Infants' expectations about the recipients of infant-directed and adult-directed speech

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Abstract

Across cultures, adults produce infant-directed speech (IDS) when addressing infants. We explored whether infants expect IDS to be directed at infants and adult-directed speech (ADS) to adults. Infants from Spain and Turkey (12-15 months) watched animated videos with geometric figures, where one adult figure talked to an infant or another adult figure, while they were gazing at each other (Experiments 1 and 2). In some events, the adult figure addressed the infant figure with IDS, or the other adult figure with ADS (congruent); and in others, the same adult figure addressed the other adult figure with IDS or the infant figure with ADS (incongruent). Both groups of infants showed greater looking at incongruent than congruent events. This preference disappeared when the two figures gazed away from each other (Experiment 3). Thus, by 12 months of age, infants have nuanced expectations that different speech registers such as IDS and ADS are appropriate for addressing different recipients in third-party communicative contexts.

Keywords: Social cognition, infant-directed speech, communication, infancy, speech register

1. Introduction

Manner of speech is a rich source of social information, as it varies considerably depending on the recipient characteristics (e.g., Hirsh-Pasek & Treiman, 1982; Kitamura & Burnham, 2003; Uther, Knoll, & Burnham, 2007; Xu, Burnham, Kitamura, & Vollmer-Conna, 2013). A well-known example is the way adults across cultures instinctively modify their speech when addressing infants. Despite the variation in the extent of the differences between infant-directed speech (IDS) and adult-directed speech (ADS) across languages and contexts (Broesch & Bryant, 2018; Englund & Behne, 2006; Farran, Lee, Yoo, & Oller, 2016; Fernald et al., 1989; Newman, 2003), adults can reliably identify IDS and ADS (Bryant & Barrett, 2007; Fernald, 1989). Here we explore whether similar expectations regarding the recipients of IDS and ADS are present in infants.

Communicative signals tend to differ depending on the qualities of the communication partners and the context in which communication occurs. For instance, adults use distinct speech registers when talking to foreigners (e.g., Uther et al., 2007), to their pets (e.g., Burnham, Kitamura and Vollmer- Conna 2002; Hirsh-Pasek & Treiman, 1982), and to infants (e.g., Stern, Spieker, Barnett, & MacKain, 1983). Infant-directed speech is a widely studied phenomenon, where speech tends to have higher pitch, greater pitch variation, greater positive affect, slower speed, and shorter utterances, in comparison to adult-directed speech (Fernald et al., 1989; Fernald, 1992; Fernald & Kuhl, 1987; Kitamura & Burnham, 2003). Adults from diverse cultures engage in this type of communication style when addressing infants and they can correctly identify whether the speech they hear addresses an infant or an adult, even in languages they are not familiar with (Bryant & Barrett, 2007; Fernald, 1989). Developmental studies suggest that children as young as 2 years of age tend to modify their speech when addressing younger recipients (Dunn & Kendrick; 1982; Sachs & Devin, 1976; Shatz & Gelman; 1973) and expect speech register to change depending on the listeners' age (Ikeda,

Kobayashi, Itakura, 2018; Wagner, Vega-Mendoza, Van Horn, 2014).

A number of functions have been attributed to the use of IDS. For instance, it has been suggested that IDS serves to elicit infants' attention (Fernald & Simon, 1984; Werker & McLeod, 1989) and to communicate affective intentions (Fernald, 1989; 1992). Others have argued that IDS might facilitate language acquisition by helping infants discriminate vowel categories (Kuhl et al., 1997; Trainor & Desjardins, 2002), learn grammar (Christophe, Nespor, Guasti, & Van Ooyen, 2003), segment words (Thiessen, Hill, & Saffran, 2005), and learn word-object pairings (Graf-Estes & Hurley, 2013). IDS is also argued to serve as a pedagogical signal that is available to infants, informs them about an upcoming teaching episode, and prepares them for learning (Csibra & Gergely, 2006). Other purposes that emphasize the social nature of this communication style have also been proposed. It has been suggested, for instance, that IDS might facilitate face–voice associative learning (Kaplan, Jung, Ryther, & Zarlengo-Strouse, 1996), help attaining vocal social convergence when communicating with infants (Kalashnikova, Carignan & Burnham, 2017), and enable infants to identify appropriate teachers or social partners (Schachner & Hannon, 2011).

IDS and ADS elicit different ERP responses even in newborn infants (Háden, Mády, Török, & Winkler, 2020) and several studies have shown that infants from different cultural backgrounds exhibit a robust preference for infant directed vocalizations. Infants' preference has been shown across different ages and languages (Cooper, Abraham, Berman, & Staska, 1997; Cooper & Aslin, 1990; 1994; Fernald, 1985; Hayashi, Tamekawa, & Kiritani, 2001; Masataka, 1999; Pegg, Werker, & McLeod, 1992; Werker & McLeod, 1989). Infants prefer IDS regardless of the speaker's gender (e.g., Pegg et al., 1992; Werker & McLeod, 1989) and language (e.g., Hayashi et al., 2001; Werker, Pegg, & McLeod, 1994), even preferring IDS when a foreign language is contrasted with ADS in a familiar language (Fernald & Morikawa, 1993). Hearing newborn infants of deaf mothers with presumably minimal exposure to this

communication style, nevertheless exhibit a preference for ID over AD singing, suggesting that prenatal exposure may not be necessary to elicit the preference for infant-directed vocalizations (Masataka, 1999).

While previous research has established that infants are sensitive to IDS, to date it is not known whether infants expect to be addressed with IDS or have a general expectation that people use IDS when addressing infants and they use ADS when addressing adults in third party contexts. From early in life, infants not only are sensitive to the communicative cues such as gaze, speech or gestures that are directed at them (e.g., Aureli, Perucchini, & Genco, 2009; Esteve-Gibert, Prieto, & Liszkowski, 2017; Farroni, Csibra, Simion, & Johnson, 2002; Fernald, 1985; Senju, & Csibra, 2008; Vouloumanos & Werker, 2007) but also show an understanding of the signals that are indicative of communication between third parties. Pre-linguistic infants expect native (Martin, Onishi, & Vouloumanos, 2012; Vouloumanos, Martin, & Onishi, 2014; Vouloumanos, Onishi, & Pogue, 2012) and even non-native speech (Vouloumanos, 2018) to transfer information from one person to another. For instance, after having seen an agent repeatedly picking up one object, infants as young as 6 months expect a novel agent, who had not witnessed the first agent's choice, also to pick up the same object, but only if she was addressed by the first agent uttering a nonsense word to a recipient (Martin et al., 2012; Vouloumanos, 2018). By 10 months of age, infants expect an agent to direct his or her gaze and speech to an agent rather than an object, and they expect agents who engage in a conversation to also engage in mutual gaze (Beier & Spelke, 2012). When shown two individuals facing each other and one directs speech to the other, one year-old infants form an expectation that the other party will respond (Thorgrimsson, Fawcett, & Liszkowski, 2015). Similar expectations are not observed when agents are not facing each other, or when one party produces non-speech sounds (Thorgrimsson, et al., 2015).

Building on these findings pointing to an early developing sensitivity to the

communicative signals between third parties, the present research asks whether infants expect that different communication styles such as IDS and ADS are appropriate for addressing different recipients in third-party contexts, and if so, whether these expectations depend on infants' familiarity with the language, the speech is produced in. In order to examine infants' expectations regarding whom IDS and ADS should be directed at, we measured infants' attention to communicative and non-communicative events between third parties featuring animated geometric shapes of different sizes[1]. Such computer-animated events allow portraying social events in a simplified way as well as having greater control over various aspects of the stimuli presentation. Previous research using similar events involving shapes with facial features (e.g., eyes) and/or self-propelled motion suggests that infants readily make social inferences based on such events (Hamlin, Wynn, & Bloom, 2007; Johnson, Dweck, & Chen, 2007; Kuhlmeier, Wynn, & Bloom, 2003; Mascaro & Csibra, 2012; Powell & Spelke, 2013; Spokes & Spelke, 2017; Thomsen, Frankenhuis, Ingold-Smith, & Carey, 2011). Previous research also suggests that infants between 12 and 16 months of age infer caregiving interactions between two animated, different-sized characters (Johnson et al., 2007; Spokes & Spelke, 2017). While speech is uniquely-human and infants generally see and expect human agents to produce speech sounds (e.g., Athena Vouloumanos, Druhen, Hauser, & Huizink, 2009), previous research suggests that infants are willing to accept puppets of different animals to produce speech sounds (e.g., Buyukozer Dawkins, Sloane, & Baillargeon, 2019; Stavans & Baillergeon, 2019), and they readily perceive novel artificial sounds as produced by humans when exposed to them in a communicative context (e.g., Ferguson & Waxman, 2016). Previous studies using comparable animated figures that were associated with artificial sounds (e.g., Powell & Spelke, 2013, 2018) and biological sounds (Johnson et al., 2007; Spokes & Spelke, 2017) including speech (Margoni, Baillargeon, & Surian, 2018) suggest that these sounds are perceived by infants as generated by these animated shapes.

2. Experiment 1

Experiment 1 examined whether 12-15 months old infants hold different expectations regarding the recipients of infant-directed and adult-directed speech. This age group was chosen because infants of this age are shown by previous research to make social attributions based on animated characters similar to the ones used in the current experiments (Johnson et al., 2007). Monolingual Spanish or Catalan hearing infants were presented with animation videos, where they were introduced to three novel characters (See Figure 1). Two of these characters represented adults and one represented an infant, distinguished by their vocalizations and their size (e.g., Johnson et al., 2007; Spokes & Spelke, 2017). Infants then saw either two adult characters or one adult and one infant character facing each other and the same adult character produced either IDS or ADS when communicating with the other character. Speech segments were either in Spanish or Catalan depending on the language mothers used when interacting with their infants. Infants' attention to these events were measured, as a window into their expectations.

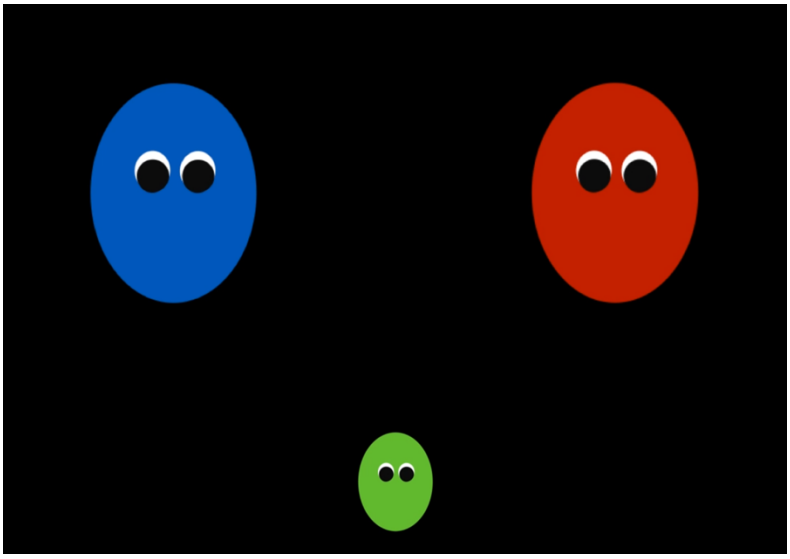

Figure 1. Example scene from familiarization trials featuring two adult characters (blue and red) and one infant character (green) used in all Experiments.

2.1 Method

2.1.1 Participants: Eighteen full term (≥ 37 weeks) and healthy infants (10 girls; mean age: 13 months, 14 days; range 12 months, 1 day - 14 months, 28 days) were participants in Experiment 1. Infants came from families where mothers spoke to their infants mainly in Spanish (6) or Catalan (12). Twelve infants were reported to be exposed to a second language including Catalan (6) and Spanish (6). Four additional infants were tested but were excluded from the final sample due to fussiness. To ensure that infants heard the speech stimuli sufficiently on each test trial, we also excluded infants who did not attend to the test videos for at least 2 seconds. One infant was excluded for this reason. Ethics approval was obtained from the Institutional Review Board at Universitat Pompeu Fabra. Before their participation, parents gave informed consent and they received partial travel reimbursement, a small gift and a participation certificate for their infants.

2.1.2 Stimuli: Familiarization stimuli consisted of three 41 seconds long animation videos and test stimuli consisted of sixteen 38 seconds long animation videos. All videos were created using Keynote software.

The familiarization videos started with a yellow rectangular shaped figure (14 cm X 7 cm) that was positioned in the middle of the display against a uniform black background, rotating along with a chime sound and then disappearing (3 sec). Following this introduction, two big (13,5 cm X 10 cm) and one small (6 cm X 4 cm) oval figure with eyes facing forward, entered the display one by one. The big figures were red and blue, and the small figure was green. The red figure appeared from the upper right side, the blue figure appeared from the upper left side and the green figure appeared from the bottom (15 sec). The figures then approached each other by moving towards the center of the screen and jiggled in synchrony with each other along with a bongo sound (7 sec). Then the figures moved back to

their original positions (4 sec) and one of the figures pulsed for about 5 seconds along with a laughter sound that belonged to an adult or an infant. Following this, the figures approached each other and jiggled again (7 sec). Across three familiarization videos, the side from which each figure appeared from was kept constant, however the order of their appearance varied. In each video, the figure that appeared the last, pulsed along with the laughter sound.

In the test videos, the red figure and one of the other figures were presented next to one another with both figures' eyes gazing at each other (1 sec), positioned at the center of the display. The figure on the right (the red figure) pulsed for about 5 seconds along with different speech stimuli consisting of AD or ID utterances in Spanish or in Catalan, depending on the native language of the infant. Next, the two characters remained silent and stationary for about 32 seconds. The speech stimuli were recorded by a female bilingual adult, who was a native speaker of both languages. The speaker was instructed to utter a number of predetermined sentences as if she was interacting with a baby or with an adult. The content of these sentences was varied in an attempt to mimic naturalistic conversations with infants and adults. These sentences are provided in the supplementary materials on the OSF page. Previous studies similarly simulated IDS and ADS showed that, adults perceive simulated IDS as more infant directed, and infants not only show preference for IDS (Cooper & Aslin, 1990) but also for agents who produce it (Schachner & Hannon, 2011). In the present study, IDS samples had higher mean fundamental frequency ($t(6) = 13.95$, $p < .001$) and greater pitch range ($t(6) = 5.52$, $p = .001$) (Spanish: $M_{F0} = 314.16$. Hz, $SD_{F0} = 82.81$ Hz; Catalan: $M_{F0} = 295.5$ Hz, $SD_{F0} = 89.85$ Hz) than did ADS samples (Spanish: $M_{F0} = 205.36$ Hz, $SD_{F0} = 48.08$ Hz; Catalan: $M_{F0} = 202.91$. Hz, $SD_{F0} = 39.97$ Hz), paralleling main acoustic differences between natural IDS and ADS (Fernald & Kuhl, 1987). Spanish and Catalan samples did not differ from one another on these dimensions ($ps > .7$). A group of adults (N = 8 [4 females], $M_{age} = 25.87$ years, $SD = 2.16$ years) whose native language was Turkish and who had no

knowledge of Spanish or Catalan rated these utterances in terms of their affective valence (1: positive, 7: negative), affective intensity (1: low, 7: high) and affective register (1: infant-directed, 7: adult-directed) on a scale of 1 to 7. ID utterances in Catalan were rated as affectively more positive (M = 2, SD = .89), more intense (M = 4.50, SD = 1.59) and more infant-directed (M = 2.31, SD = 1.14) compared to AD utterances (valence: M = 4.75, SD = .85; intensity: M = 2.94, SD = 1.39; register: M = 6.5, SD = .82) (All ps ≤ .003). Similarly, ID utterances in Spanish were rated as affectively more positive (M = 1.50, SD = 1.21), more intense (M = 4.69, SD = 2.09) and more infant-directed (M = 2, SD = 1.37) compared to AD utterances (valence: M = 4.63, SD = .88; intensity: M = 2.75, SD = 1.29; register: M = 6.56, SD = .73) (All ps ≤ .006). Spanish and Catalan samples did not differ from one another in terms of the ratings they received for the ID utterances (All ps > .16) or for the AD utterances (All ps > .56).

2.1.3 Design and Procedure: Testing took place at the CBC Babylab at Universitat Pompeu Fabra in Barcelona, Spain. Each infant was seated on a parent's lap in a softly lit, soundproofed testing room. A 27" monitor was located in front of the infant, at an approximately 70 cm distance. Two loudspeakers were hidden centrally behind the monitor. A hidden camera located above the monitor recorded infants' attention to the events shown on the monitor. Parents were instructed not to speak or intervene, and they listened to music over noise-cancelling headphones throughout the experiment.

Each trial started with a flashing red screen to direct infants' attention to the display. Infants first saw the three familiarization videos. The trial durations were fixed and lasted for 41 seconds each. After the familiarization phase, infants received 8 infant-controlled test trials (2 blocks). The trials were terminated if the infant looked away from the display for more than 2 seconds or if 38 seconds had elapsed. Half of the trials were "congruent", such that infants saw the adult character addressing the infant character with IDS, or the other adult

character with ADS (See Figure 2a and 2b). The other half of the trials were "incongruent", such that infants saw the adult character addressing the infant character with ADS, or the other adult character with IDS (See Figure 2c and 2d). Depending on their native language, infants saw videos featuring voice recordings in Spanish or Catalan.

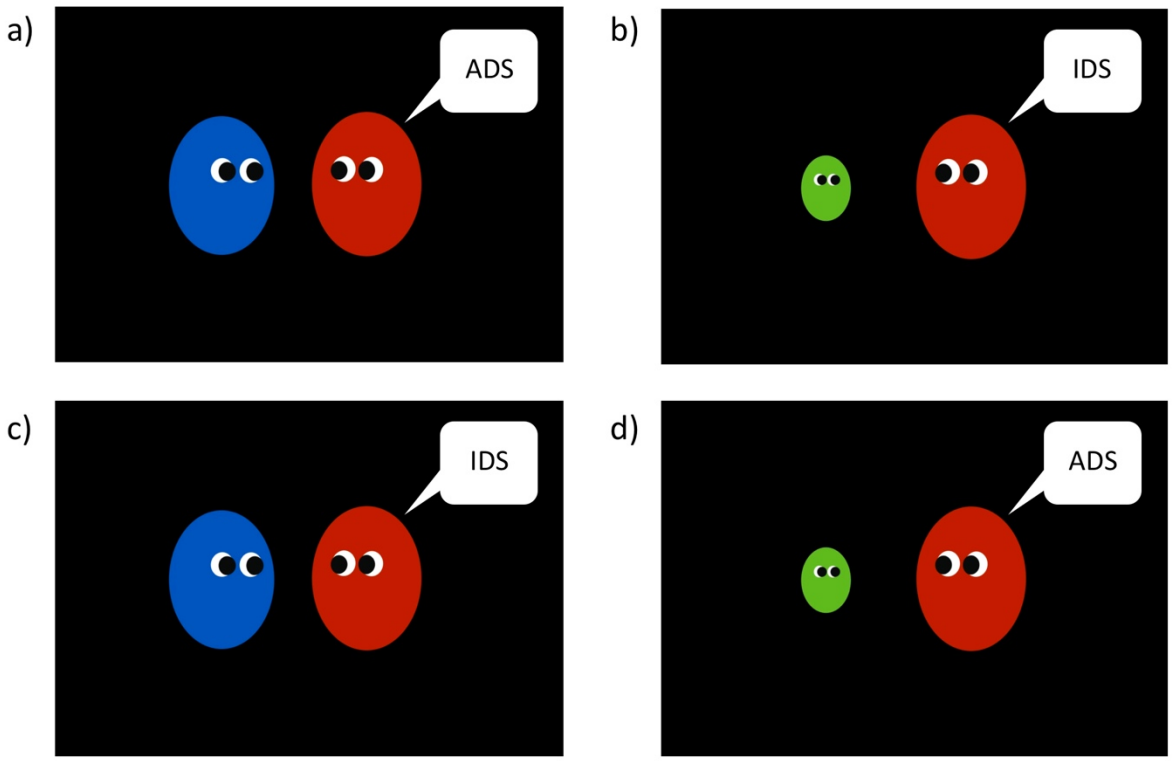

Figure 2. Example scenes from congruent (Figures 2a and 2b) and incongruent test trials (Figures 2c and 2d) in Experiments 1 and 2.

The order of the familiarization videos was kept constant across infants. The presentation order of congruent and incongruent videos and the speech register (IDS vs. ADS) during the test phase were counterbalanced across infants, yielding four different conditions. Speech style alternated in ABAB order (e.g., IDS-ADS-IDS-ADS) and congruency alternated in ABBA order (e.g., C-I-I-C) across trials. The presentation orders of the first and the second blocks were identical, however, infants saw a different set of videos in the second block, as each speech stimulus was paired once with a congruent animation, and once with an

incongruent animation. Within each condition, the presentation order of the videos featuring different speech stimuli was randomly assigned to each participant.

A blind observer recorded infants' looking times using Habit software v. 2.1.21 (Oakes, Sperka, & Cantrell, 2015) from an adjacent room. Another blind observer performed frame-by-frame coding of looks using Supercoder v.1.5 (Holich, 2005), and these off-line measurements were used for the analyses.

2.2 Results and Discussion

Fixation times were log-transformed and all parametric tests were performed on these values (Csibra, Hernik, Mascaro, & Tatone, 2016). A preliminary analysis revealed no difference with regard to language (Spanish vs. Catalan) (*p*s > .3), therefore we dropped language from subsequent analyses. A repeated measures ANOVA with Congruency (congruent vs. incongruent), Speech Register (IDS vs. ADS), and Block (first vs. second) as within-subjects factors revealed an effect of Block ($F(1, 17) = 4.98$, $p = .039$, $\eta_p^2 = .22$), suggesting that infants fixated longer during the first block ($M = 15.78$ s, $SD = 5.99$ s) compared to the second block ($M = 12.56$ s, $SD = 3.21$ s). There was also a significant effect of Congruency ($F(1, 17) = 5.33$, $p = .034$, $\eta_p^2 = .24$), suggesting that infants fixated longer at incongruent events ($M = 14.80$ s, $SD = 4.69$ s) compared to congruent events ($M = 13.54$ s, $SD = 4.18$ s). The results also yielded a significant interaction between Block and Congruency ($F(1, 17) = 6.97$, $p = .017$, $\eta_p^2 = .29$). None of the other main effects and interactions were significant (All *p*s > .16). Analyses following up on the interaction effect revealed that while infants' fixations at incongruent ($M = 15.07$ s, $SD = 7.04$ s) and congruent events ($M = 16.49$ s, $SD = 6.14$ s) did not differ during the first block ($t(17) = 1.41$, $p = .18$, $d = .33$), infants attended significantly longer at incongruent compared to congruent events during the second block (Incongruent: $M = 14.53$ s, $SD = 4.8$ s, Congruent: $M = 10.6$ s, $SD = 3.32$ s, $t(17) = -3.32$, $p = .004$, $d = .78$). (See Figure 3a). The means and the standard deviations of infants'

looking times at the congruent and incongruent test trials are provided separately for each speech register in Table 1.

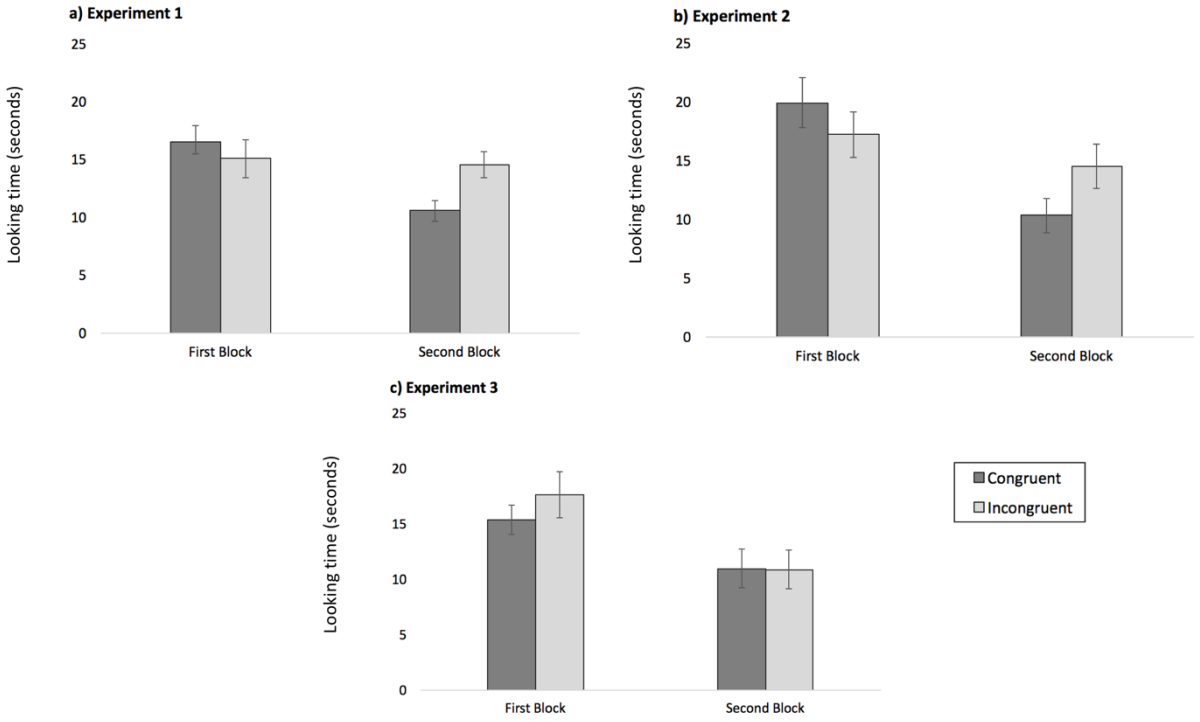

Figure 3. Mean looking times at congruent and incongruent test events in Experiment 1 (Figure 3a), in Experiment 2 (Figure 3b) and in Experiment 3 (Figure 3c). Error bars represent standard error.

Table 1. Mean looking times at congruent and incongruent test events reported separately for trials in which infants heard IDS and ADS.

		Block 1				Block 2			
		IDS		ADS		IDS		ADS	
		C	I	C	I	C	I	C	I
Exp 1	*M* (s)	14.63	14.22	18.36	15.92	10.95	14.07	10.24	14.98
	SD	8.24	7.42	11.11	8.85	4.13	3.95	5.19	10.04
Exp 2	*M* (s)	20.22	18.24	19.60	16.14	10.64	14.56	10.00	14.45
	SD	10.13	10.03	10.69	9.96	6.20	8.71	6.78	9.94
Exp 3	*M* (s)	16.73	18.39	13.89	16.82	11.58	10.45	10.29	11.21
	SD	6.78	10.03	8.60	10.01	5.97	8.61	9.79	7.62

These findings suggest that infants have expectations regarding whom IDS and ADS should be directed to and they find it more surprising when IDS is directed to an adult figure and when ADS is directed to an infant figure than vice versa. The results also revealed that infants' greater looking at the incongruent events was only apparent during the second block. This might be due to familiarization and test trials being rather different: Because infants saw the characters speaking for the first time during the test trials, the speech registers may not have been adequately processed during the first block, leading to the emergence of greater looking at the incongruent events only during the second block.

While infants exhibited greater looking at incongruent compared to congruent events during the second block, suggesting that they might identify IDS as more infant-appropriate and ADS as more adult-appropriate, it is not clear which properties of speech elicited this effect. In Experiment 1, in an attempt to create more natural stimuli, the content of the speech was varied along with the speech register (IDS vs. ADS). Accordingly, infants' looking patterns might have been driven by the prosodic characteristics of IDS and ADS as well as by their contents. In the next experiment, we aimed to test whether the prosodic characteristics of IDS and ADS are enough to elicit similar expectations in infants. Using the same stimuli and procedure as in Experiment 1, we tested Turkish-learning infants, who are not familiar with Spanish or Catalan.

3. Experiment 2

3.1 Method

3.1.1 Participants: Seventeen full term and healthy infants (6 girls; mean age: 13 months, 11 days; range 12 months, 5 days - 14 months, 25 days) were included in the final sample of Experiment 2. Infants came from families where the mothers spoke to their infants mainly in Turkish. Among these infants, 10 were reported to be exposed to a second language including

English (6), Russian (3) and Kurdish (1). Eight additional infants were tested but were eliminated from the final sample due to fussiness (1), parental interference (3), equipment failure or experimenter error (2), or not meeting the minimum fixation criterion on one or more test trials (2). All infants were tested at the Baby and Child Development Laboratory at Bogazici University, Istanbul, Turkey. Ethics approval was obtained from the university ethics review board. Before their participation, parents gave informed consent and they received a small gift and a participation certificate for their infants.

3.1.2 Stimuli: These were identical to Experiment 1, except that all infants were tested with videos featuring speech stimuli in Catalan used in Experiment 1.

3.1.3 Design and Procedure: These were identical to Experiment 1.

3.2 Results

As in Experiment 1, fixation times were log-transformed and all parametric tests were performed on these values. A repeated measures ANOVA with Congruency (congruent vs. incongruent), Speech Register (IDS vs. ADS), and Block (first vs. second) as within-subjects factors revealed a significant effect of Block ($F(1, 16) = 16.37$, $p = .001$, $\eta_p^2 = .5$), suggesting that infants fixated longer during the first block ($M = 18.55$ s, $SD = 7.59$ s) compared to the second block ($M = 12.41$ s, $SD = 5.90$ s). The analysis also yielded a significant interaction between Block and Congruency ($F(1, 16) = 8.78$, $p = .009$, $\eta_p^2 = .35$). None of the other main effects and interactions were significant (All ps > .17). Analyses following up on the interaction effect revealed that while infants' fixations at incongruent ($M = 17.19$ s, $SD = 7.97$ s) and congruent events ($M = 19.91$ s, $SD = 8.56$ s) did not differ during the first block ($t(16) = 1.81$, $p = .089$, $d = .43$), infants attended significantly more to incongruent ($M = 14.51$ s, $SD = 7.82$ s) compared to congruent events ($M = 10.32$ s, $SD = 5.98$ s) during the second block $t(16) = -2.81$, $p = .012$, $d = .68$) (See Figure 3b).

A mixed ANOVA with Congruency (congruent vs. incongruent), Speech Style (IDS vs. ADS), and Block (first vs. second) as within-subjects factors and Experiment (Experiment 1 vs. 2) as the between subjects factor yielded a main effect of Block ($F(1, 33) = 21.52$, $p < .001$, $\eta_p^2 = .39$), as, overall, infants fixated longer during the first block compared to the second block. We found a significant effect of Congruency ($F(1, 33) = 5.42$, $p = .026$, $\eta_p^2 = .14$) and a significant interaction between Block and Congruency ($F(1, 33) = 15.88$, $p < .001$, $\eta_p^2 = .32$), suggesting that infants' greater looking at incongruent compared to congruent events was essentially driven by infants' fixations during the second block across Experiments 1 and 2. We also found a significant interaction between Block and Experiment ($F(1, 33) = 4.24$, $p = .047$, $\eta_p^2 = .11$), elicited by the block effect being stronger in Experiment 2 compared to in Experiment 1. All other main effects and interactions were non-significant (All ps > .24).

3.3 Discussion

Closely paralleling the results of Experiment 1, in Experiment 2, infants exhibited greater looking at incongruent events compared to congruent events during the second block, suggesting that they expected IDS to be directed at the infant figure and ADS to be directed to the adult figure, even when the speech was not in their native language. The combined results of Experiments 1 and 2, thus, suggest that the prosodic properties of IDS and ADS are sufficient to elicit infants' expectations regarding whom these speech registers should address. One possibility that arises from these results is that infants' expectations are driven by an association between higher pitch vocalizations and small agents and vice versa. Across different species, body-size is inversely related to the frequency of the vocalizations, such that smaller animals tend to produce higher-pitched vocalizations (Bowling et al., 2017; Morton, 1977), and infants as young as 3 months are sensitive to this relationship (Pietraszewski, Wertz, Bryant, & Wynn, 2017). While in the present studies, the agent who produced speech

was always the same size, the agent that was addressed differed in size. Accordingly, infants' looking times might be driven by an expectation to simply see a smaller agent when listening to a higher-frequency sound, and a larger agent when listening to a lower-frequency sound. To probe this prediction, a final experiment was conducted. In this experiment, Turkish-learning infants saw the same videos, except that the characters, even though were presented side by side as before, did not gaze at each other. Previous research suggests that by 10-months of age, infants discriminate between two individuals who engage in mutual gaze versus averted gaze, and expect individuals to gaze at their social partners when they engage in a conversation with them (Beier & Spelke, 2012). Thus, if infants' expectations are driven by an association of small agents and high-pitched sounds, then the results of Experiment 3 should be similar to the results of Experiment 2. If, on the other hand, infants' looking times are driven by their expectations regarding whom IDS and ADS should address, the looking time patterns should differ from the previous experiments, given that in this case, the agents did not gaze at each other, suggesting that the character who produced speech did not direct it at the other character.

4. Experiment 3

4.1 Method

4.1.1 Participants: Seventeen full term and healthy infants (7 girls; mean age: 13 months, 6 days; range 12 months, 3 days - 14 months, 14 days) were participants in Experiment 3. Infants came from families where the mother spoke to the infant mainly in Turkish. Among these infants, 6 were reported to be exposed to other languages, including English (2), Russian (1), Serbian (1), Kurdish (1) and Bulgarian (1). Five additional infants were tested but were eliminated from the final sample due to fussiness (3), parental interference (1), or not meeting the minimum fixation criterion on one or more trials (1). All infants were tested

at the Baby and Child Development Laboratory at Bogazici University, Istanbul, Turkey. Before their participation, parents gave informed consent and they received a small gift and a participation certificate for their infants.

4.1.2 Stimuli: The stimuli were identical to Experiment 2 with the following exception: The test videos featured characters that gazed away from each other (See Figure 4)[2].

4.1.3 Design and procedure: They were identical to Experiments 1 and 2.

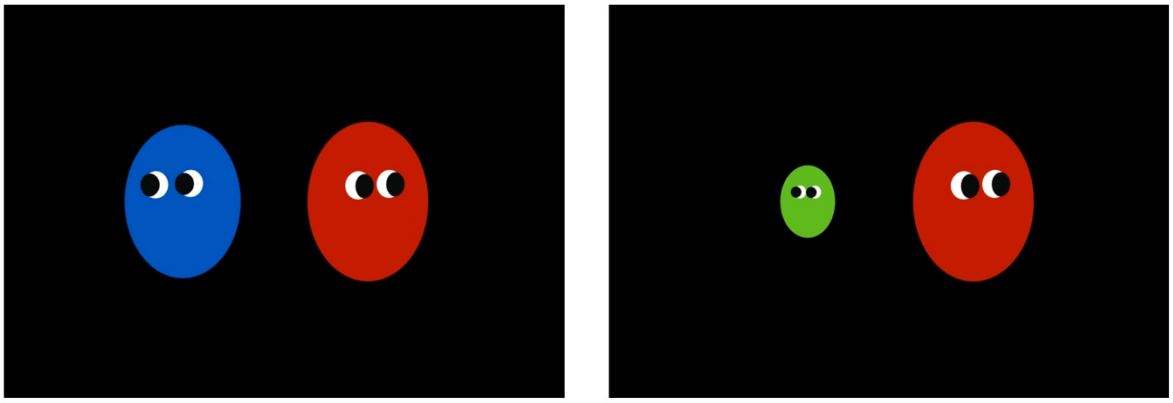

Figure 4. Example scenes from test trials in Experiment 3.

4.2 Results and Discussion

A repeated measures ANOVA with Congruency (congruent vs. incongruent), Speech Register (IDS vs. ADS), and Block (first vs. second) as within-subjects factors revealed an effect of Block ($F(1, 16) = 27.17$, $p < .001$, $\eta_p^2 = .62$), suggesting that infants fixated longer during the first block ($M = 16.46$ s, $SD = 5.38$ s) compared to the second block ($M = 10.88$ s, $SD = 6.84$ s). The other main effects and interactions were not significant (All ps $> .09$) (See Figure 3c).

Finally, data were compared across Experiments 2 and 3 using a mixed ANOVA with Congruency (congruent vs. incongruent) and Block (first vs. second) as within-subjects factors and Experiment (Experiment 2 vs. 3) as the between subjects factor.[3] As Speech Register did not yield any significant main effects nor interactions with any of the other

variables in previous analyses, it was dropped from this analysis. We found a main effect of Block ($F(1, 32) = 38.08$, $p < .001$, $\eta_p^2 = .54$) and a three-way interaction between Block, Congruency, and Experiment ($F(1, 32) = 7.01$, $p = .012$, $\eta_p^2 = .18$), driven by the interaction between Block and Congruency being significant in Experiment 2, but not in Experiment 1. All other main effects and interactions were non-significant (All ps > .09).

The results of Experiment 3 show that infants' greater looking at incongruent events disappeared when speech was produced in a non-communicative context. Thus, infants' expectations that IDS should address infants and ADS should address adults are unlikely to be guided by their associations of small agents with high-pitched sounds and vice versa.

5. General Discussion

The present research examined infants' expectations regarding whom IDS and ADS should address in communicative third-party contexts. The results show that infants looked longer to incongruent events in which an adult character either produced IDS when addressing another adult character or produced ADS when addressing an infant character, compared to congruent events where the same adult character addressed an infant with IDS or an adult with ADS. These looking patters were not influenced by whether the speech was in infants' native language or not. Further, infants' greater looking to incongruent events was no longer observed if IDS and ADS were not produced in a communicative context, that is, when figures did not gaze at each other. Together, these findings suggest that around the age of one year, infants expect infant-directed speech to address infants and adult-directed speech to address adults, in third-party communicative contexts. Further, infants' expectations are not driven by the semantic content of speech, but rather by its acoustic properties.

The design of the present studies allows us to rule out a number of alternative explanations that could potentially account for infants' looking time patterns. Because the

visual displays for congruent and incongruent trials were identical, the looking patterns cannot be explained by factors such as more information being presented on the display. Further, because infants looked longer at the displays, when they heard IDS in combination with the two adult characters, and when they heard ADS in combination with one adult and one infant character, the results are also unlikely to be driven by infants' mere preference for IDS over ADS. Finally, the results further show that infants' looking patterns only hold when speech is produced in a communicative context, indicating that they are not driven by infants' associations of higher pitch with smaller agents and vice versa.

Across two experiments, we consistently found that infants' expectations have become apparent in the second block of the test trials. As said, this effect is likely to be driven by familiarization and test trials being rather dissimilar. Because familiarization trials introduced each character, but did not involve any speech stimuli, infants possibly needed some time to process different speech registers during the first block of test trials. Thus, the emergence of greater looking at the incongruent events during the second block could be explained by the additional processing load in the first block. Future research could examine this possibility using a habituation paradigm, where infants are habituated to an agent speaking and are shown the addressee in subsequent test trials.

The current experiments used animated videos in an attempt to have greater control over various aspects of the stimuli across conditions. These videos allowed us, for instance, to swap the sound clips between different conditions or to eliminate mutual gaze while keeping various other aspects of the displays (e.g., agents' facial expressions, movements etc.) constant. Given these, the contrasting looking patterns in Experiments 1-2 and 3 are notable: The adult character was perceived as communicating with the infant character when the characters gazed each other, but not when the characters gazed away from each other. These findings provide further support for the significance of mutual gaze in triggering expectations

about communicative behavior (Beier & Spelke, 2012; Thorgrimsson et al., 2015) by showing that the removal of mutual gaze suffices to eliminate infants' expectations about communication between third parties, even in these highly simplified animated events. It is also important to note, however, that because the current experiments used animated shapes, they leave open the question of whether infants' expectations are indeed about different speech registers addressing adults and infants. It is, therefore, important for future research to examine infants' expectations using human agents.

These findings might have implications regarding what function(s) IDS may serve and they may be particularly relevant to functions that are social in nature. The results suggest that by their first birthday, infants have already formed expectations that, in communicative contexts, individuals produce recipient-appropriate speech registers. Thus, speech manner seems to provide a social cue that is available to infants, that would not only allow them to notice when someone addresses them, but also to infer whom someone might be addressing to in third party contexts. These findings contribute to a growing body of evidence showing infants' early emerging understanding of communicative interactions between third parties (Beier & Spelke, 2012; Martin et al., 2012; Thorgrimsson, et al., 2015; Vouloumanos, 2018) and extend them by showing infants' nuanced expectations regarding the nature of such communicative interactions. Beyond their implications for infants' understanding of different speech manners, the present results, thus, provide a basis for further investigating the developmental origins of social reasoning. Future studies should explore whether infants at this age also use speech register to make inferences about an agent's social interactions with other agents. Previous research suggests that infants prefer to gaze at a familiar individual if that person previously produced IDS when communicating with the infant, whereas they prefer to gaze at an unfamiliar individual, if the familiar individual previously produced ADS in a similar context (Schachner & Hannon, 2011). These results were interpreted as IDS

functioning as a cue for choosing proper social partners, who would be willing to produce infant-appropriate vocalizations (Schachner & Hannon, 2011). Future studies can explore whether infants have similar expectations in third-party contexts, and anticipate, for instance, agents to be affiliated with those who produce recipient-appropriate vocalizations.

These findings raise important questions concerning the mechanisms by which infants' expectations are formed. Our findings show that infants have formed expectations not only about the recipients of IDS, but also the recipients of ADS, suggesting that their expectations are not formed based solely on their own experiences, but also on their observations of interactions between adults. Infants might develop these expectations as they get exposed to different speech registers when others around them communicate with infants and adults. If so, infants' expectations might differ depending on the extent to which the adults in their environments produce IDS. It will be important for future research to ask when infants' expectations regarding whom IDS and ADS should address, would be evident in development. As mentioned in the introduction, IDS preference is evident in infants shortly after birth (Cooper & Aslin, 1990; Pegg et al., 1992). On the other hand, some studies also suggest interesting developmental changes in infants' responsiveness to IDS (Cooper et al., 1997; Cooper & Aslin, 1994; Hayashi et al., 2001; Kitamura & Lam, 2009; Werker & McLeod, 1989). A recent large-scale cross-cultural study revealed, for instance, that IDS (North-American English) preference becomes stronger with age: Infants exhibit greater IDS over ADS preference when they are around 12 months compared to when they are 4 months of age (Frank et al., in press, but also see Newman & Hussain, 2006). Together these studies highlight the fact that testing younger infants using a similar paradigm will be informative about the developmental course of infants' expectations about ID and AD communications, and about the role of exposure to such communication styles in guiding infants' social inferences.

Another interesting future direction will be to explore infants' social inferences based on different means of communication. The recipient characteristics not only change speech manner but also the manner of different communicative cues, such as singing (Trehub, Unyk, Trainor, 1993), facial gestures (Chong, Werker, Russell, & Carroll, 2003), or actions (Brand, Baldwin, & Ashburn, 2002). Further, similar modifications in infant-directed vocalization are observed in other animals, suggesting that they are not unique to humans (Chen, Matheson, & Sakata, 2016; Luef & Liebal, 2012; Whitham, Gerald, & Maestripieri, 2007). Future studies could explore whether infants' sensitivity is limited to speech and to humans, or whether they have expectations regarding these different means of communications as well. Such studies would shed further light on the role of experience in infants' sensitivity to ID and AD communications.

Infants' expectations regarding the recipients of IDS and ADS point to the social importance of these different communication styles and suggest that, from early on, the acoustic cues that are associated with these different speech registers are available to infants and guide their social expectations.

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Footnotes

[1]All materials and data are available at https://osf.io/mhtw8/

[2]The two large characters were placed slightly closer to each other than the large and the small characters in Experiments 1 and 2. In Experiment 3, these distances were the same. After carefully considering possible ways in which this slight difference could have affected the pattern of results in the current experiments, we have concluded that it could not account for the incongruency preference to be evident in Experiments 1 and 2 and not in Experiment 3.

[3]The same pattern of results is observed when data from Experiments 1 and 2 are collapsed.