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Who's My Little Monkey? Effects of Infant-Directed Speech on Visual Retention in Infant Rhesus Macaques

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Abstract

Both human and nonhuman primate adults use infant-directed facial and vocal expressions across many contexts when interacting with infants (e.g. feeding, playing). This infant-oriented style of communication, known as infant-directed speech (IDS), seems to benefit human infants in numerous ways, including facilitating language acquisition. Given the variety of contexts in which adults use IDS, we hypothesized that IDS supports learning beyond the linguistic domain and that these benefits may extend to nonhuman primates. We exposed 2.5-month-old rhesus macaque infants ($N=15$) to IDS, adult-directed speech (ADS), and a nonsocial control (CTR) during a video presentation of unrelated stimuli. After a 5- or 60-minute delay, infants were shown the familiar video side-by-side with a novel video. Infants exhibited a novelty preference after the 5-minute delay, but not after the 60-minute delay, in the ADS and CTR conditions, and a novelty preference in the IDS condition only after the 60-minute delay. These results are the first to suggest that exposure to IDS affects infants' long-term memory, even in non-linguistic animals.

Key terms

motherese; learning; vocalization; eye tracking; visual paired comparison; habituation; comparative psychology

When people speak to infants, they often use a style of speech known as motherese or infant-directed speech (IDS). This speech style differs from adult-directed speech (ADS), which is used when addressing older children or adults, in that it includes fewer words per utterance, more repetition, better articulation, and an overall decreased structural complexity (Cooper & Aslin, 1990; Fernald et al., 1989). IDS also differs from ADS in its prosodic qualities, which include higher overall pitch, more frequent pitch glides, more distinctive pitch contours, increased emphatic stresses, longer pauses, and slower tempos (Cooper & Aslin, 1990; Soderstrom, 2007). All of these features combine to create a unique and melodic speaking style.

IDS plays an important role in at least three distinct but related areas of development. It has been proposed that IDS (1) captures infant attention (Cooper & Aslin, 1990; Fernald &

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Kuhl, 1987; Fernald et al., 1989; Werker & McLeod, 1989), (2) conveys speaker affect (Fernald, 1989; Trainor, Austin, & Desjardins, 2000; Werker & McLeod, 1989), and (3) facilitates some aspects of language learning (Fernald, 1991; Karzon, 1985; Kemler-Nelson, Hirsh-Pasek, Jusczyk, & Wright-Cassidy, 1989; Thiessen, Hill, & Saffran, 2005). The unique prosodic qualities of IDS seem to draw infants' gaze towards the speaker and improve infants' understanding of affect. Infants appear to have an inherent preference for attending to IDS (Cooper & Aslin, 1990; Fernald & Kuhl, 1987; Werker & McLeod, 1989) and better differentiate between approving and prohibitive sentences when spoken in IDS compared to when spoken in ADS (Fernald, 1993). The linguistic features of IDS expose infants to a simplified version of their native language, which seem to facilitate language learning (Cooper & Aslin, 1990). For example, 1-to 4-month-old infants discriminate syllabic changes only when the phonetic contrast is accompanied by prosodic features found in IDS, such as increased fundamental frequency, intensity, and duration (Karzon, 1985). Infants also prefer and better recognize speech that breaks at natural clausal boundaries when spoken in IDS, compared to ADS (Kelmer-Nelson et al., 1989).

Yet, the involvement of IDS in more general learning beyond the linguistic domain remains largely untested. Given that IDS is associated with an increase in arousal (Berlyne, Borsa, Hamacher, & Koenig, 1966; Bradley, Greenwald, Petry, & Lang, 1992; Fernald, 1984; Kaplan, Bachorowski, & Zarlengo-Strouse, 1999; Kaplan, Jung, Rythers, & Zarlengo-Strouse, 1996; Maltzman, Kantor, & Langdon, 1966), which is associated with better performance on long-term memory tasks (Butter, 1970; Geen, 1974; Howarth & Eysenck, 1968; Kleinsmith & Kaplan, 1963, 1964; McLean, 1969; Park, 2005), it seems possible that the learning facilitation effects of IDS could be more domain-general.

Kaplan et al. (1996) tested this domain-general IDS learning hypothesis using a conditioned attention paradigm in which 4-month-old infants viewed a picture of an adult woman's face immediately before or after listening to a 10-second IDS or ADS audio clip. Infants then experienced a 10-second delay before hearing the same audio clip, this time presented with a novel black and white checkerboard pattern. Infants who listened to IDS before seeing the face attended towards the checkerboard pattern while those who listened to IDS after the picture or to ADS before or after the picture did not. These results suggest that IDS played before the encoding of a social image may improve associative learning after a short delay.

However, the extent to which IDS improves memory of non-social, non-linguistic information after a longer delay remains an open question. In an effort to explore this topic, we carried out a recognition test using a collection of videos that were novel and non-social with a unique population of subjects: infant rhesus macaques reared under controlled environmental conditions. Rhesus macaques, an Old World monkey species, possess cognitive and perceptual capabilities similar to human infants (Behar, Cronholm, & Loeb, 1965; Pflugst, Laycock, Flammino, Lonsbury-Martin, & Martin, 1978), making them an excellent model for this study. Furthermore, they engage in complex mother-infant interactions similar to those observed in humans, such as mutual gaze and mouth-to-mouth contact (Ferrari, Paukner, Ionica, & Suomi, 2009). Macaque adults also produce exaggerated facial expressions and acoustically unique vocalizations called girneys when addressing infants (Ferrari et al., 2009; Whitham, Gerald, & Maestripieri, 2007). Another advantage of

macaques is that they are non-linguistic, i.e. they do not understand or produce human language, which makes them an ideal candidate for testing whether IDS improves learning from a strictly non-linguistic point of view. This characteristic allows us to reasonably interpret differences in retention as stemming from a fundamental, prosodic characteristic of IDS, as we can rule out linguistic influences.

We hypothesized that when infants listen to IDS while viewing a novel, unrelated, non-social video, they will demonstrate unique recognition capabilities after a delay, compared infants who listen to ADS or a non-social audio control. Specifically, we predicted that when infants are exposed to IDS during encoding, they will demonstrate a novelty preference and look significantly more at a new video during a recognition test, thereby demonstrating evidence of discrimination and memory (Colombo, Mitchell, & Horowitz, 1988; Fagan, 1974; Richards, 1997; Rose, Gottfried, Mellow-Carminar, & Wagner, 1982). In contrast, infants unable to recognize the video from the familiarization phase will show no significant difference in looking at the two videos during a recognition test.

A significant difference in recognition rates between those in the IDS condition and those in the ADS and control conditions would indicate that IDS modulates learning and memory retention beyond language acquisition. Furthermore, finding these results in nonhuman primate (NHP) infants would suggest that a fundamental, non-linguistic component of IDS could be the driving force behind the cognitive advantages resulting from IDS.

Methods

Subjects

Subjects were 15 rhesus macaque (*Macaca mulatta*) infants, eight females and seven males, with a mean age of 81 days ($SD = 3.5$ days, $range = 75$ to 88 days). One additional female subject was tested but excluded from the analyses due to insufficient data. As part of an unrelated experiment, these infants were separated from their mothers on day one post-partum and raised in a nursery facility by human caretakers. Half of the infants were individually housed in cages, while the other half were housed together in peer cages, with four infants per group. The individually housed infants could see, hear and touch other infants at all times and took part in two-hour play sessions with same-aged peers every weekday. All infants were given inanimate cloth-covered surrogates, along with daily enrichment such as loose fleece squares, plastic toys, forage balls and climbing chains. Like most human infants, the macaque infants were exposed to both IDS and ADS. See Simpson et al. (in press) for more details on rearing practices. All procedures were approved by the NICHD Animal Care and Use Committee and were conducted in accordance with the Guide for the Care and Use of Laboratory Animals and the Animal Welfare Act.

Stimuli

This study used both audio and visual stimuli. The audio stimuli consisted of four 15-second passages, spoken in both IDS and ADS by an adult female, for a combined total of eight passages. These passages were previously created for a study exploring other aspects of infants' preference for IDS (Newman & Hussain, 2006). The four 15-second passages were

combined back-to-back in the same order within each condition to make two recordings: a one-minute IDS recording and a one-minute ADS recording. The same recordings were used for both delay conditions. We created a 15-second, non-social audio control (CTR) using Audacity audio editor and recording software. The audio sample consisted of overlapping sine waves generated at random frequencies. Each wave was 0.25 seconds long and separated by 0.25 seconds of silence. This 15-second clip was repeated to create a 1-minute long recording.

The visual stimuli consisted of 12, 15-second videos. Each video measured 570×325 pixels. The videos were found on YouTube.com and consisted of novel, non-social stimuli, such as coffee dripping into a pot or a time lapse of a flower blooming. The 15-second videos were looped until they totaled one minute in length. For the familiarization phase, the videos were combined with the audio stimuli using iMovie software for a total of 36 unique video-audio combinations, 12 in each of the three audio conditions. For the recognition test, the 12 videos were visually matched for action and content and split into six pairs (see supplemental materials). These pairs were presented side-by-side during the recognition test with no audio. No videos were re-used across conditions within each infant.

Procedure

Infants were tested in a visual paired-comparison test once per day for six consecutive days in a 2 (delay duration) × 3 (audio condition) within-subjects design, with all infants tested once in each of the six conditions. The order in which infants were exposed to each condition was randomized. We adapted a visual paired-comparison method from Flom, Janis, Garcia, & Kirwan, 2014, with certain measures and stimuli modified for our macaque population. Specifically, we used videos instead of pictures, as they tend to capture and hold macaque infants' attention more readily than static images, a shorter long-term delay, and shorter cumulative looking time criteria. Stimuli were presented using a Tobii TX300 eye tracker, with a 58.4 cm monitor with integrated eye tracking technology and speakers. At the beginning of each session, the infant was held approximately 60 centimeters in front of the screen by a caretaker. Each infant was calibrated using Tobii Studio's 5-point calibration routine. Following this calibration, the infant began the familiarization phase.

During this phase, infants were shown one of 12 different 1-minute videos while listening to one of three different 1-minute audio recordings. The minute-long videos and audio were repeated until the infant reached 15 seconds of cumulative looking, as measured by an experimenter with a stopwatch. We chose this method to ensure that all infants visually attended to the videos for the same amount of time, and the time length was chosen based on previous research with macaque infants (Bachevalier, Brickson, & Hagger, 1993; Gunderson & Swartz, 1986; Monk, Gunderson, Grant & Mechling, 1996; Paukner, Huntsberry, & Suomi, 2009; Simpson et al., 2016). Any looks away from the video were not included in the 15 seconds of cumulative looking, even though the video and audio continued to play. After the familiarization phase was completed, infants experienced either a 5-minute delay or a 60-minute delay. Infants spent the 5-minute delay held by a caretaker and the 60-minute delay back in their home cage. Infants held during the 5-minute delay were given a toy to

play with similar to those in their home cages. Infants were undisturbed (i.e., no other testing) during both delays, and caregivers did not speak to infants during these delays.

After the delay, infants completed a recognition test using the same calibration and handling described for the familiarization phase. The recognition test consisted of two trials. During the first trial, infants were shown the video from the familiarization phase side-by-side with a novel video until they accumulated a total of 5 seconds of cumulative looking. The first location of the familiar video (left or right) was counterbalanced between infants to avoid side biases. Infants then immediately participated in a second trial in which the videos switched sides laterally for an additional 5 seconds of cumulative looking. Once both trials were completed, the test was finished and infants were returned to their home cage.

Results

We created an Area of Interest (AOI) encompassing the videos shown during the familiarization phase using Tobii Studio software. All AOIs measured 635×380 pixels. Using the Tobii Fixation Filter, we extracted the amount of time each infant spent looking at the videos, as well as the total time it took infants to reach 15-seconds of cumulative looking at the video. We found that infants' looking time at the video did not differ across audio conditions ($p = .82$), indicating that the stopwatch used during testing accurately measured infants' cumulative looking at the video. We also found that the total trial time it took infants to reach 15-seconds of cumulative looking did not significantly differ across audio conditions ($p = .70$), suggesting that there were no noticeable differences in attention across conditions (see supplemental materials).

We then created two AOIs within the recognition test, one encompassing the familiar video and one encompassing the novel video. Each AOI also measured 635×380 pixels. We extracted the total fixation time within these two AOIs for both trials of the recognition test. We found no significant difference between the two trials across delays (*all ps* > .05) and therefore averaged the two trials so each infant had a single novel fixation and familiar fixation score within each condition. We calculated the sum of these two scores for each infant—to get a measure of the total time attending to both stimuli—and found no significant differences across audio conditions ($p = .65$), thereby indicating again that the stopwatch was an accurate measure of infant looking. We also found that the total trial time it took infants to reach 5-seconds of cumulative looking when averaged across trials did not differ between conditions, $p = .19$ (see supplemental materials).

We then divided the novel fixation score (i.e., total duration of time looking to the novel video) by the sum of the novel fixation and familiar fixation scores to compute a novel preferential looking score (proportion of time looking at the novel video) in each condition. To analyze the novel preferential looking scores, we ran a 2 (delay: 5-minute, 60-minute) × 3 (audio condition: IDS, ADS, CTR) analysis of variance (ANOVA) and included rearing condition as a between-subjects factor. There was no main effects for delay, $F(1, 14) = 1.05$, $p = .32$, audio condition, $F(2, 28) = 0.38$, $p = .69$, or rearing condition ($p = .74$). However, we did find a significant interaction between delay and audio condition, $F(2, 28) = 3.92$, $p = .03$, $\eta_p^2 = .22$. To further assess the delay × audio condition interaction, we ran three

pairwise comparisons of the audio conditions within each delay and found no significant differences when adjusting for multiple comparisons using a Bonferroni correction, $\alpha = .017$ (*all ps* > .017). See supplemental materials.

We then ran additional one-sample *t*-tests comparing all conditions to chance, as represented by a test value of 0.5 (Figure 1), a statistical analysis that is commonly used when analyzing preferential looking scores (Flom et al., 2014; Fulkerson & Waxman, 2007; Quinn & Eimas, 1996; Quinn, Yahr, & Kuhn, 2002; Rieth & Sireteanu, 1994; Waxman & Markow, 1995). For the 5-minute delay, we found that infants in the ADS ($M = .71$, $SD = .11$) and CTR ($M = .60$, $SD = .16$) conditions exhibited novelty preferences, $t(14) = 7.29$, $p < .001$, $d = 1.88$, and $t(14) = 2.43$, $p = .03$, $d = .63$, respectively. Infants did not differ from chance in the 5-minute delay IDS condition ($M = .55$, $SD = .19$), $t(14) = 0.98$, $p = .34$. However, for the 60-minute delay, infants exhibited a novelty preference only in the IDS condition, ($M = .64$, $SD = .20$), $t(14) = 2.68$, $p = .02$, $d = .69$. In the ADS ($M = .53$, $SD = .18$) and CTR ($M = .56$, $SD = .26$) conditions, infants' looking preferences did not differ from chance, $t(14) = 0.64$, $p = .53$, $t(14) = 0.82$, $p = .42$, respectively.

Discussion

Our results suggest that different styles of speech may differentially influence 2.5-month-old macaques' memory for visual information. Specifically, we were interested in whether IDS would improve infants' memory for non-linguistic visual stimuli. While a pairwise comparison showed no significant differences across audio conditions, only infants in the IDS condition exhibited a novelty preference above chance after the 60-minute delay. These results are difficult to interpret due to the flexible nature of novelty preferences (i.e. infants can switch preferences based on a variety of factors, see Bahrick, Hernandez-Reif, & Pickens, 1997; Flom & Bahrick, 2010; Hunter & Ames, 1988; Pascalis & de Haan, 2003). Nonetheless, our *t*-tests suggest infants were either better at discrimination in the IDS condition or were shifting faster from a familiarity to novelty preference after the 60-minute delay, which seems to reflect better recognition in the IDS condition than in the ADS or CTR condition after one hour.

However, we were surprised by the infants' inability to perform the recognition test in the IDS 5-minute delay condition. Further review of related literature reveals that these results mirror past research exploring the relation between arousal and memory. Specifically, exposure to arousing stimuli, both positive and negative, results in a temporarily inhibited ability to retrieve memories (Butter, 1970; Geen, 1973, 1974; Howarth & Eysenck, 1968; Kleinsmith & Kaplan, 1963, 1964; McLean, 1969; Park, 2005).

Although the mechanisms that underlie this phenomenon are still unclear, a recent meta-analysis of 48 studies in human adults showed an interaction between arousal and retention delay on memory (Park, 2005): memory performance is poor immediately after encoding arousing stimuli while performance for non-arousing stimuli is high. As time passes, the ability to retrieve arousing stimuli increases while the ability to retrieve non-arousing stimuli decreases. Approximately 20 minutes after encoding, memory performances for the two

types of stimuli equalize, and participants subsequently recognize the arousing stimuli more easily while struggling with the non-arousing stimuli (see supplemental materials).

While no specific measures of arousal were taken during the present study, it seems that these findings corroborate our current data, as our two delays (5 and 60 minutes) fall on either side of the 20-minute mark. Given that IDS is suggested to cause arousal in infants (Berlyne et al., 1966; Bradley et al., 1992; Fernald, 1984; Kaplan et al., 1996; Kaplan et al., 1999; Maltzman et al., 1966), we think it is possible that, in our study, heightened arousal may explain infants' apparent inability to discriminate visual stimuli encoded with IDS after a 5-minute delay, while exhibiting above-chance performance during the 60-minute delay. However, it is important to note that these results were found in NHPs, so interpretations cannot necessarily be generalized to human infants. Seeing as we know of no comparable IDS findings in human infants, follow up studies using human infants and similar parameters are necessarily to verify this arousal hypothesis.

However, we can draw some new conclusions based on the present study design. Specifically, we demonstrated that the content of IDS does not necessarily have to relate to the associated object in order to affect memory, i.e. the object can be non-social and novel. Furthermore, finding these results with NHPs suggests that a fundamental, nonverbal component of IDS may be responsible for the unique recognition capabilities provided by the speaking style. Given that NHPs are non-linguistic, we can rule out language or syntax-based explanations. This interpretation aligns with past research conducted in human infants, which suggests that the prosodic characteristics of IDS alone efficiently capture infants' attention, assist with language learning, and convey speaker affect (Fernald & Kuhl, 1987; Grieser & Kuhl, 1988; Kemler-Nelson et al., 1989).

In addition, these results suggest that IDS can have a significant effect on animals, specifically NHPs, and may affect their learning and memory. To the best of our knowledge, no study has explored what effect, if any, IDS has on animals, even though humans often talk to animals using a style of speech called pet-directed speech, which shares many characteristics with IDS (Burnham et al., 2002). Given this fact, our findings suggest this may be an area of research worth exploring, as the implications could be beneficial on both a practical and theoretical level. Further confirmation and expansion of these findings could benefit animal care practices and also contribute to our understanding of the evolutionary links between NHPs and humans, specifically as they pertain to language development (see Falk, 2004).

Follow up studies could also clarify and strengthen other aspects of the current study. Including a measure of infant arousal, such as pupil dilation, or adding more delay conditions to the study, specifically around the 20 minute mark, could help identify what role, if any, arousal played. It would also be helpful for future endeavors to standardize the treatment of infants between the two delay conditions, as differences in treatment could result in differing levels of consolidation and arousal.

In addition, testers were not blind to the experimental condition. While it seems unlikely, it is possible that researchers unconsciously biased infants' performance. As mentioned

previously, we found that infants' cumulative looking time at the videos did not differ across audio condition during the familiarization phase and recognition test respectively, suggesting that the experimenters efficiently used the stopwatch to measure infant looking. In addition, the total trial length it took infants to reach 15-seconds of cumulative looking did not differ significantly between audio conditions, nor did the trial length required to reach 5-seconds of cumulative looking. If condition specific biases existed, it seems likely that we would have found differences within these measures.

Finally, our small sample size limits the power of our analyses and requires a certain amount of ambiguity when interpreting our results. While the trends presented by the *t*-tests suggest a unique pattern of recognition, replication is required to make definitive claims about the degree to which IDS can affect memory. Replication of these results, specifically with human infants, may help tease apart the mechanisms at work and could strengthen the proposal that IDS facilitates learning beyond language.

For decades, researchers have worked to identify the many roles IDS plays in infant development, and our results serve to expand these roles. While it is widely suggested that IDS can improve certain aspects language learning in human infants, the current study presents promising results that the speech style may affect retention of more general, non-linguistic information. Furthermore, it seems that these benefits extend to NHPs, suggesting that sensitivity to nonverbal vocal characteristics may not be unique to humans. Although further exploration is required to fully understand these benefits, our findings reemphasize the importance of considering IDS in infant development and highlight the possibility that other unidentified benefits of IDS may exist.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Research Highlights

- Infant-directed speech has been reported to improve some aspects of language learning; however, it is unclear whether it may also improve memory for non-linguistic information.
- Using a visual paired-comparison test, we found that exposure to infant-directed speech during encoding inhibited visual discrimination 5 minutes after exposure but increased discrimination 60 minutes after exposure in infant macaques.
- Infant-directed speech appears to influence learning in nonhuman primates even though they are non-linguistic, suggesting sensitivity to nonverbal vocal characteristics may not be unique to humans.

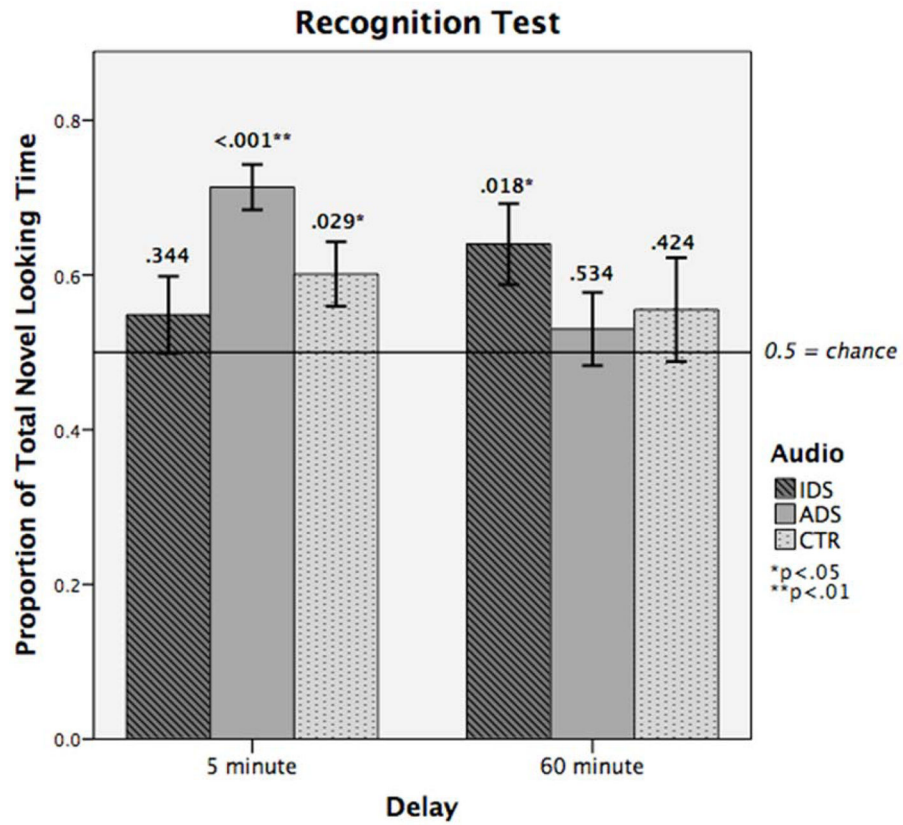


Figure 1. Mean proportion of total looking time at the novel video during the recognition test across delay intervals as a function of audio condition during familiarization. Audio conditions include infant-directed speech (IDS), adult-directed speech (ADS), and a non-speech control (CTR). Error bars represent SEM.