential to extend clinical services to remote, rural, and underserved populations, and to culturally and linguistically diverse populations (ASHA, 2005). Telepractice helps minimize barriers of distance and travel (Fairweather et al., 2016; McCarthy et al., 2018; Sarsak, 2020) and provides a unique opportunity for clinicians to connect with patients in their natural environments (ASHA, 2019; Cason & Cohn, 2014; Kraljevic et al., 2020; Weidner & Lowman, 2020). Telepractice can provide services to patients in rural areas (Cason, 2009) and to patients with impaired mobility. Additionally, telepractice provides increased flexibility in scheduling which may be associated with a reduction in number of missed appointments (McCarthy et al., 2018). Previous research has indicated telepractice to be met with high satisfaction rates regarding clinician responsiveness and accessibility (Cason, 2009; Crutchley & Campbell, 2010; Heimerl & Rasch, 2009; Kelso et al., 2009; Peter-Lailos, 2012). Telepractice has been increasingly used to provide early intervention services to deaf or hard-of-hearing (DHH) children who have received assistive devices such as hearing aids (HAs) or cochlear implants (Houston et al., 2018; Keck & Doarn, 2014; McCarthy et al., 2018) Telepractice can be used to both deliver clinician-directed therapy interventions (Grogan-Johnson et al., 2013b; Theodoros, 2011) and family-centered models (Anderson et al., 2014a; Daczewitz et al., 2020; Galvan et al., 2014; Hall et al., 2014)

Clinician-directed therapy interventions involve direct therapeutic strategies provided by a speech-language pathologist. Family-centered models involve the clinician teaching strategies to be implemented by caregivers (DeVeney & Hagaman, 2016). With telepractice, it is difficult for the parent to passively observe while the speech-language pathologist (SLP) interacts with the child (Hamren & Quigley, 2012) As a result, parent-coaching is a central component of telepractice (Houston et al., 2018).

Despite known benefits of telepractice, this delivery approach introduces new challenges to the provider, caregiver, and pediatric patient interaction by altering both the availability and quality of auditory, visual, and tactile information (Anderson et al., 2014a; Grogan-Johnson et al., 2013b; Keck & Doarn, 2014; Tucker, 2012). Additionally, telepractice may introduce technical difficulties such as frozen video connections, unreliable Internet connections, delayed sound transmission, and limited Information Technology support (McCarthy et al., 2018; Tucker, 2012). As a result, telepractice may change the degree of naturalness of communication (Anderson et al., 2014a; Hall et al., 2014; Snodgrass et al., 2017; Tucker, 2012). In pediatric therapy, the clinician may have difficulty effectively prompting the child since they are not in the same physical location and cannot move freely in the shared environment (Anderson et al., 2014b). A child may have difficulty staying in view of the camera as well as directing and maintaining their attention to the screen (Gibson et al., 2010; Grogan-Johnson et al., 2013b). Parents perceive their children have greater problem behaviors, such as externalizing (e.g., acting out, anger) and internalizing (e.g., withdrawal, sulking) when technological interruptions occur during telepractice (McDaniel & Radesky, 2018).

The use of telepractice alters the quality of auditory, visual, and tactile information the patient and clinician receive (Anderson et al., 2014a; Grogan-Johnson et al., 2013b; Keck & Doarn, 2014; Tucker, 2012). These challenges may increase a participant's cognitive effort (Harvey et al., 2017) which may in turn affect linguistic performance. An increase in cognitive demand negatively impacts linguistic performance in children with and without hearing loss (Bess & Hornsby, 2014; Brännström et al., 2021; Lyberg-Åhlander et al., 2015; McGarrigle et al., 2019; von Lochow et al., 2018).

A child's linguistic performance may be more effortful under challenging listening conditions such as remote communication (Mattys et al., 2012) because fewer cognitive resources become available for other learning tasks (Howard et al., 2010; Norman & Bobrow, 1975; Pittman, 2011; Prodi et al., 2019; Rudner et al., 2018). Currently, there is limited research on whether the quantity and the quality of vocal interaction between the provider, the pediatric patient and the caregiver are affected using telepractice. The aim of this study is to examine the characteristics of vocal interaction between DHH children who received cochlear implants, their mothers, and a speech-language pathologist during in-person and tele- speech-language interventions.

Turn-taking is a cognitive, evolving, and pragmatic system fundamental for human interaction (Schegloff, 2007). Turns vary in length, but are mostly short, about 2 sec in length on average, and consist of one syntactic clause (Levinson & Torreira, 2015; Sacks et al., 1974). The quantity and quality of turns between child and caregiver facilitate linguistic development in normal-hearing (NH) children (Bloom et al., 1987; Caskey et al., 2011; Gilkerson et al., 2018; Ginsburg & Kilbourne, 1988; Romeo et al., 2018; Stern et al., 1983; Zimmerman et al., 2011b) and children with hearing loss (Ambrose et al., 2014; Quittner et al., 2013; VanDam et al., 2012; Vanormelingen et al., 2016). Children with hearing loss may experience more difficulty in conversational turns because many early interactions require being able to localize and respond to auditory information (Sininger et al., 1999). As a result, children who received cochlear implants may engage in fewer vocal turns with their caregiver compared to normal hearing children and their caregiver (Kondaurova et al., 2019; Tait et al., 2007).

The use of telepractice (as a form of remote communication) may alter conversational turns by introducing a two-way transmission delay (Michael & Möller, 2020). The length of transmission delay might be less than a millisecond but still present problems to fluidity of social interaction (Jefferson, 1973; Seuren et al., 2021). Face-to-face conversations involve more turns, shorter duration of turns, and more interruptions compared to conversations using remote communication (O'Malley et al., 1996).

Conversations conducted remotely tend to be more formal with fewer interruptions and longer utterances (O'Conaill et al., 1993).

Prosody plays a critical role in language acquisition by prompting children to imitate segmental properties of speech and help word learning (Wells et al., 2004). Infant-directed speech is a speech pattern addressed to infants characterized by changes in prosodic elements such as higher pitch, greater pitch variability, slower rate of speech, shorter utterances, and longer pause duration (Bernstein Ratner, 1986; Fernald & Simon, 1984; Fernald, Taeschner, Dunn, Papousek, de Boysson-Bardies, et al., 1989; Kitamura et al., 2002; Papoušek et al., 1987; Stern et al., 1983). Exaggerated prosody in infant-directed speech serves to modulate the infant's attention and arousal level, communicate maternal affect, and facilitate language acquisition (A. Fernald, 1989). Prosody plays a role in providing listeners with acoustic cues to linguistic structure by providing information about word, phrase, and clause boundaries (Fernald & Mazzie, 1991).

Prosodic characteristics of speech (mean fundamental frequency, fundamental frequency range, speaking rate, and utterance duration) produced by children with cochlear implants may be altered because cochlear implants provide limited information about temporal structures of speech such as pitch (Geurts & Wouters, 2001; Greene et al., 2004). Children who wear cochlear implants may have a higher mean fundamental frequency than normal-hearing children (Valero Garcia et al., 2010). However, some evidence suggests 4 months following the activation children will produce a normal fundamental frequency (Seifert et al., 2002). Additionally, children who wear cochlear implants speak at a significantly slower rate than their normal-hearing peers (Freeman et al., 2017; Vanormelingen et al., 2016). Children who received cochlear implants speak at a slower rate for an increased utterance duration (Clark, 2007).

The use of remote communication may alter prosodic characteristics of speech produced by speakers in telepractice sessions. Remote communication may degrade the quality of speech signal (Mattys et al., 2012) as a result, speakers may modify acoustic characteristics of their speech to compensate (Hazan & Baker, 2011; Mattys et al., 2012). The Lombard effect, which describes the phenomenon in which speakers increase their vocal intensity in the presence of background noise (Shewmaker et al., 2010), may be generalized to speakers alter their vocal intensity in situations in which communication hindered or perceived to be hindered (L. Tracy et al., 2020). Previous research suggests normal-hearing individuals increase their mean fundamental frequency (Hotchkin & Parks, 2013) and decrease speech rate (Summers et al., 1988) when using remote communication.

Mean length of utterance (MLU) is a measure of utterance length and used as an index of the complexity of a child's grammatical forms (Bedore et al., 2010). MLU is calculated by dividing the number of morphemes by the number of utterances (Brown, 1973). Previous research has demonstrated lexical diversity and syntactic complexity in a child with cochlear implants were lower than typically developing hearing age peers (Ertmer et al., 2003). The MLU values of children with cochlear implants may demonstrates a delayed onset, however, their values improves over time and may eventually approximate peers with normal hearing (Flipsen & Kangas, 2014). Duration of hearing experience after cochlear implant implantation is an important factor for acquiring speech and language abilities (Tavakoli et al., 2015). However, normal-hearing children have comparable MLU between in-person and telepractice sessions (Manning et al., 2020). There is a gap in our knowledge how children who have received cochlear implants alter speech characteristics while engaged in a telepractice speech-language intervention.

The aim of the current study is to examine the effect of telepractice on turn-taking, prosodic (mean fundamental frequency, fundamental frequency range, speech rate, utterance duration) and lexical (MLU) characteristics of speech between the provider, child who wears cochlear implants, and caregiver during an in-person and telepractice speech therapy intervention. It is expected the participants will modify prosodic elements of their speech (Amazi & Garber, 1982b; Hotchkin & Parks, 2013; Mattys et al., 2012) by increasing their mean fundamental frequency, exaggerating fundamental frequency range, and decreasing speech rate during telepractice interventions. Previous research examining turn-taking during remote communication in normal-hearing adults (Boyle et al., 1994; Jaffe & Feldstein, 1970; Kira et al., 2009; Matarazzo & Sellen, 2000; O'Conaill et al., 1993; O'Malley et al., 1996; Rutter & Stephenson, 1977) suggests there will be fewer turns, slower speech rate, less speech overlap, and longer pause duration during SLP-child or SLP-caregiver interaction in the telepractice compared to the in-person sessions. Since telepractice facilitates parental involvement with therapy (Hamren & Quigley, 2012), it is expected there will be a higher turn-taking rate between caregivers and their children in telepractice sessions. No differences in pause duration or speech overlap are expected in the telepractice compared to the in-person intervention because the caregiver and the child interact in person only.

METHOD

Participants

Mother-Child Dyads

Seven mother-child dyads were recruited from the Heuser Hearing Institute and Language Academy in Louisville, KY to participate in this study. The seven mothers were all normal-hearing (NH) and their children were deaf and hard -of -hearing (DHH) and received cochlear implants (CIs). The mean chronological age of the children with CIs (Male = 4, Female = 3) at the time of testing was 4 years; 11 months (*SD* =1 year; 2 months). The mean hearing age was 2 years; 11 months (*SD* = 1 year; 3 months) and the mean age of CI activation was 2 years; 1 month (*SD* = 1 year; 8 months). Table 1 presents the children's demographic characteristics. Table 2 presents etiology, type of CI device, and the children's expressive and receptive skills as measured by the Preschool Language Scales, Fifth Edition (PLS-5) (Zimmerman et al., 2011b)

Table 1

Child Demographic Characteristics

Participant	Sex (F,M)	Age	Age at CI Activation	Hearing Age
1	F	6:01	5:00	1:01
2	M	6:09	1:02	5:07
3	M	4:01	3:02	0:11
4	F	4:10	3:01	1:09
5	M	3:11	1:09	2:02
6	F	3:07	3:00	0:07
7	M	5:06	3:05	2:01
mean (sd)		4:11 (1:2)	2:11 (1:2.8)	2:0.3 (1:8)

Note: CI = cochlear implant.

Table 2

Etiology, Type of CI Device, and PLS-5 scores

Participant	Device (L-left ear; R- right ear, HA- hearing aids)	Communication Method	Auditory	PLS-5 Verbal	Total
1	MED-EL (L,R)	OC suppl. with ASL	26	28	50
2	N6 Cochlear Americas, Nucleus (L,R)	OC	119	120	121
3	N6 Cochlear Americas, Nucleus (L,R-HA)	OC	67	72	68
4	N7 Cochlear Americas, Nucleus (L,R-HA)	OC suppl. with ASL	59	59	56
5	N7 Cochlear Americas, Nucleus (L,R)	OC	65	75	68
6	Naida Q90, Advanced Bionics (R)	TC	76	68	70
7	N7 Cochlear Americas, Nucleus (L-HA,R)	OC	59	59	51
mean (sd.)			67.3 (27.7)	68.7 (27.5)	69.1 (24.4)

Note: OC = oral communication; TC = total communication; ASL = American Sign Language; PLS-5 = the Preschool Language Scales, Fifth Edition (Zimmerman et al., 2011).

The mean age of the NH mothers was 34 years (*SD* = 2.8) and their mean age of education was 15.1 years (*SD* = 3.6). Six mothers identified themselves as non-Hispanic, Caucasian and one mother identified herself as Hispanic. All the mothers reported they had no prior experience with telepractice. The mothers were paid $40 for their participation. Children and caregivers had participated in in-home, school-based, and/or clinic-based speech-language intervention services for approximately 1 – 2 hours each week prior to the start of the study. The mothers had no prior experience with telepractice. Six of the children had received in-home early intervention services from time of identification of hearing loss until age 3 years, when they transitioned to school-based and/or clinic-based intervention. The remaining participant was adopted from China and came to the United States at 4 years of age; she was immediately placed in school-based and clinic-based speech-language intervention programs.

Speech-Language Pathologist

One speech-language pathologist (SLP) was recruited from the Heuser Hearing Institute and Language Academy to conduct the in-person and telepractice sessions (referred to as *tele* sessions). The SLP had 33 years of experience with children who had received CIs and rated herself as having high expertise in providing telepractice services to children with CIs. The SLP was reimbursed $90 per hour of her work. This study was approved by the University of Louisville Institution Review Board.

Procedures

In-Person Session Set Up

Four digital Panasonic Full HD Video Camera Camcorders HC-V770 with SanDisk Extreme memory cards were positioned in the four corners of an isolated therapy room to make audio-visual recordings of in-person and tele sessions. The SLP used toys (a “sheep”, a “shoe” and a “sling shot”) and Melissa & Doug reusable stickers to teach the children language skills appropriate to their stage of linguistic development. The choice of toys was determined by aims of another study that examined the effect of telepractice on the characteristics of acoustic vowel space in all three participants. Each in-person and tele session lasted 30 minutes. The in-person session was conducted in a therapy room at the Heuser Hearing Institute and Language Academy. The participants sat in a triangular position with the child in the center position so they could address the SLP and mother. Figure 1 presents the visual representation of the child, mother, and SLP in the in-person session.

Telepractice Session Set Up

In the tele-session the SLP was in her office sitting at the desk with a Dell OptiPlex 3070 desktop computer with a HP LV2011 20-inch monitor; Logitech C270 HD webcam was mounted on the top center of the monitor (Figure 2). The mother-child dyad sat in an isolated therapy room sitting at the table with a Dell Lattitide 5590 laptop with a built-in 15.6 inch HD monitor and a webcam. Both the SLP’s desktop computer and mother and child's laptop were equipped with Doxy.me telemedicine system preinstalled. Doxy.me is a free Web-based system specifically designed for telemedicine purposes (Agnisarman et al., 2017)The mother-child dyad used the same set of Melissa & Doug stickers and toys as the in-person session. The order of the in-person and tele-sessions were counterbalanced across participants. In total there were 14 sessions (in person: 7 sessions; tele: 7 sessions). The total duration of the experiment was 1 hour 5 minutes (in-person: 30 minutes, tele: 30 minutes) with a five-minute break between sessions. Figure 2 presents the visual representation of the child, mother, and SLP in the tele session.

Figure 1

Visual Representation of In-Person Set Up

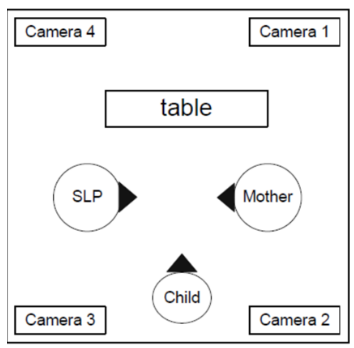
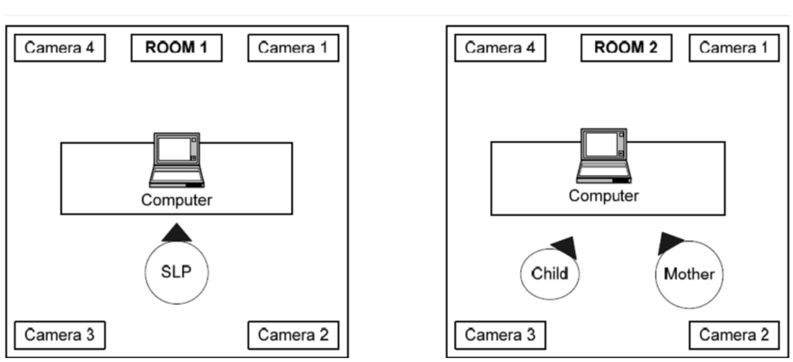


Figure 2

Visual Representation of Telepractice Session Set Up



Description of Intervention

The SLP conducted all intervention sessions using the toys and sticker pads to teach the child specific language skills appropriate for level of linguistic development. The child-centered play therapy (CCPT) approach was selected to target receptive and expressive language and communication skills the way most typically developing children naturally develop by playing and interacting with others (Danger & Landreth, 2005; Lin & Bratton, 2015). The following approaches were used: imitation, expansions, extensions, buildups/breakdowns, and recasts.

Analysis of Recordings

There were 14 recordings total (In-Person: 7 recordings; Tele: 7 recordings). The audio track from each recording was extracted from the audio-visual recordings and imported as audio tracks into PRAAT 5.0.21 speech editor software (Boersma & Weenink, 2013) for analysis. In order to examine the quantity and the temporal structure of vocal turn-taking between the provider, the DHH pediatric patient, and the caregiver in the in-person and tele- sessions, each recording was manually segmented into 4 types of events: a SLP vocalization; a mother vocalization; a child vocalization; or simultaneous speech. Non-speech behavior (e.g., a cry of laugh) were excluded from analysis.

Vocalizations

A SLP, mother, or child vocalization was defined as the production of a vocal sound by the same speaker that was either continuous or included a silence of < 300 milliseconds (ms). Two consecutive vocalizations were coded if a silence following an audible vocal sound from the same speaker was < 300 ms (Gratier, Devouche, Guellai, Infanti, Yilmaz, & Parlato-Oliveira, 2015)

Speech Overlap

Speech overlap was coded when the SLP, the child, or the mother vocalized over the vocalization of the other partner(s). The entire vocalization was coded as speech overlap even if overlapped only partially by either two (e.g., the child and the SLP) or three (e.g., the child, the SLP and the mother) speakers (Depowski et al., 2015; Fagan et al., 2014). The coding resulted in four types of speech overlap between (a) the child and the SLP, (b) the mother and the SLP, (c) the mother and the child and (c) the child, the SLP and the mother.

Conversational turns

Conversational turns were defined as one speaker vocalization followed within 3 seconds by another speaker's vocalization (Gratier, Devouche, Guellai, Infanti, Yilmaz, & Parlato, 2015; Hilbrink et al., 2015; Kondaurova et al., 2020; Smith & McMurray, 2018). Speaker directionality was coded for each vocalization in the interactions (Hedenbro & Lidén, 2002b) Speaker directionality was assessed from the audio-video recordings using the following: (a) facial/body/gaze direction; (b) direction of physical movement (e.g., gestures) (Hedenbro & Lidén, 2002a, 2002b) ; (c) shared attentional focus (usually an object) for at least 3 seconds (Barton & Tomasello, 1991; Tomasello & Todd, 1983); and (d) vocalization semantic content (Tamis-LeMonda et al., 2012). Resulting codes for each participant vocalization were: 1 = vocalization directed to the child; 2 = vocalization directed to the mother; and 3 = vocalization directed to the SLP.

Using these methods, six pairwise turn types indicated both the speakers involved and speaker order: SLP-child, child-SLP, SLP-mother, mother-SLP, child-mother, and mother-child. If it was not possible to determine to whom the vocalization was addressed or when the vocalization was directed to two participants (< 1% of all vocalizations), it was excluded from turn type calculations.

Between-Speaker Pause Duration

Between-Speaker Pause Duration (BSP) was defined as the duration between two speaker's vocalizations (i.e., child-mother) that lasted up to 3 seconds.

Normalization Procedure

To control for session length, the following normalization procedures were employed. The quantity of each speaker's vocalization was normalized as number of vocalizations per second. The frequency of speech overlap was normalized as the rate of speech overlap per second. Turn-taking behaviors were normalized as the rate of each turn type per second (SLP-child, child-SLP, SLP-mother, mother-SLP, child-mother, mother-child).

To analyze prosodic and lexical characteristics of the provider, DHH child, and caregiver speech, approximately 30 utterances from each participant were chosen for the further analysis starting 5 minutes after the beginning of the recording in the in-person and tele sessions. In total, 2361 utterances were analyzed and classified into three categories: (a) SLP (In-Person: 420; Tele: 420): utterances produced by the provider addressing the child, (b) Children (In-Person: 410; Tele: 363): utterances produced by the child addressing the SLP; (c) Mothers (In-Person: 353; Tele: 395): utterances produced by mothers addressing the child.

There were too few utterances to analyze for the SLP-mother interaction in both tele- (SLP addressing mother: M = 3.1 utterances, SD = 2.5, range 0 - 6; Mother addressing SLP: M = 6.3 utterances, SD = 10.8, range 0-30) and in-person (SLP addressing mother: *M* = 0.7 utterances, *SD* = 0.9, range 0 - 2; Mother addressing SLP: *M* = 5.4 utterances, *SD* = 8.9, range 0-25) sessions. Only four children produced more than 30 utterances addressing their mother in the in-person (*M* = 34.3 utterances, *SD* = 29, range 0 - 76) session, given the clinician-directed model of service delivery (Campbell et al., 2009; Salisbury & Cushing, 2013). Thus, the SLP-mother interaction and child utterances addressing the mother in both sessions were excluded from the analysis.

Pitch Characteristics. The mean fundamental frequency (F0), measured in Hertz (Hz), maximum F0 (Hz), minimum F0 (Hz) were measured for each vocalization produced by the SLP, mother, and child. The pitch range (Hz) was calculated as a difference between maximum and minimum F0 from each vocalization.

Syllables per Utterance. Syllables per utterance was measured by counting the number of syllables in each vocalization.

Utterance Duration. Utterance duration (seconds) was defined by the duration from the onset of the initial consonant/vowel to offset of the final consonant/vowel from each vocalization.

Mean Length of Utterance. Mean length of utterance in morphemes (MLU) was measured by counting the number of morphemes per utterance.

Reliability

Two speech-language pathology students (one of whom is the author of this thesis) were trained until they reached at least 90% reliability on all variables with a master coder. Inter-coder reliability (Pearson product-moment correlations) for the number of the SLP, mother, and child vocalizations was above 0.95. The start and end time of each utterance was considered identical if they occurred within 50 ms of each other (Hilbrink et al., 2015)

Statistical Analysis

For vocalization rate, rate of speech overlap, and turn-taking rate, a mixed linear regression model was run with Session (*In-Person, Tele*) as the between-subjects predictor variable, with follow-up Wald t-tests. Additionally, for utterance rate and rate of speech overlap the same mixed linear regression model was run with Participant (*SLP, Child, Mother*) as the between-subjects predictor variable. The between-subjects variables (Session and Participant) were treated as fixed effects. A random intercept was introduced to account for subject-specific effects (i.e., variability) in both models (Perry & Kucker, 2019).

BSP duration was analyzed for each of the six turn types using linear regression analysis with Session (*In-Person, Tele*) as the between-subjects variable. The same analysis was run separately for the in-person and tele sessions with Participant (*SLP, Child, Mother*) as the between-subjects variable.

RESULTS

Turn-Taking

Vocalization Rate

10,184 vocalizations (In-Person: 5,702; Tele: 5,112) were analyzed. Table 3 shows the total number of vocalizations, vocalization rate for each participant, and speech overlap in the in-person and tele sessions.

Table 3

Total Number of Vocalizations, Vocalization Rate, and Speech Overlap

Participant	Total Number of Vocalizations		Vocalization Rate *(SD)* (number of vocalizations/second)	
	In-Person	Tele	In-Person	Tele
DHH Children	1716	1418	0.18 (0.03)	0.15 (0.05)
SLP	2615	1697	0.27 (0.04)	0.18 (0.03)
Mothers	884	1628	0.09 (0.04)	0.18 (0.08)
Speech Overlap	487	369	0.05 (0.03)	0.04 (0.02)
child-SLP	144	139	0.02 (0.01)	0.01 (0.01)
child-mother	73	68	0.01 (0.01)	0.01 (0.01)
mother-SLP	221	141	0.02 (0.02)	0.02 (0.01)
child-SLP-mother	49	21	0.006 (0.007)	0.002 (0.003)

Note: DHH = deaf and hard-of-hearing children; SLP = speech-language pathologist.

Vocalization Rate by Participant. In the in-person session, the SLP had a significantly higher vocalization rate than the child, $\beta = -0.095$, $p < 0.001$, and mother, $\beta = 0.090$, $p < 0.001$. Additionally, in the in-person session the child had a significantly higher vocalization rate than the mother, $\beta = 0.090$, $p < 0.001$. In the tele sessions there was no significant difference between the rate of SLP, child, and mother vocalizations.

In-Person vs. Tele Session. The child vocalization rate was lower in the tele session compared to the in-person session, β = -0.031, p = 0.03. The SLP vocalization rate was also lower in the tele compared to the in-person session, β = -0.095, $p < 0.001$. Conversely, the mother had a higher vocalization rate in the tele compared to the in-person session, β = 0.087, $p < 0.001$. No significant difference existed in speech overlap between the in-person and tele sessions.

Turn-Taking Rate

3,867 (In-Person: 2,236; Tele: 1,631) turns were analyzed. Table 4 presents the total number of six turn types and turn taking rate by session type.

Table 4

Total Number of Turn Types and Turn-Taking Rate by Session Type

Turn Type	Total Number of Turns		Turn-Taking Rate *(SD)* (number of turns/second)	
	In-Person	Tele	In-Person	Tele
SLP-child	976	433	0.57 (0.11)	0.31 (0.14)
Child-SLP	880	321	0.33 (0.07)	0.18 (0.09)
Mother-child	194	442	0.12 (0.09)	0.34 (0.14)
Child-mother	154	410	0.17 (0.09)	0.26 (0.12)
SLP-mother	18	11	0.03 (0.02)	0.01 (0.01)
Mother-SLP	14	14	0.01 (0.01)	0.01 (0.01)

Note: SLP = a speech-language pathologist.

In-Person vs Tele Session. There was a lower rate of child- SLP and SLP-Child turns in the tele compared to the in-person session (Child-SLP: β = -0.151, SLP-Child: β = -0.255, both $ps < 0.001$). There was a higher rate of Child-Mother and Mother-Child turns in the tele compared to the in-person session (Child-Mother: β = 0.087, p = 0.040;

Mother-Child: $\beta = 0.220$, $p < 0.001$). There were no significance differences in the rate of Mother-SLP and SLP-Mother turns in the tele compared to the in-person session.

Between-Speaker Pause Duration.

Table 5 presents BSP duration in the in-person and tele sessions.

Table 5

Between-Speaker Pause Duration by Turn Type

Turn Type	Between-Speaker Pause Duration (mean, *SD*)	
	In-Person	Tele
SLP-child	0.48 (0.53)	0.65 (0.54)
Child-SLP	0.31 (0.43)	0.81 (0.63)
Mother-child	0.40 (0.48)	0.50 (0.50)
Child-mother	0.23 (0.32)	0.38 (0.48)
SLP-mother	0.26 (0.41)	0.10 (0.09)
Mother-SLP	0.35 (0.62)	0.48 (0.61)

Note: SLP = speech-language pathologist.

In-Person vs. Tele Session. In the tele session, there was a longer pause duration compared to the in-person session for both the Child-SLP and SLP-Child turns (Child-SLP turns, $\beta = 0.491$, SLP-Child turns, $\beta = 0.150$, both *ps* < 0.001.) Additionally, there was a longer pause duration in the tele compared to the in-person session for the child-mother turns ($\beta = 0.120$, $p = 0.005$). There were no significant differences in the pause duration for the Mother-Child, Mother-SLP, or SLP-Mother turns between the tele and in-person session.

SLP-child and Mother-Child Turns. In the tele session, the pause duration in the SLP- Child turns were significantly longer than that in the Mother-Child turns (β = 0.114, $p = 0.002$). In the in-person session, there was not a significant difference in pause duration in the SLP-Child and Mother-Child turns.

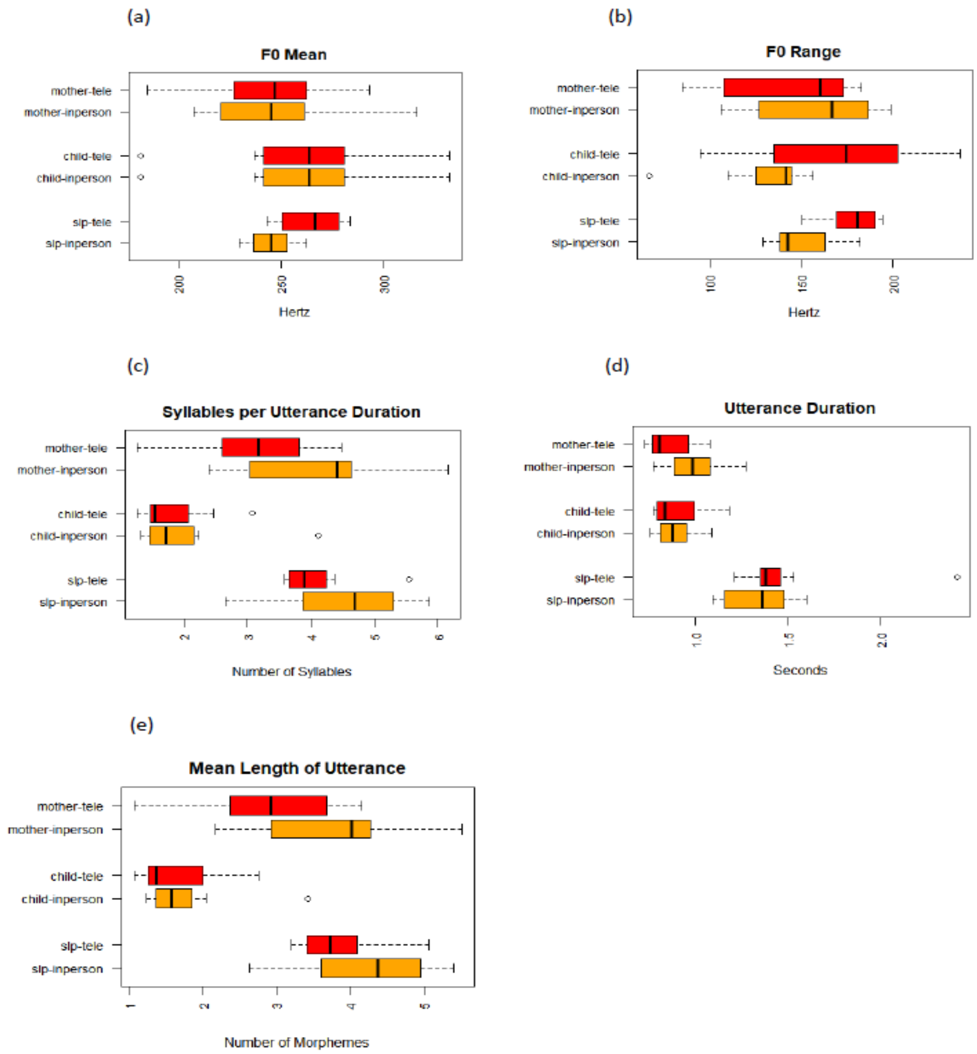
Child-SLP and Child-Mother Turns. In the tele session, the pause duration in the Child-SLP turns was significantly longer than in the Child-Mother turns, $\beta = 0.395$, $p < 0.001$. In the in-person session, there was no significant difference in the pause duration in the Child-SLP and Child-Mother turns.

Prosodic and Lexical Features

2, 361 vocalizations (In-Person: 1,178; Tele: 1,183) were analyzed. Figure 3 presents the (a) mean fundamental frequency (F0, Hz), fundamental frequency range (F0 range, Hz), (c) the number of syllables per utterance duration, (d) the mean utterance duration (sec) and (f) the mean length of utterance (MLU) in the SLP, child, and maternal speech during the in-person and telepractice sessions.

Figure 3

(a) F0 Mean (Hz), (b) F0 Range (Hz), (c) Number of Syllables per Utterance Duration, (d) Utterance Duration (seconds); (e) Mean Length of Utterance (MLU) in the SLP, Child and Maternal Speech.



F0 Mean (Hz)

The SLP produced a significantly higher F0 mean (Hz) in the tele (*M* = 264 Hz, *SD* = 16) compared to the in-person (*M* = 245 Hz, *SD* = 12) session, *t* (6) = 2.44, *p* =.02. There was no significant difference in F0 mean (Hz) in the in- person and the tele sessions for the mother (In Person: *M* = 247 Hz, *SD* = 19; Tele: *M* = 243 Hz, *SD* = 35) or children's speech (In Person: *M* = 260 Hz, *SD* = 46; Tele: *M* = 275 Hz, *SD* = 55), *t* (6) = 1.14, *p* = 0.29.

F0 Range (Hz)

The SLP produced a significantly higher F0 range in the tele (*M* = 177 Hz, *SD* = 16) compared to the in-person session (*M* = 150 Hz; *SD* = 19) session, *t* (6) = 2.44, *p* = .03. The children also produced a significantly higher, *t* (6) = 2.44, *p* = .02, F0 range in the tele (*M* = 168 Hz, *SD* = 49) compared to the in-person session (*M* = 129 Hz, *SD* = 30). There was no significant difference in F0 range (Hz) in the mother's speech (In Person: *M* = 157 Hz, *SD* = 38; Tele: *M* = 141 Hz, *SD* = 41), *t* (6) = 2.44, *p* = .12.

Syllables per Utterance Duration

There was no significant difference in the number of syllables per utterance duration in the in person and the tele sessions in the SLP (In Person: *M* = 4.50, *SD* = 1.17; Tele: *M* = 4.11, *SD* = 0.69), *t* (6) = 2.44, *p* = 0.25, or children's speech (In Person: *M* = 2.05, *SD* = 0.97; Tele: *M* = 1.84, *SD* = 0.67), *t* (6) = 2.44, *p* = 0.28. The mothers produced a higher, *t* (6) = 2.44, *p* = .01, number of syllables per utterance duration in the in-person (*M* = 4.02, *SD* = 0.92) compared to the tele sessions (*M* = 3.64, *SD* = 0.97).

Utterance Duration

There was no significant difference in utterance duration (sec.) in the in person or tele sessions for the SLP (In Person: *M* = 1.33, *SD* = 0.21; Tele: *M* = 1.51, *SD* = 0.4), *t* (6) = 2.44, *p* = 0.27, and children's speech (In Person: *M* = 0.89, *SD* = 0.12; Tele: *M* = 0.91, *SD* = 0.15), *t* (6) = 2.44, *p* = 0.51. The mother produced a significantly longer speech utterance duration (in seconds), *t* (6) = 2.44, *p* = .003, in the in-person (*M* = 0.99 sec, *SD* = 0.17) compared to the tele session (*M* = 0.87 sec, *SD* = 0.13).

Mean Length of Utterance

There was no significant difference in MLU in the in person and the tele sessions in the SLP (In Person: *M* = 4.22, *SD* = 1.02; Tele: *M* = 3.85, *SD* = 0.64), t (6) = 2.44, *p* =

0.16, or children's speech (In Person: *M* = 1.81, *SD* = 0.76; Tele: *M* = 1.67, *SD* = 0.67), t (6) = 2.44, *p* = 0.30. The mother produced a significantly higher, *t* (6) = 2.44, *p* = 0.01, MLU in the in-person (*M* = 3.73, *SD* = 1.12) compared to the tele session (*M* = 2.9, *SD* = 1.1).

DISCUSSION

The aim of the current study was to examine the effect of telepractice on the quantity of vocal turn-taking, prosodic, and lexical characteristics of speech between the provider, the child with cochlear implants, and caregiver during clinician-directed speech language intervention. The SLP and child had a lower vocalization rate in tele compared to in-person sessions. The mother, however, had a higher vocalization rate in tele compared to in-person sessions. The results demonstrated there was a lower rate of turns between the child and SLP and a higher rate of turns between the child and the mother in tele compared to in-person sessions. It was found that the SLP had a higher mean fundamental frequency and more expanded fundamental frequency range in the tele compared to in-person sessions. In addition, the SLP had the highest vocalization rate in the in-person sessions compared to the child and the mother. The child had a higher vocalization rate in the in-person sessions than the mother. Between speaker pause duration was longer in child-SLP and SLP-child turns in tele compared to in-person sessions. The mother had a longer utterance duration, higher number of syllables per utterance, and higher MLU and longer utterance duration when speaking to the child in the in-person compared to the tele sessions.

SLP-Child Vocal Interaction

It was found that the SLP produced fewer vocalizations during the tele compared to the in-person sessions. Previous studies suggest the use of telepractice may affect the fluidity and naturalness of conversation because the SLP is not in a shared physical environment with the child (Anderson et al., 2014; Grogan-Johnson et al., 2013; Hall et al., 2019; Keck & Doarn, 2014; Snodgrass et al., 2017; Tucker, 2012). In the literature, the lack of physical proximity between the child and SLP has been reported as a challenge for the SLP to physically prompt or comfort the child during intervention (Anderson et al., 2014; Grogan-Johnson et al., 2013). The lack of physical proximity during telepractice is perceived as a hindrance to establish rapport with clients (Tucker, 2012). Specifically, the use of telepractice might have limited the SLP's delivery of verbal and non-verbal cues, such as body language and posture that support building rapport during in-person situations (Murphy & Rodríguez Manzanares, 2012). Therefore, the lack of physical proximity between the child and SLP may have affected the SLP's vocalization rate.

Additionally, there was a lower rate of SLP and child vocalizations in SLP-child and child-SLP turns during tele compared to in-person sessions. This finding is supported by results from previous studies on remote versus in-person communication (Malley et al., 1996). The child and SLP were not in the same physical environment which may have altered their vocal engagement (Anderson et al., 2014; Grogan-Johnson et al., 2013). Additionally, the introduction of a two-way transmission delay could affect the fluidity of conversation in telepractice (Michael & Möller, 2020). The lack of shared environment during remote communication may have altered the shared vocal interaction between the child and SLP.

There was a longer pause duration in between child and SLP turns during the telepractice session compared to the in-person sessions. It is possible that an increased between-speaker pause duration in child-SLP and SLP-child turns during telepractice was caused by a less efficient temporal estimation of turn duration on the behalf of participants

(Levinson & Torreira, 2015). There may have been a less efficient mutual comprehension and coordination of turns between the child and SLP in telepractice sessions (Beebe et al., 1988; Garrod & Pickering, 2015; Jaffe et al., 2001; Jasnow & Feldstein, 1986; Smith & McMurray, 2018). In previous research, providers have noted the lack of physical contact with and diminished visual cues from students during telepractice, which may have potentially affected the timing of vocal responses (Anderson et al., 2014b; Grogan-Johnson et al., 2013a; C. S. Keck & C. R. Doarn, 2014; Tucker, 2012).

Mother-Child Vocal Interaction

It was found the child produced fewer vocalizations during tele compared to in-person sessions. Previous evidence suggests engaging in telepractice intervention requires a child to remain within view of the screen as well as direct and maintain their attention to the screen (Gibson et al., 2010; Grogan-Johnson et al., 2013b). Additionally, the SLP might require a skilled adult present with the child to assist with the child's loss of attention (Hall et al., 2014). The use of telepractice may have made it difficult for the SLP to direct the child's attention throughout the session (Akamoglu et al., 2018). The absence of shared physical environment may have affected the child's vocalization rate.

Conversely, the mother produced more vocalizations during telepractice sessions compared to the in-person sessions. Since the SLP is no longer in the same physical space, the mother may have vocalized more to maintain the child's attention. Previous research has suggested the use of a tele-assistant is often required in telepractice sessions with young children (Hines et al., 2015). The mother may have produced more vocalizations in the telepractice session to manage her child's behavior (Chen & Liu, 2017). Previous research has suggested the use of telepractice necessitates active participation from the parent since the SLP is not in the room and cannot take control of the session (Houston et al., 2018). The mother may have vocalized more in the telepractice sessions because she could not be a passive observer of the intervention.

There was a higher rate of child and caregiver turns during tele compared to the in-person session. Previous evidence has suggested parents become more involved in communication with the child during telepractice interventions since they must maintain the child's attention, keep the child on task, and provide support during intervention (Grogan-Johnson et al., 2013b; Houston et al., 2018; Tucker, 2012). Caregivers must allocate more time and energy in telepractice sessions compared to in-person sessions to solve technical issues and control their child's behavior (Grillo, 2017; Yoo et al., 2020). The child and mother may have had more vocal engagement in the tele sessions since they were in the same physical space and the mother's effort and input were required.

SLP-Mother Vocal Interaction

There were no significant differences in the turn rate between the SLP and mother in either type of session. Previous evidence has suggested the clinician may assume the role of a trainer for caregivers during telepractice sessions (McCarthy et al., 2010; Snodgrass et al., 2017). However, in the present study there were few utterances in the SLP-mother interaction in both tele and in-person sessions. This finding may be due to the clinician-directed model of service delivery used in the study (Campbell et al., 2009; Salisbury & Cushing, 2013) in which the clinician guides and directs the child's attention to a language task. The SLP and caregiver may have had less vocal engagement between one another because they were both focused on the child's behavior and language output.

Prosodic and Lexical Characteristics of Child, SLP, and Caregiver Speech

It was found that the SLP had a higher mean fundamental frequency and more expanded fundamental frequency range in the tele compared to in-person sessions. These results are consistent with recent research on the effect of remote communication on vocal function in adults (L. F. Tracy et al., 2020). However, they extend it by including the analysis of the SLP's mean fundamental frequency and range, which have not been previously examined (L. F. Tracy et al., 2020). Previous evidence suggests speakers alter time-based measures of their speech (e.g. fundamental frequency and its range, harmonics-to-noise ratio and relative fundamental frequency) if there is transmission/environmental degradation of the speech signal due to noise (the Lombard effect) (Hotchkin & Parks, 2013; McKenna & Stepp, 2018).

The child did not modify their mean fundamental frequency but expanded their pitch range when addressing the clinician in the tele- compared to the in-person session. This finding could be accounted by several factors. First, theories of speech development assume children need the auditory feedback to monitor productions and make the correct match (D. E. Callan et al., 2000; J. S. Perkell, 2012; Scheerer et al., 2020). It is possible the CIs affected the perception of prosodic characteristics (Green et al., 2004; Peng et al., 2008). The use of telepractice may have had a limited effect on the auditory feedback in the DHH children who only modified fundamental frequency range.

Additionally, the high individual variability in the production of prosodic characteristics by DHH children may have contributed to the absence of difference in the mean fundamental frequency, given the abnormal voice quality and the lack of laryngeal control in pediatric population with hearing loss (Bolfan-Stosic & Simunjak, 2007; A. Dehqan & R. C. Scherer, 2011; Kasbi, Sadollahi, Bakhtiyari, Ghorbani, et al., 2014).

However, since speakers, including children, also respond differently to the auditory feedback when performing different communication tasks (Amazi & Garber, 1982a; Garnier et al., 2010), it is possible that the expanded fundamental frequency range identified in the tele- relative to the in-person session reflects increased bids for attention or approval (A. Fernald, 1989; Fernald, Taeschner, Dunn, Papousek, & de Boysson-Bardies, 1989) from the child while addressing the clinician.

To our knowledge this is the first study showing the effect of telepractice on fundamental frequency measures of child vocal production in pediatric population with severe-to-profound hearing loss. These findings extend the previous research that focused predominantly on noise-induced changes of speech intensity in normal-hearing pre-school-aged children (Amazi & Garber, 1982a; Garber et al., 1980; Siegel et al., 1976).

There were no significant differences found in the number of syllables per utterance, utterance duration, or MLU produced by the child or SLP in either type of session. These findings are supported by previous research suggesting normal-hearing children produce a similar mean length of utterance in in-person and telepractice sessions (Manning et al., 2020).

There were no differences in the prosodic characteristics of maternal speech directed to the child between the tele- and the in-person session were identified. These results were expected given that both the caregiver and the child were in the same room interacting in-person all the time. However, the results have demonstrated longer utterance duration (in seconds), higher speech rate and MLU in maternal speech directed to the child in the in-person compared to the tele- session. These results suggest that the digital device use, such as a laptop computer, affects the quality of the caregiver speech directed to the child during telepractice. Technoference, or brief interruptions to the caregiver-child social interaction, due to technological device use (McDaniel, 2019; Stockdale et al., 2020) may have introduced distraction (Radesky et al., 2016). Since the caregiver is multitasking during telepractice sessions by assisting the provider with the technology and interacting simultaneously with the child (e.g. brining child's attention to the computer screen) (Anderson et al., 2014b; Houston, 2011; M. R. Snodgrass et al., 2017), it is possible that the caregiver's attention is divided. Multitasking studies have demonstrated that divided attention can lead to inefficiencies and more errors (Chen & Yan, 2016; Dindar & Akbulut, 2016). In parental interviews, caregivers have expressed they find it difficult to accurately interpret and respond to child cues when they are distracted with their mobile device (Radesky et al., 2016). The quality of the caregiver speech directed to the child during telepractice may be affected as a result of divided attention between several tasks. Future research examining the effect of technoference on the quantity and quality of parent-child interaction during telepractice is warranted to maximize child language outcomes in both clinician-led and family-centered intervention modalities (Moeller et al., 2013; M. R. Snodgrass et al., 2017).

LIMITATIONS

One limitation of the current study was dyad sample size (*n* = 7). The sample size was sufficient for data analysis and to determine meaningful differences between interventions. However, future research should include an increased number of mother-child dyads to see if these results are replicated on a larger scale. This study included DHH children who received CIs. Future research could include children with different degree of hearing loss to provide a more robust understanding of how telepractice affects pediatric patient-provider vocal interaction. One provider participated in the study, limiting generalizability to other providers (Grogan-Johnson et al., 2013a). Future research could include more SLPs to account for individual variability. Future research including a control group of NH children matched with the DHH children by chronological age and/or the amount of hearing experience is necessary to understand the effect of telepractice on the acoustic-phonetic characteristics of child voice and their relation to child communicative needs.

CONCLUSION

The purpose of the current study was to examine the effect of telepractice on turn-taking, prosodic (mean fundamental frequency, fundamental frequency range, speech rate, utterance duration) and lexical (MLU) characteristics of speech between the provider, child who wears cochlear implants, and caregiver during an in-person and telepractice speech therapy intervention. The results demonstrate the use of telepractice alters the frequency of vocalizations, turn-taking rate and, temporal characteristics of turn-taking, and prosodic characteristics of provider, DHH child and caregiver speech. These results help to inform the child, clinician, and caregiver about their own behavior during a telepractice session which may be useful in determining the benefits and drawbacks of using telepractice. Future research could include more mother-child dyads and clinicians in order to account for individual variability and improve generalizability of results.

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PUBLICATIONS:
Kondaurova, M.V., Betts A., Donaldson C.W., Zheng Q., Smith, A F. (2021) Telepractice in pediatric speech therapy: prosodic and lexical characteristics of patient, provider and caregiver speech. *Proceedings of Meetings on Acoustics.*

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CONFERENCE PRESENTATIONS:

Kondaurova, M., Kinney, K., Betts A., Nolan, L., Vandam, M. (2019, May). *Infant-directed speech register in children with and without hearing loss.* Poster presented at Acoustical Society of America meeting, Louisville, KY.

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