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“Es una pelota, do you like the ball?”: Pitch in Spanish-English bilingual infant directed speech

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ABSTRACT

The goal of this research is to understand how bilingual and monolingual parents adjust their speech when talking to infants. We examined pitch characteristics of infant-directed speech (IDS) and adult-directed speech (ADS) with Spanish-English bilingual and English monolingual parents and their infants (8–20 months of age). Thirty-eight parent-infant dyads participated in two naturalistic play tasks. Parents spoke with a bilingual researcher to collect samples of ADS. Results showed that both parent groups produced higher maximum and average fundamental frequency in IDS than ADS, suggesting that caregivers adjust pitch similarly in IDS across registers. However, for bilinguals, the IDS versus ADS difference was larger in English than Spanish; bilingual parents differentiated IDS adjustments across languages. The analyses across word repetitions revealed that in bilingual parents' IDS, there was no change in pitch across the first and second repetitions of target words, even when repetitions occurred in different languages. Taken together, results suggest that bilingual parents adjust their IDS pitch similarly to English-speaking monolinguals, but they differentiate English and Spanish IDS adjustments. Overall, this project contributes to our understanding of parents' register adjustments across multilingual language learning contexts.

Introduction

When talking to infants, caregivers tend to make acoustic-phonetic adjustments that differ from how they talk to adults. This speaking style is known as “infant-directed speech” (IDS). Common features of IDS include higher pitch (perceived fundamental frequency, F0) and greater pitch range, slower rate of speech, and longer utterances and pause durations in comparison to adult-directed speech (ADS) (e.g., Fernald, 1989; Fernald et al., 1989; Stern et al., 1983). Parents also exaggerate some vowel distinctions in some languages, including English, Russian, and Swedish (Kuhl et al., 1997; but see Burnham et al., 2002, as well as some consonant contrasts (Cristia, 2010; Liu et al., 2003). The features of IDS suggest a speech signal that may support early attention to and learning of language. However, there is limited understanding of the properties of IDS that multilingual parents produce with their multilingual children. Worldwide, nearly two thirds of children grow up learning more than one language (Konishi et al., 2014), but the majority of IDS research has been conducted with monolingual English-speaking North American samples (e.g., Spinelli et al., 2017) or compared different languages in monolingual populations (e.g., Kitamura et al., 2001). In the present research, we examined how bilingual and monolingual caregivers produce IDS and ADS across the languages they speak (Spanish and English, or English only). We also probe specific contexts shaping how bilinguals produce IDS,

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including repetitions and code-switching. Our research investigates whether there are characteristics of bilingual IDS that might support bilingual learning.

The following sections of the Introduction include (A) an overview of the proposed roles of IDS in language acquisition, (B) prior work examining universal and language-specific features of IDS, (C) bilingualism, IDS, and language learning, (D) IDS and code-switching, and (E) an introduction of the current study.

Role of IDS in language acquisition

Given the nature of IDS, there have been several proposals regarding the role of IDS in first language acquisition. One hypothesis is that the acoustic characteristics of IDS represent its listener-focused nature – a speech signal designed to accommodate a developing listener who is early in the learning process. Fernald (2000) argued for an extension of the hyper- and hypo-articulation (H&H) model of speech production (Lindblom, 1990) to understand IDS. She proposed that infants rely on adults to adjust the speech signal in ways that support learners, and that, accordingly, adults produce a form of hyperspeech that has greater clarity than what is typically used with other adults with mature language knowledge. Fernald's account is also broadly consistent with the principles of Audience Design that speakers produce utterances in ways that maximize the likelihood that listeners will understand (Clark & Murphy, 1982; Ferreira, 2019). Thus, characteristics of IDS may be suited to making language easier for infants to process (Morgan, 1996). Hyper-articulated phonemes may allow for greater differentiation of phoneme categories compared to more casual ADS (Fernald, 2000; but see; Ochs & Schieffelin, 1984). Consistent with this idea, infants who hear more clearly articulated vowels have more advanced neural measures of speech perception than infants who hear fewer clear vowels (Garcia-Sierra et al., 2016). The exaggerated prosody of IDS may also help to identify word boundaries and highlight words that infants are unfamiliar with (Albin & Echols, 1996; Fernald & Mazzie, 1991; Thiessen et al., 2005). In addition, IDS has higher rates of repetition than ADS (Fernald & Morikawa, 1993; Fernald & Simon, 1984); young children benefit from repetition when learning new words (Schwab & Lew-Williams, 2016). Thus, many features of IDS seem to be well-suited to promoting early speech processing and learning.

Other discussions of IDS have focused on how it contains features designed to garner infant attention. The exaggerated prosody of IDS may promote attention to the speech signal. Fernald and Kuhl (1987) demonstrated that infants 4 months of age preferred to listen to IDS over ADS. In a large cross-cultural and cross-linguistic sample of infants tested in many different laboratories around the world, Byers-Heinlein et al. (2021) found that infants across ages 3–15 months showed longer attention to American English IDS than to ADS; the effect was stronger for older infants. They found no difference in IDS preference for monolinguals versus bilinguals. Studies of older infants ages 18–21 months have also consistently reported preferences for IDS over ADS (Robertson et al., 2013; Spinelli et al., 2017). When parents engage with their infants in IDS, infants may perceive this interaction as a social cue that elicits and holds attention (Senju & Csibra, 2008), promoting learning. Thus, acoustic and social cues within IDS may promote attention to language.

Universality vs. language-specific properties of IDS

Cross-cultural studies suggest that IDS prosody, particularly elevated pitch, occurs in many languages and cultures. In a study conducted across 184 countries and 15 languages, Hilton et al. (2022) found that across the countries, adult listeners were able to differentiate between IDS and ADS in unfamiliar languages based on their sensitivity to acoustic regularities that were specific to the speech registers. In a recent meta-analysis, Cox et al. (2023) found that across languages and cultures, acoustic features of IDS (i.e., fundamental frequency, vowel space area) were distinct from ADS (see also Broesch & Bryant, 2015; Fernald et al., 1989). However, not all languages demonstrate elevated pitch with the same magnitude. Kitamura et al. (2001) investigated

average pitch and pitch range in Thai and Australian English IDS. They found that in both languages, IDS had a higher mean pitch than ADS. However, the difference between IDS and ADS pitch was larger in Australian English than in Thai. American English IDS also exhibits exaggerated IDS prosodic features relative to other languages, including French, Italian, German, Japanese, and British English (Fernald et al., 1989).

While elevated pitch is common in IDS, it is not universal. Han et al. (2020) compared features of IDS in Mandarin Chinese- and Dutch-speaking mothers. Dutch-speaking mothers produced a higher pitch in IDS than ADS, but Mandarin Chinese-speaking mothers' IDS mean pitch and pitch range were similar to ADS. More broadly, IDS use varies across cultures, including cultures where adults produce little speech directed to infants (Bernstein Ratner, 1984; Casillas et al., 2020; Cristia et al., 2019; Ingram, 1995; Shneidman & Goldin-Meadow, 2012). For example, Casillas et al. (2020) showed that Tzeltal Mayan children in Southern Mexico had very limited exposure to IDS because parents only spoke to them in the morning or during "interactional peaks" (Casillas et al., 2020), periods of time where social interactions with infants are at their highest. This literature indicates that there is wide variability in the use of IDS. Therefore, one cannot assume that properties of IDS that appear in one language or a set of languages generalize across all languages, language combinations, or cultures.

Bilingualism, IDS, and language learning

A growing body of work has started to examine how IDS and ADS are realized across languages within the *same* individual (Bosch & Ramón-Casas, 2011; Danielson et al., 2014; Fish et al., 2017). For example, Danielson et al. (2014) studied French-English bilingual and French and English monolingual mothers' point vowels (/a, i, u/) in IDS. They found that French-English bilingual mothers' point vowels produced in IDS were distinct when speaking each language. The French vowels produced by bilingual mothers were similar to those produced by monolingual French mothers; English point vowels of bilinguals were also similar to those of monolingual English mothers. In this sample, the bilingual mothers showed little cross-language influence on vowel productions. This finding contrasts with results from a study of Spanish-Catalan bilingual mothers from Barcelona, Spain. Bosch and Ramón-Casas (2011) found that mothers' vowel productions differed; Spanish-Catalan bilingual mothers produced Catalan contrast vowels with more variability (i.e., more errors produced in sounds) and category errors (substituting incorrect vowel sounds) than Catalan monolingual mothers. Furthermore, Fish et al. (2017) also demonstrated that Spanish-English bilingual caregivers in Washington, USA, generally exaggerated voice onset time (VOT) in stop consonants in IDS, as did English monolinguals. Moreover, in the sample of Spanish-dominant bilinguals, VOT in English was affected by VOT properties of Spanish. In summary, these studies suggest that bilingual speakers sometimes produce acoustic differences in IDS when speaking different languages, but the patterns of differences vary based on the linguistic context (e.g., languages spoken) and acoustic features.

Amount of exposure to IDS across languages relates to language learning outcomes both for monolingual (e.g., Spanish; Weisleder & Fernald, 2013) and bilingual infants (Spanish and English; Hoff et al., 2020; Ramírez-Esparza et al., 2014). Ramírez-Esparza and colleagues (Ramírez-Esparza et al., 2014) examined the language development of young bilingual Spanish-English learners. They showed that at 12 months of age, greater exposure to IDS was associated with a larger vocabulary at 24 months across languages. Furthermore, Hoff (2020) found that bilingual infants who heard relatively more Spanish than English had greater knowledge of Spanish vocabulary than English vocabulary. In addition, the amount of input in each language (Spanish and English) was related to the parent's language skill in each language. Parents tended to use their stronger language more often with their infants. Marchman et al. (2017) also found that Spanish-English bilingual parents' rates of IDS in Spanish and English correlated positively with children's language outcomes in each language at 3 years of age. Ramírez-Esparza et al. (2014, 2017) also found that exposure to IDS predicted language

knowledge and vocabulary in monolingual and bilingual infants. Taken together, these findings suggest that the amount of language experience in IDS relates to infants' dual language learning.

IDS and code-switching

A feature of IDS that occurs in multilinguals is that they can switch languages. Code-switching, which has primarily been studied with bilingual adults, is the process of combining multiple languages within and across utterances without violating grammatical rules in either language (

Poplack, 1988). In ADS, there is evidence that bilinguals provide acoustic cues around code-switching events. Olson (2016) investigated Spanish-English bilingual adults' code-switching features, examining pitch range and duration. Bilingual speakers participated in an oral production task where they were instructed to speak as if they were speaking to another bilingual adult (imagined condition) across three different days to be able to control for the language context. Each day had a separate condition: Monolingual non-switched target token in a monolingual context (e.g., The *teachers* are in charge of the class), Monolingual context, code-switched target word (e.g., Mi hermana tiene *teachers* muy buenos) and Bilingual context, code-switched target tokens in a bilingual context (e.g., "La escuela tiene *teachers* buenos en cada clase," my dad told her). To counterbalance the stimuli, corresponding stimuli was created using Spanish target tokens to have opposite language pairings across the days. They found that when participants used code-switched target tokens, they produced a higher pitch and greater stressed vowel durations than non-code-switched words. The evidence that bilinguals adjust their speech in a way that might highlight the language change (increasing pitch and duration at a switch) aligns with predictions of the H&H model (Lindblom, 1990). Hyper-articulating or exaggerating features of words may provide a speech signal that facilitates language processing. For bilingual speech, the elevated pitch and duration at code-switching events could provide a signal for the listener to detect that a language switch has occurred.

Many bilingual infants are exposed to code-switching in their communities (Goodz, 1989; Myers-Scotton, 2017). One specific area of interest regarding code-switching is how it affects word learning. Bail et al. (2015) found that Spanish-English bilingual caregivers who frequently code-switched in speech with bilingual adults code-switched more often in their speech with their 18- to 24-month-old infants than bilinguals who infrequently code-switched in ADS. Overall, caregivers used inter-sentential code-switching (language switching at sentence boundaries) more often than intra-sentential code-switching (language switching within the sentence) (Bail et al., 2015). There may also be changes in how parents use code-switching as infants' language knowledge progresses. In a recent study, Kremin et al. (2022) reported that French-English bilingual parents' use of inter-sentential code-switching in speech to infants increased between 10 and 18 months of age. The results suggest that parents may use code-switching to help infants understand the connections between languages as infants get older.

Current study

There is an emerging literature about IDS in bilingual environments, but there is little known about the acoustic features of bilingual IDS and how bilingual parents might use IDS to support dual language learning. The present study sought to characterize how Spanish-English bilingual parents elevate pitch in IDS, a common cross-linguistic IDS characteristic, and whether they show similar or distinct pitch adjustments relative to monolingual English-speaking parents. We also examined whether bilingual parents differentiate IDS and ADS similarly in each of their languages. In addition, the current study analyzed whether bilingual parents use pitch in a way that emphasizes language changes from one language to another. To address these topics, parents participated in a series of lab-based interactive tasks designed to collect IDS and ADS samples with a consistent vocabulary of target words. In two IDS tasks, parents played with their infants with a set of target objects (e.g., animals and vehicles). The ADS task required that parents discuss the same items with an adult experimenter. To understand how bilingual parents adjust speech to

infants versus adults in each of their languages, we analyzed fundamental frequency, a measure of pitch, for target words that occurred in IDS and ADS interactions. We analyzed both maximum and mean fundamental frequency for word tokens. Mean fundamental frequency is a commonly used measure of IDS prosody that has been analyzed in many samples and across languages (Fernald & Kuhl, 1987; Fernald & Mazzie, 1991). Maximum fundamental frequency allowed us to examine a consistent value for pitch across languages, as the English and Spanish words differed in word length (i.e., more two-syllable Spanish words). Maximum pitch has been used in prior studies of IDS in American English (Fernald & Mazzie, 1991; Fernald et al., 1989). Maximum pitch is well-suited to analyzing multisyllabic words and words that vary in length because it allows for comparison of a standard single point in each word, which might be obscured across variable syllable structures. One prediction is that Spanish-English bilingual parents may exaggerate pitch more in IDS than monolingual parents because, based on the H&H model of speech production (Lindblom, 1990), bilingual parents may adjust their speech to suit the challenges of simultaneously learning two languages. In addition, bilingual parents may provide multiple cues to help infants learn the languages by repeating words across languages. The second set of analyses tested whether bilingual parents adjust pitch to highlight repetitions of words across languages in IDS.

Method

Participants

Participants were Spanish-English bilingual parents ($n = 18$; 16 mothers, 2 fathers; two additional fathers were excluded because they only used Spanish in the tasks) and monolingual English-speaking parents ($n = 20$; 16 mothers, 4 fathers). The infants were aged 8–20 months old (bilinguals mean age = 13.2 months, $SD = 3.27$; monolinguals mean age = 15.4 months, $SD = 2.66$). Although the difference in age across groups was significant [$t(32.84) = -2.29$, $p = .03$], there was substantial overlap in the age ranges (range: 7.93 months–19.87 months). Therefore, we tested for age effects in the models. All infants were born full-term and were typically developing, with no known hearing or vision impairments. Infants attended the lab session with the parent who spent the most awake time with the infant.

All bilingual parents' Spanish language exposure occurred from birth: 67% of parents' English exposure started in the preschool years (around or before 5 years of age), while 33% of them were exposed to English as an adult. The bilingual sample self-reported their race/ethnicity to be 100% Hispanic (45.3% further specified Mexican or Mexican American), 44.4% White, 11.1% Indigenous and White. The monolingual sample reported their race/ethnicity to be 25% Hispanic and White, 50% not Hispanic and White, 10% not Hispanic and African American and White; and 15% not Hispanic and Asian and White. The study was approved by the UC Davis Institutional Review Board (IRB) and subjects completed informed consent before participating. All participants were recruited through the Center for Mind and Brain at the University of California, Davis. The Spanish-English bilingual parents spent an average of 76.75 hours per week ($SD = 8.93$) of infants' awake time with their infant. Bilingual parents spent an average of 57% ($SD = 25.24$) of time speaking in Spanish to their infants on a weekly basis and 43% ($SD = 20.58$) speaking in English. The English-speaking monolingual parents spent an average of 77.73 hours per week ($SD = 5.54$) of infants awake hours with their infant.

To calculate bilingual infants' overall exposure to each language, parents reported all of the individuals who the infants interacted with for at least 1 h per week and the language(s) they spoke with the infant. Based on this, the mean percentage of awake-time exposure to Spanish was 62% ($SD = 25.24$) and English was 38% ($SD = 20.5$). Monolingual parents reported that their infant heard languages other than English for less than 5% of their awake time.

Language measures

Parents completed the Language Mixing Questionnaire (Byers-Heinlein, 2013), to provide information about how frequently they mix Spanish and English when speaking with their infant. The

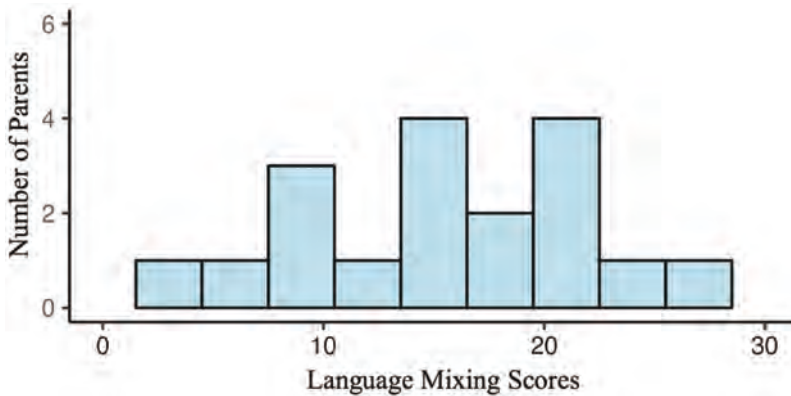


Figure 1. Frequency distribution of Spanish-English bilingual parents' language mixing scores.

Table 1. Vocabulary measurements for bilingual and monolingual infants.

Language group	CDI Version form	Mean percentile of words understood (SD)	Mean percentile of words produced (SD)	Mean raw scores of words understood (SD)	Mean raw score of words produced (SD)
Bilingual	English	27.08 (26.24)	38 (17.40)	62.2 (56.76)	11.36 (9.86)
Bilingual	Spanish	29.27 (23.98)	48.67 (15.75)	74.6 (58.17)	9.62 (7.91)
Monolingual	Spanish	34.64 (17.37)	38.39 (26.42)	124.89 (96.27)	27 (31.74)

questionnaire examined the use of code-switching and lexical borrowing. Parents were asked to estimate language mixing with a six-point Likert scale in response to five questions such as “I often start a sentence in English and then switch to speaking Spanish,” converted into numeric values for scoring. [Figure 1](#) displays the range of summed scores from 0 (no language mixing) to 30 (highest possible mixing score). The mean Code-Switching score was 15.72 (SD = 6.7), indicating a moderate amount of language mixing.

Infant vocabulary size was measured by using the English MacArthur-Bates Communicative Development Inventory (MBCDI; Fenson et al., 2007) and the Spanish MacArthur Inventario del Desarrollo de Habilidades Comunicativas (Jackson-Maldonado et al., 2003). These parental vocabulary reports have demonstrated high validity in a bilingual sample (Marchman & Martínez-Sussmann, 2002). Spanish-English bilingual parents completed the Spanish and English versions of the inventories; English-speaking monolingual parents only completed the English version. Parents completed one of two forms depending on their infant's age: Words and Gestures (for infants 8–18 months; measures vocabulary comprehension and production = 34) or Words and Sentences (for infants 19–20 months, measures vocabulary production = 2). Vocabulary sizes are reported in [Table 1](#). Based on percentile scores that account for sex and age, monolinguals and bilinguals did not differ in their comprehension [$t(19) = -0.85, p = .40$] or production vocabulary size [$t(30) = -0.05, p = .96$] in English. Bilingual infants did not differ in vocabulary size percentile across languages for comprehension [$t(23) = -0.22, p = .8$] or production vocabulary size [$t(28) = -1.76, p = .09$].

Stimuli

Stimuli consisted of 10 object names that are commonly understood early in vocabulary development by English- and Spanish-learning infants, based on norms available in Wordbank (Frank et al., 2016). The same objects were used for IDS and ADS tasks. The target objects were a set of 10 small plastic toys (see [Figure 2](#)). Each object had the target label written on the bottom. Parents were instructed to refer to the objects by these labels to allow us to analyze a consistent set of word forms. Labels appeared in Spanish and English for the bilinguals and in English only for the monolinguals.



Figure 2. Labeled toy objects stimuli for free-play and object-labeling tasks in IDS and ADS.

Procedure

The first author, a Spanish-English bilingual, conducted the experiment. Throughout the visit, the researcher code-switched while speaking with bilingual parents. For English-speaking monolinguals, all material and explanations were given in English only. Parents wore a Tascam DR-10 L Digital audio recorder with a lavalier microphone and video cameras mounted to two walls recorded the sessions. All parents participated in the IDS tasks before the ADS tasks because initial testing showed that infants were more likely to cry or become fussy later in the lab visit which prevented collecting IDS samples.

In the IDS session, there were three tasks: object labeling, free play, and book reading (order counterbalanced across participants). Because the book did not contain the target words, we do not report the book task analyses. Each task was 6 minutes long; at the 4-minute mark a timer sounded to indicate that 2 minutes remained. In the IDS object-labeling task, parents were asked to play with the objects with their child and to name each object using the provided label while playing. In the IDS free-play task, the parent-infant dyads received the same toys as in the labeling task. The parent was instructed to play with their infant as they normally would at home. Bilingual parents were instructed to use both language labels if they normally used Spanish and English at home. Between tasks, the experimenter entered the room to provide additional instructions.

In the ADS object labeling task, the parent received the same set of toys as in the IDS tasks. The parent was asked to label and describe each item to an adult experimenter. The task duration was 6 minutes. Bilingual parents were asked to use labels in both languages if they used Spanish and English at home. Parents also participated in a reading task that did not include the target words and was excluded from the present analyses.

Data preparation

Native Spanish-English bilingual research assistants annotated the bilingual speech sample recordings. Native English-speaking monolingual research assistants annotated the monolingual samples. The 10

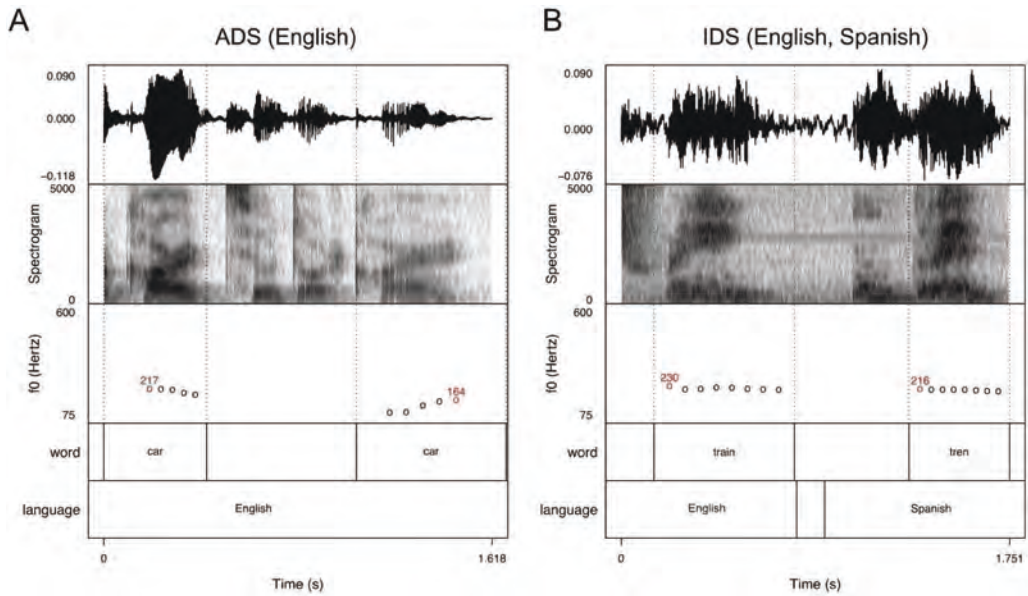


Figure 3. Spectrogram of (A) ADS and (B) IDS from a bilingual parent, illustrating repetitions of the same word object. (A) shows English (car, car), while (B) shows code-switching (train, tren). The maximum pitch (hertz) is shown in red. Note that values outside of the f_0 range (75–600 Hz) were excluded, leading to fewer than 10 values where there was no voiced element (e.g.,/k/release). (color online).

target words in each language were manually annotated using Praat (Boersma & Weenink, 2021). Bilingual parents produced 2250 target words in IDS (1184 Spanish and 1066 English) and 456 words in ADS (202 Spanish 254 English). Monolingual parents produced 1816 target words in IDS and 444 words in ADS. Bilingual and monolingual parents differed in English target label production in IDS ($R^2 = 0.22$, $F(1,36) = 9.95$, $p < .01$); monolingual parents produced more English labels than bilingual parents. In ADS, the same pattern was observed ($R^2 = 0.09$, $F(1,38) = 3.90$, $p < .01$). Bilingual parents did not differ in rates of English and Spanish labels in IDS ($R^2 = 0.01$, $F(1,34) = 0.38$, $p = .5$) or ADS ($R^2 = 0.06$, $F(1,34) = 2.308$, $p = .14$).

For each target word, we extracted the pitch contour by calculating the fundamental frequency (f_0) at 10 equidistant timepoints using a Praat script with the autocorrelation method (Cohn, 2021, 2022; adapted from; DiCanio, 2007), using plausible maxima and minima for speaker genders (female: 75–600 Hz; male: 70–500 Hz). We set the F_0 ceiling for 600 Hz (for female speakers) based on prior research on infant-directed speech (Knoll et al., 2009). Measurements in Hertz (Hz) were converted to semitones with the *hqmisc* R package (Quené, 2022), relative to 100 Hz, so that f_0 was on a perceptually linear scale. After being converted to semitones, we filtered each contour to remove any values that were greater than three standard deviations from the contour mean (in semitones) (note that no values exceeded 3 SD) (see Figure 3 for an illustration). We then calculated the mean and maximum f_0 (in Hz and semitones) in each contour. We filtered any values more than three deviations for each speaker's values in semitones (resulting in $n = 38$ max f_0 and $n = 37$ mean f_0 observations were replaced with NA). Data were coded by object label for monolingual and bilingual participants, with 10 object labels.

Statistical Analysis and Results

General Methods

In the following sets of analyses, we modeled mean and maximum pitch in separate linear mixed effects models with the *lme4* package (Bates et al., 2015) and *lmerTest* package (Kuznetsova, 2017). All

models were specified with a maximal random effects structure (Barr et al., 2013) and simplified in the case of a singularity or convergence error (Barr et al., 2013; Cohn et al., 2022). We additionally assessed collinearity of predictors in each model with the *performance* R package (Lüdtke et al., 2021) to ensure independence of predictors. All factors were sum coded relative to the grand mean.

Comparisons of IDS and ADS in English

To examine how bilingual and monolingual parents adjust speech when talking to infants versus adults, the current study compared the pitch (maximum, mean) of their productions of the target words, first in English, the shared language across both language groups. Fixed effects for the models included Speech Register (IDS, ADS), Parent Language Background (bilingual, monolingual) and their interaction, as well as Infant's Age (centered). Random effects included by-Subject, and by-Object label random intercepts and by-Subject and by-Object label random slopes for Speech Register. The retained model structure is provided below.

$$\text{Pitch Value} \sim \text{Speech Register} * \text{Parent Language Background} + \text{Infant's Age (centered)} + (1 + \text{Speech Register} | \text{Subject}) + (1 + \text{Speech Register} | \text{Object label})$$

The mean and maximum pitch models are provided in Table 2 and the summarized raw values are plotted in Figure 4. As seen in Table 2, both models revealed an effect of Speech Register: parents produced a higher pitch in IDS than in ADS. There were no effects of the Parent Language Background: the bilingual parents' pitch values did not differ from monolinguals' values. Additionally, there were no effects of Infant's Age. Both pitch models also showed no significant interactions between Speech Register and Parent Language Background: bilingual and monolingual parents made comparable pitch increases in IDS, relative to ADS, in English. There was no evidence that bilinguals produced greater IDS pitch adjustments than monolinguals in English.

Comparing Bilingual Parents' IDS and ADS Adjustments in English and Spanish

The next analyses examined how Spanish-English bilingual parents adjusted speech when talking to infants versus adults across languages. The model compared pitch across Spanish and English. Both mean and maximum pitch were analyzed with separate models. Fixed effects included Speech Register (IDS, ADS) and Language Produced (Spanish, English), and their interaction, as well as Infant's Age

Table 2. Fixed and random effects parameters between maximum pitch and mean pitch models comparing IDS and ADS in English.

Predictors	Maximum pitch			Mean pitch		
	Coef	CI	p	Coef	CI	p
(Intercept)	13.88	12.71 – 15.06	< 0.001	11.93	10.77 – 13.10	< 0.001
Register (IDS)	2.08	1.53 – 2.64	< 0.001	2.17	1.67 – 2.68	< 0.001
Parent Language Background (Bilingual)	0.64	–0.36 – 1.64	0.21	0.74	–0.22 – 1.70	0.13
Infant's Age (centered)	–0.21	–0.54 – 0.11	0.19	–0.23	–0.54 – 0.08	0.14
Register (IDS) * Parent Language Background (Bilingual)	0.36	–0.10 – 0.83	0.13	0.39	–0.04 – 0.83	0.08
Random Effects						
σ^2	25.33			23.20		
τ_{00}	8.34	Subject		7.72	Subject	
	1.24	Object		1.32	Object	
τ_{11}	1.62	Speech Register Subject		1.38	Speech Register Subject	
	0.22	Speech Register Object		0.18	Speech Register Object	
ρ_{01}	–0.00	Subject		0.18	Subject	
	–0.18	Object		0.12	Object	
ICC	0.31			0.33		
N	38	Subject		38	Subject	
	10	Object		10	Object	
Observations	3482			3488		
Marginal R ² /Conditional R ²	0.10/0.38			0.12/0.41		

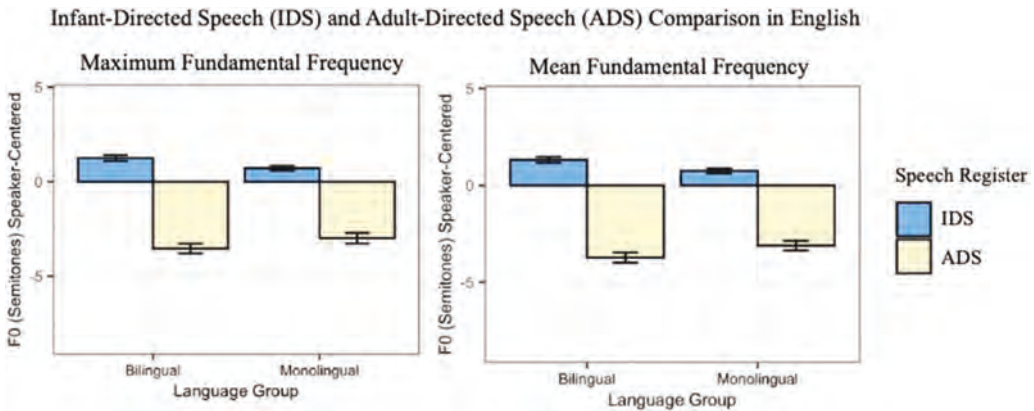


Figure 4. Monolingual English and Spanish-English bilingual parents’ pitch adjustments across infant-directed speech (IDS) and adult-directed speech (ADS) in English. Maximum and mean pitch (fundamental frequency, centered within the speaker) are on the left and right plots, respectively. Error bars indicate standard error of the means (color online).

(centered). Random effects included by-Subject random intercepts and by-Object label random intercepts, as well as by-Subject random slopes for Speech Register and Language. The retained model structure is provided below.

$$\text{Pitch Value} \sim \text{Speech Register} * \text{Language Produced} + \text{Infant's Age (centered)} + (1 + \text{Speech Register} + \text{Language} | \text{Subject}) + (1 | \text{Object label})$$

The model outputs are provided in Table 3, while mean and maximum pitch values are plotted in Figure 5 respectively. As seen in Figure 5, both models revealed effects of Speech Register, with a higher maximum and mean pitch in IDS than ADS. There was no effect of Language Produced or an effect of Infant’s Age. However, there were significant interactions between Speech Register and Language Produced. When bilingual parents spoke English, they produced a larger increase in IDS maximum and mean pitch (shown in Figure 5). The findings are consistent with prior evidence that American English has exaggerated IDS features compared to other languages (Fernald et al., 1989).

Table 3. Fixed and random effects parameters of the maximum pitch and mean pitch models examining bilinguals’ language used (English vs Spanish) across registers.

Predictors	Maximum pitch			Mean pitch		
	Coef	CI	p	Coef	CI	p
(Intercept)	14.36	13.12 – 15.59	< 0.001	12.52	11.30 – 13.74	< 0.001
Speech Register (IDS)	2.18	1.56 – 2.80	< 0.001	2.26	1.68 – 2.84	< 0.001
Language Produced (English)	0.23	−0.14 – 0.61	0.23	0.23	−0.17 – 0.64	0.26
Infant’s Age (centered)	−0.16	−0.49 – 0.17	0.35	−0.2	−0.53 – 0.13	0.24
Register (IDS) *Language (English)	0.25	0.03 – 0.47	0.03	0.29	0.07 – 0.51	0.01
Random Effects						
σ^2	16.87			17.14		
τ_{00}	5.56 Subject			5.35 Subject		
	0.56 Object			0.56 Object		
τ_{11}	1.56 Speech Register Subject			1.33 Speech Register Subject		
	0.43 Language Subject			0.52 Language Subject		
ρ_{01}	−0.22 Speech Register Subject			−0.11 Speech Register Subject		
	−0.29 Language Subject			−0.20 Language Subject		
ICC	0.3			0.3		
N	18 Subject			18 Subject		
	10 Object			10 Object		
Observations	2654			2653		
Marginal R ² /Conditional R ²	0.12/0.38			0.13/0.39		

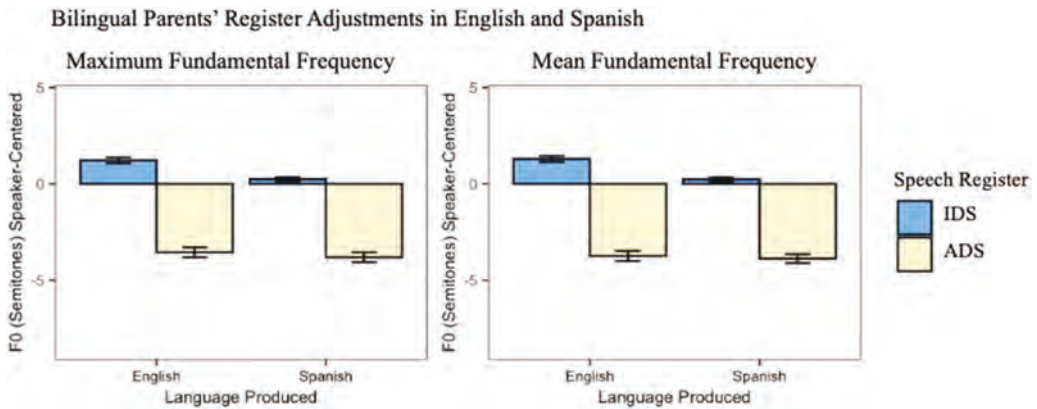


Figure 5. Bilingual parents' pitch adjustments in English and Spanish across infant-directed speech (IDS) and adult-directed speech (ADS) maximum and mean pitch (fundamental frequency, centered within speaker) are on the left and right plots, respectively. Error bars indicate standard error of the means (color online).

Here, these results demonstrated that the difference between English and Spanish IDS occurs within the same participants.

Comparing Reduction Effects in Word Repetitions within and across Languages

Features of IDS may provide cues to bilingual infants for differentiating their languages. Prior evidence in ADS suggests that bilinguals increase pitch when language changes occur (Olson, 2016). We looked for changes in parents' pitch that occurred across language changes and within a language as parents repeated the target object names. In ADS, when speakers repeat words (within a language), there is often a reduction effect from the first repetition of a word to the next, meaning that pitch is typically higher in the first repetition and decreases in the second repetition (Fowler & Housum, 1987; Lieberman, 1963). We examined changes in pitch across repeated object label words in IDS and ADS. We were specifically interested in whether bilingual parents differentiate pitch patterns when switching from one language to the other across word repetitions (e.g., Look at the dog, el perro!) versus repeating the word within the same language (e.g., Look at the dog, a dog!). One prediction is that in ADS bilingual parents would exhibit a reduction effect across repeated words, as demonstrated in prior work with monolinguals (Fowler & Housum, 1987). However, when changing languages across repetitions of a word, speakers might emphasize the second repetition by increasing pitch, highlighting the language change, particularly for infants who are still learning words in the two languages and how they correspond.

We identified repetitions of object label words that parents produced in adjacent utterances or within the same utterance (e.g., Look at the dog! The dog is coming to see you.; Tienes una vaca, a cow!). Repetitions were coded as occurring within the same language (dog; dog) or across language changes (vaca; cow).

Comparing Reduction Effects in Word Repetitions in English: IDS vs. ADS

To examine reduction effects, both mean and maximum pitch over each word in ADS and IDS were analyzed across a subset of the data, consisting of the first and second repetitions in English. Fixed effects included Parent Language Background (bilingual, monolingual), Speech Register (IDS, ADS), Word Repetition Order (first repetition; second repetition), and their interactions. Infant's Age (centered) was included as a fixed effect as well. Random effects included by-Subject and by-Object

Table 4. Fixed and random effects parameters of the maximum pitch and mean pitch models examining repetition across Parent language Background (monolingual vs bilingual) in English.

Predictors	Maximum pitch			Mean pitch		
	Coef	CI	p	Coef	CI	p
(Intercept)	13.32	11.53 – 15.12	< 0.001	11.5	9.71 – 13.29	< 0.001
Speech Register (IDS)	2.4	1.57 – 3.23	< 0.001	2.39	1.59 – 3.19	< 0.001
Parent Language Background (Bilingual)	0.05	-1.61 – 1.71	0.952	0.37	-1.25 – 2.00	0.66
Word Repetition Order (Rep. 2)	-0.53	-0.97 – -0.09	0.02	-0.49	-0.90 – -0.08	0.02
Infant's Age (centered)	-0.47	-0.98 – 0.05	0.07	-0.43	-0.93 – 0.07	0.10
Speech Register (IDS) *Parent Language Background (Bilingual)	0.36	-0.39 – 1.11	0.35	0.25	-0.50 – 0.99	0.52
Speech Register (IDS) *Repetition (Rep. 2)	0.31	-0.13 – 0.75	0.17	0.33	-0.08 – 0.73	0.12
Parent Language Background (Bilingual) *Repetition (Rep. 2)	0.2	-0.24 – 0.64	0.37	0.18	-0.23 – 0.59	0.38
Register (IDS) *Parent Language Background (Bilingual) *Repetition (Rep. 2)	0.2	-0.24 – 0.64	0.37	0.18	-0.23 – 0.59	0.38
Random Effects						
σ^2	24.05			21.05		
t_{00}	20.56 Subject			19.70 Subject		
	1.71 Object			2.03 Object		
t_{11}	1.67 Speech Register Subject			1.92 Speech Register Subject		
	0.33 Speech Register Object			0.20 Speech Register Object		
ρ_{01}	0.08 Subject			0.15 Subject		
	-0.27 Object			-0.24 Object		
ICC	0.51			0.54		
N	37 Subject			37 Subject		
	10 Object			10 Object		
Observations	1374			1376		
Marginal R ² /Conditional R ²	0.10/0.56			0.11/0.59		

random intercepts and by-Subject and by-Object label random slopes for Register. The retained model structure is provided below.

$$\text{Pitch Value} \sim \text{Speech Register} * \text{Parent Language Background} * \text{Word Repetition Order} + \text{Infant's Age (centered)} + (1 + \text{Speech Register} | \text{Subject}) + (1 + \text{Speech Register} | \text{Object Label})$$

The model outputs are provided in Table 4, while the raw values are plotted in Figure 6. The models for mean and maximum pitch revealed an effect of Speech Register: IDS pitch is higher than ADS pitch. There were no effects of Parent Language Background; monolinguals and bilinguals did not differ. There was no effect of Infant's age. For Word Repetition Order, there were effects: both mean and maximum pitch decreased from the first repetition to the second repetition of the target word (as shown in Figure 6). There were no significant interactions between Speech Register, Parent Language Background, or Word Repetition Order.

Language-Switching Repetitions: Bilingual Parents

We then analyzed whether bilingual parents used pitch to emphasize a change in language, increasing pitch from the first to second word repetition when the second word repetition was a label for the same object in a new language (e.g., vaca, cow). For repetitions of target object names, bilingual parents made 283 switches from English to Spanish and 297 from Spanish to English in IDS ($t(37.96) = 0.29, p = .77$). In ADS, bilingual parents made 139 switches from English to Spanish and 134 from Spanish to English ($t(33.91) = 0.33, p = .74$). For same-language repetitions, bilingual parents produced 274 in

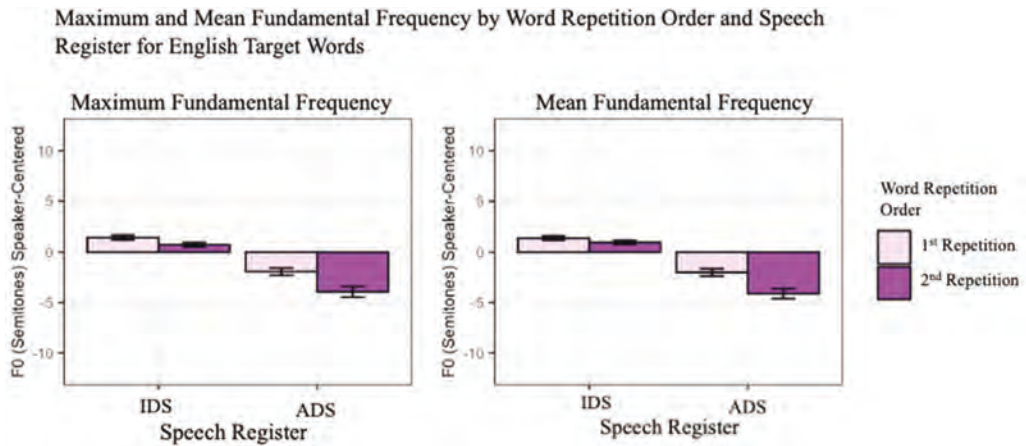


Figure 6. Word repetition effects across IDS and ADS in English, collapsing across monolinguals and bilinguals. Maximum and mean pitch (fundamental frequency, centered within the speaker) are on the left and right plots, respectively (color online).

English and 356 in Spanish. Pitch (mean and maximum) of bilingual parents' 1st and 2nd repetition words were modeled with a mixed effects regression, consisting of fixed effects of Speech Register (IDS, ADS), Language Condition (Same Language, Language Change), Word Repetition Word Order (first repetition, second repetition), and their interactions. Infants' Age (centered) was also included as a fixed effect. Random effects included by-Subject and by-Object random intercepts, and by-Subject random slopes for Speech Register, and Word Repetition Order.

$$\text{Pitch Value} \sim \text{Speech Register} * \text{Language Condition} + \text{Word Repetition Order} + \text{Infants' Age (centered)} + (1 + \text{Speech Register} + \text{Word Repetition Order} \mid \text{Subject}) + (1 \mid \text{Object})$$

The model outputs are provided in Table 5 while the raw values are plotted in Figure 7. The models revealed effects of Speech Register: IDS had higher maximum and mean pitch than ADS. Word Repetition Order also showed an effect, wherein the second word repetitions had lower maximum and mean pitch than first word repetition, showing a reduction effect. There was no effect of Language Condition: Bilingual parents did not differ in their pitch when repeating words in one language (e.g., dog-dog) or language switching (e.g., dog-perro). Contrary to the English-only repetition findings described in the previous analysis, both models showed interactions between Register and Word Repetition Order: bilingual parents produced a higher pitch in second mentions in IDS than in ADS. Put another way, bilingual parents did not show repetition reduction effects in IDS across both English and Spanish. The models showed no significant interactions between Speech Register and Language Condition. Bilingual parents did not modify their pitch across language changes differently when speaking in IDS or ADS. The models indicated that bilingual parents produced similar repetition effects regardless of whether those repetitions crossed languages or were in the same language.

General discussion

This experiment investigated IDS in Spanish-English bilingual and monolingual English-speaking parents interacting with their 8- to 20-month-old infants. The goal was to provide new understanding of how bilingual parents modify their speech in both languages during IDS, shedding light on how global and local contexts (e.g., code-switching locations, repetitions) vary compared to monolingual speakers. First, we found that bilingual and monolingual parents produced higher pitch during IDS than ADS, consistent with patterns of elevated IDS pitch seen in monolingual IDS across many studies and languages (see Fernald & Kuhl, 1987; Fernald & Mazzie, 1991; Fernald et al., 1989; Spinelli et al., 2017).

Table 5. Fixed and random effects parameters of the maximum pitch and mean pitch models examining bilingual’s repetitions across registers.

Predictors	Maximum pitch			Mean pitch		
	<i>Coef</i>	<i>CI</i>	<i>p</i>	<i>Coef</i>	<i>CI</i>	<i>p</i>
(intercept)	12.65	11.35 – 13.94	< 0.001	14.52	13.23 – 15.82	< 0.001
Speech Register (IDS)	1.9	1.28 – 2.52	< 0.001	1.87	1.20 – 2.53	< 0.001
Language Condition (Language Change)	-0.25	-0.57 – 0.08	0.14	-0.2	-0.53 – 0.13	0.24
Word Repetition Order (Rep. 2)	-0.47	-0.83 – -0.10	0.01	-0.5	-0.86 – -0.14	< 0.01
Infant’s Age (centered)	-0.26	-0.61 – 0.10	0.15	-0.17	-0.52 – 0.18	0.34
Register (IDS) * Lang Condition (Language Change)	0.03	-0.29 – 0.36	0.85	0.02	-0.31 – 0.35	0.89
Register (IDS) * Word Order (Rep. 2)	0.39	0.09 – 0.68	0.01	0.47	0.17 – 0.77	< 0.01
Lang Condition (Language Change) * Word Order (Rep. 2)	0.15	-0.14 – 0.45	0.31	0.23	-0.08 – 0.53	0.14
Register (IDS) *Lang Condition (Language Change) * Word Order (Rep. 2)	-0.04	-0.33 – 0.26	0.81	-0.06	-0.36 – 0.24	0.67
Random Effects						
σ^2	13.16			13.47		
τ_{00}	6.23	Subject		6.23	Subject	
	0.34	Object		0.35	Object	
τ_{11}	1.33	Speech Register Subject		1.62	Speech Register Subject	
	0.22	Word Repetition Order Subject		0.19	Word Repetition Order Subject	
ρ_{01}	0.11	Speech Register Subject		-0.03	Speech Register Subject	
	-0.28	Word Repetition Order Subject		-0.34	Word Repetition Order Subject	
ICC	0.39			0.38		
N	18	Subject		18	Subject	
	10	Object		10	Object	
Observations	1410			1411		
Marginal R2/Conditional R2	0.15/0.48			0.13/0.46		

Bilingual Only: Maximum and Mean Fundamental by Speech Register and Repetition Word Order

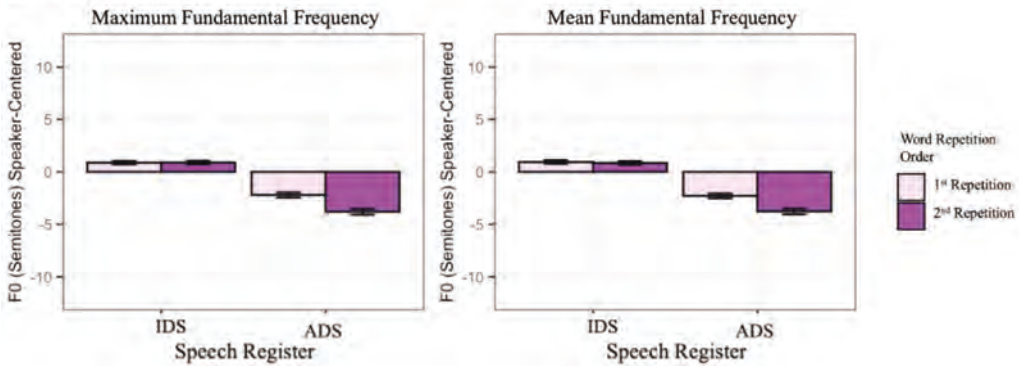


Figure 7. Bilingual parents’ word repetition pitch changes across infant-directed speech (IDS) and adult-directed speech (ADS). Maximum and mean pitch (fundamental frequency, centered within the speaker) are on the left and right plots, respectively. Error bars indicate standard error of the means (color online).

The finding that parents produced speech with elevated pitch in IDS is not surprising. Yet the way it was realized varied by language. In the current study, the Spanish-English bilingual and English monolingual participants shared some dimensions of culture (i.e., living in Northern California) and differed in others (i.e., Mexican heritage, language backgrounds). In English, there was no difference in the magnitude of the difference in IDS versus ADS pitch across monolinguals and bilinguals. However, bilinguals differed across their two languages; parents produced greater differentiation of

IDS versus ADS pitch in English than in Spanish. To our knowledge, this differentiation of IDS pitch adjustments across languages, within speakers, has not been previously demonstrated in Spanish-English bilinguals or bilinguals with other language combinations (Fish et al., 2017; Marchman & Martínez-Sussmann, 2002). At the same time, there are previous results indicating that in some language varieties, including American English, pitch may be more exaggerated in IDS than other languages (Fernald et al., 1989, see reviews by Soderstrom et al., 2008; Spinelli et al., 2017). One interpretation of the current findings is that bilingual parents use IDS features that correspond to each linguistic environment. Many bilingual parents are invested in two cultures and may use the IDS style common to each. The elevated pitch in English IDS by American bilingual parents may reflect the influence of the American English-speaking environment. Code-switching across languages or dialects can also involve cultural code-switching (Nilep, 2006, Poplack, 1988; Ritchie & Bhatia, 2012), and parents may perform this subtle shift within play sessions. Future work studying bilingual parents who have diverse cultural influences, in addition to monolingual and monocultural parents, will lead to greater understanding of how culture and language interact in bilingual families and in language acquisition.

In addition to investigating overall pitch, we tested whether local pressures – here, a first or second mention of an object label – shape speech patterns in IDS. Both groups of parents reduced pitch from the first label production to the second production in ADS, consistent with prior findings of repeated mention within languages (Fowler & Housum, 1987; Lieberman, 1963). When speaking in English to their infants, parents also showed similar reduction effects with second repetitions. However, analyses of bilingual parents' repetitions in English and Spanish revealed that parents maintained the higher pitch from first to second repetitions in IDS. While at first glance this finding appears to contradict the English-only repetition effects, bilingual speakers produced far fewer repetitions in English (337 observations) compared to monolinguals (1102 observations) and instead showed numerous instances of code-switching from English to Spanish and vice versa. The maintained pitch in bilingual parents' IDS repetitions could be part of an effort to maintain the infant's attention, particularly when changing languages. The goals of orienting and maintaining infants' attention are proposed motivations behind using elevated pitch in IDS (for review, see Spinelli et al., 2017). Furthermore, the present results show that bilingual parents are consistent in pitch adjustments when they use a single language or change languages across repetitions. It is notable that bilingual parents seem to treat changes in the phonological form of words from Spanish to English (or vice versa) as repetitions, carrying the consistent pitch across items that represent the same concept. The language mixing measure shows that Spanish-English bilinguals from this population frequently and fluently mix languages in their everyday experience with their infants. Parents from cultures who mix languages infrequently may show the effect that we initially predicted, in which bilingual parents increase pitch when repetitions of words across languages. At the same time, this finding differs from related work with Spanish-English bilingual adults, which found that adults elevate pitch at code-switched words (Olson, 2016). However, we did not analyze pitch change relative to all words adjacent to language switches (because we did not analyze non-target words), which might display the pitch pattern Olson (2016) observed.

There are several limitations to the current study findings that can serve as avenues for future research. First, the experiment does not have a Spanish-only comparison sample in IDS and ADS, it is not possible to determine whether parents' smaller IDS adjustments in Spanish than in English are characteristic of the dialect and cultural context of this Spanish-speaking population more generally, or whether the bilingual parents are strategically contrasting IDS and ADS to help infants separate the two languages. The bilingual infant group was also younger than the monolingual group by an average of 2.2 months, although the age ranges overlapped substantially. While we found no effect of infant age, there is related work showing that parents vary in IDS pitch with children of different ages (e.g., Kitamura & Burnham, 2003; Kitamura et al., 2001). Future studies tracking parents' IDS adjustments across their individual infants' development is needed to elucidate possible repetition and/or language background effects with more nuance.

Additionally, the monolingual group was not matched to the bilinguals for heritage, race, or ethnicity. All bilingual participants were Hispanic and many reported Mexican heritage, whereas none of the monolingual English-speaking parents did. Future research analyzing bilingual parent-infant dyads in comparison to monolingual English and monolingual Spanish speakers all with similar Mexican heritage backgrounds is needed to gain a fuller understanding of cultural and linguistic influences on speech style adaptations.

It would also be highly informative to examine parents' language in conversations with other familiar adults, in addition to a researcher. Analyzing conversations with familiar adults would allow for more naturalistic observations, particularly for bilinguals talking with other bilinguals in a setting where they would naturally use both languages. More broadly, examining speakers' register adaptations *across* dialectal varieties and languages, as well as probing attitudes about language use, can shed light on the social, linguistic, and cognitive factors shaping the way people talk to adults and infants. Finally, we examined parents' IDS, but the effect of IDS adjustments for the development of bilingual infants is an area for future research.

In conclusion, this experiment found that Spanish-English bilingual and English-speaking monolingual parents elevated their pitch in IDS. In English, this increase in pitch was similar across the parent groups. However, bilingual parents adjusted their pitch more from ADS to IDS in English than in Spanish and maintained the increased pitch in IDS even across repeated mentions. Taken together, these results suggest that bilingual parents produce distinct prosodic characteristics in IDS when speaking with their infants in both languages. Overall, the current study highlights the need to examine bilingual individuals in each of their languages and that, more broadly, it is crucial to explore a broad range of languages and cultures to understand the nature of how parents and infants interact.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The data that support the findings of this paper are available from the corresponding author upon reasonable request.

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