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Face Preferences for Infant- and Adult-Directed Speakers in Infants of Depressed and Nondepressed Mothers: Association with Infant Cognitive Development

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Abstract

Face preferences for speakers of infant-directed and adult-directed speech (IDS and ADS) were investigated in 4- to 13.5-month-old infants of depressed and non-depressed mothers. Following 1-min of exposure to an ID or AD speaker (order counterbalanced), infants had an immediate paired-comparison test with a still, silent image of the familiarized versus a novel face. In the test phase, ID face preference ratios were significantly lower in infants of depressed than non-depressed mothers. Infants' ID face preference ratios, but not AD face preference ratios, correlated with their percentile scores on the cognitive (*Cog*) scale of the Bayley Scales of Infant & Toddler Development (3rd Edition; BSID III), assessed concurrently. Regression analyses revealed that infant ID face preferences significantly predicted infant *Cog* percentiles even after demographic risk factors and maternal depression had been controlled. Infants may use IDS to select social partners who are likely to support and facilitate cognitive development.

Keywords

Infant-directed speech; face preferences; familiarization-preference test; postpartum depression; cognitive development

Caregivers in many cultures modify their speech directed toward infants in ways that appear to be tailored to perceptually and motivationally support infant attention, state, and learning: utterances are slowed, simplified, and repeated; vocal pitch is elevated, and changes in pitch are exaggerated relative to adult-directed speech (ADS; Kuhl, 2007; Fernald, 1984). Infant-directed speech (IDS) has been shown to be more effective than ADS at attracting infant attention (Cooper & Aslin, 1990; Fernald & Kuhl, 1987), regulating infant affect and state (Kaplan, Goldstein, Huckleby, & Panneton Cooper, 1995), facilitating the learning of associations with contiguous visual stimuli (Kaplan, Jung, Ryther, & Zarlengo-Strouse, 1996), and promoting rudimentary language processing (Golinkoff, Can, Soderstrom, & Hirsh-Pasek, 2015; Liu, Kuhl, & Tsao, 2003; Ma, Golinkoff, Houston, & Hirsh-Pasek, 2011; Thiessen, Hill, & Saffran, 2005).

Recent evidence indicates that IDS also may provide cues to the selection of social partners. Schachner & Hannon (2011) found that after 1-min exposure to an unfamiliar adult female IDS speaker, 5-month-old infants given a choice between looking at a still, silent image of the face of the ID speaker or a novel face exhibited a slight but significant preference for the face of the ID speaker. In contrast, after 1-min exposure to an unfamiliar adult female speaker of ADS, infants exhibited a significant preference for a (different) novel face over that of the AD speaker (see Figure 1 for a diagram of this procedure). This effect was not obtained after infants had been familiarized with ID or AD faces without accompanying sounds. These findings are consistent with the idea that infants use IDS as cue to select social partners who are likely to have the interest and capacity to be good caregivers and teachers (Csibra & Gergely, 2009). If so, stronger ID face preferences may predict accelerated cognitive and communicative development.

Here we studied a sample of infants for whom the pedagogical benefits of IDS had likely been compromised. Several lines of evidence suggest that caregivers' production of IDS, and infants' responsiveness to it, are affected by caregivers' postpartum depression. Relative to non-depressed caregivers, depressed caregivers produce IDS that contains significantly less pitch modulation (Porritt, Zinser, Bachorowski, & Kaplan, 2014), and is used in a manner that is less contingent on infant behavior (Bettes, 1988; Zlochower & Cohn, 1996).

Some of the functions of IDS outlined above are also affected by caregiver depression in ways that are relevant to the present study. For example, although infants of non-depressed mothers rapidly acquire an association between a brief segment of IDS recorded from an unfamiliar non-depressed mother and a smiling female face that immediately follows it (Kaplan et al., 1996), 4- to 12-month-old infants of depressed mothers do not show evidence of having made such an association when their own depressed mother's or an unfamiliar depressed mother's IDS signals a face (Kaplan, Bachorowski, Smoski, & Hudenko, 2002; Kaplan, Dungan, & Zinser, 2004). Moreover, although 4-month-old infants of depressed mothers do learn in this paradigm in response to an unfamiliar *non-depressed* mother's IDS, older infants of more chronically depressed mothers do not (in studies involving both between-group, Kaplan et al., 2004, and within-subject, analyses, Kaplan, Danko, Kalinka, & Cejka, 2012). These findings suggest that, as a result of experience with a depressed caregiver, infants of depressed mothers may exhibit generally reduced responsiveness to IDS produced by female speakers.

We examined visual preferences for the faces of ID and AD speakers in 4- to 13.5-month-old infants of depressed and non-depressed mothers using Schachner & Hannon's familiarization-preference paradigm. We predicted that infants of depressed mothers would exhibit reduced preferences for the faces of unfamiliar female ID speakers, relative to infants of non-depressed mothers. And because younger infants exhibit familiarity preferences with stimuli and under durations that produce a novelty preference in older infants (Reynolds, Courage, & Richards, 2010; Rose, Feldman, & Jankowski, 2007; Wetherford & Cohen, 1973), we controlled for effects of infant age in analyses of looking times and face preferences reported here.

We also sought evidence of a link between ID face preferences and infant cognitive and communicative development. Although not previously tied to IDS, delays in general cognitive and language development have been observed in several longitudinal studies on children of depressed mothers (Cornish et al., 2005; Grace, Evindar, & Stewart, 2003; NICHD, 1999). We reasoned that if infants who respond relatively more strongly to ostensive cues such as IDS in the laboratory do so because they have a history of positive interactions with ID speakers, then to the extent that ID speakers provide more stimulating pedagogical encounters, those infants may exhibit accelerated cognitive development. To test this, we concurrently tested infants using the Bayley Scales of Infant and Toddler Development, 3rd edition (BSID-III; Bayley, 2006), a widely-used interviewer-based assessment of infant intellectual development that includes items on rate of habituation, magnitude of novelty responses, and other processes known to predict cognitive development (Colombo & Mitchell, 2009). It also has the strength of separately assessing cognitive and communicative skills.

METHOD

Participants

Sixty-six infants (mean age = 265.3 days, $SD = 86.5$, range = 122 to 410 days) and their mothers (mean age = 28.2 years, $SD = 5.3$; range = 18 to 38 years) were successfully recruited from an advertisement on our laboratory's Facebook page. The advertisement described the project as a "study about baby talk, mother-infant play, and how babies learn," and stated that "mothers with a history of depression are especially encouraged to participate." All participants received monetary compensation for their laboratory visit. An equal number of male and female infants were recruited. Forty-one of the infants were white (62.1%), 12 were Latino (18.2%), 9 were African-American (13.6%), and 4 were Asian-American (6.1%). Median education level was 5.2 (4.0 = high school graduate, 5.0 = 2-year college degree, 6.0 = 4-year college degree) and median family income was in the \$61,000-\$70,999 range. An additional 6 infants were tested but did not contribute data, 4 due to excessive fussiness, 1 due to equipment failure, and 1 because the mother was diagnosed with depression with psychotic features. In these six dyads, 2 mothers had elevated PDSS scores and 4 mothers had non-elevated PDSS scores, a ratio roughly equivalent to the ratio of mother with elevated versus non-elevated PDSS scores in the final sample. Demographic characteristics for these 6 dyads also did not differ from those in the 66 dyads that successfully completed the study.

This study was conducted according to guidelines laid down in the Declaration of Helsinki, with written informed consent obtained from a parent or guardian for themselves and each child prior to any data collection. All procedures involving human subjects were approved by the Colorado Multiple Institutional Review Board (COMIRB) at the University of Colorado.

Stimuli

Four, approximately 1-min color videotapes were made with two different female (Caucasian) models. In each, the model looked directly into the camera and spoke from a

memorized script. For each model, one video was recorded in which she spoke in IDS intonation, and another in which she spoke in ADS intonation. Each video contained the same words and phrases; only ID vs. AD vocal and facial expression varied. Four static, silent images of smiling female (Caucasian) faces were used in the test phase (see Fig. 1). Two of the faces were those of the video models, and two were those of novel women (who were not video models).

To document that the expected speech acoustic differences between IDS and ADS were obtained, for each phrase ($n = 30$ per video), we extracted mean fundamental frequency (F_0) using Praat Acoustic Analysis software (Boersma & Weenink, 2009). From these data, we calculated the mean fundamental frequency ranges ($F_{0\max} - F_{0\min} = F_0$) for each of the IDS and ADS utterances. Durations of each utterance were also computed.¹

Mean F_0 for the one video model's IDS and ADS soundtracks were 202.7 Hz ($SD = 77.0$) and 95.6 Hz ($SD = 26.7$), respectively, and those for the other video model 228.3 Hz ($SD = 52.2$) and 100.6 Hz ($SD = 37.1$), respectively. An ANOVA on F_0 produced a significant main effect of video type, $F(1, 116) = 151.2$, $p = .001$, but no effect of video model and no significant interaction (p 's $> .11$). F_0 was higher in nearly every IDS, in comparison with ADS, utterance.

Utterance durations were significantly longer in the IDS than ADS videos ($M_s = 1.53$ s, $SD = 0.72$, vs. 1.09 s, $SD = 0.61$, for one video model; $M_s = 1.42$ s, $SD = 0.84$, vs. 1.16 , $SD = 0.69$, for the other). An ANOVA produced a main effect of IDS vs. ADS on utterance duration, $F(1, 116) = 7.17$, $p = .01$, but no effect of video model and no significant interaction (p 's $> .48$).

Apparatus

Mothers were seated in an adjustable barber's chair and held their infants in their laps. Infants were approximately 62 cm from the center monitor. Mothers wore noise-cancelling headphones (Bose Quiet Comfort 15) and listened to classical music during the tests. Three 19-in Acer video monitors were arrayed in a horizontal plane in front of the mother and infant (Fig. 1). Behind the central monitor, a Jawbone Jambox (770-00644 Rev D) loudspeaker played sounds at an average of 65 dB, measured near the infant's head location. The videotapes and still image presentations were controlled by an iMac 2.7 GHz Intel Core 15 computer. During testing, the room was illuminated by two 13-watt, 1100 lumen, LED light bulbs positioned in the room's corners, equidistant from the left and right monitors.

Assessment of Maternal Depression

Mothers completed the Postpartum Depression Screening Scale (PDSS; Beck & Gable, 2002), a 35-item Likert-scale, self-report, summative screening tool used for identification of depression during the postpartum period. Possible total scores range from a low of 35 (no identified symptoms of depression) to a maximum of 175. The PDSS has been shown to have excellent reliability (Beck & Gable, 2002). Here, mothers were classified as having

¹There were also differences in ID versus AD facial affect, but no attempt was made to quantify those here. We estimate that the differences in extent of positive affect between ID and AD faces roughly paralleled those between ID and AD speech.

“non-elevated” (PDSS < 80) vs. “elevated” (PDSS ≥ 80) symptoms of depression based on the scale’s suggested cutoff for “positive screening for major postpartum depression,” derived from ROC curve analyses to maximize the scale’s sensitivity and specificity for detecting a DSM-IV-based diagnosis of major depression (Beck & Gable, 2002).

Assessment of Infant Cognitive Development

Each infant was administered the Bayley Scales of Infant and Toddler Development, 3rd Edition (BSID-III) to assess the level of cognitive, receptive communication, and expressive communication development. The items on the Cognitive Scale (*Cog*) assessed sensorimotor development, exploration and manipulation, object relatedness, concept formation, memory, speed of processing via rate of habituation, and responses to novel stimuli (Bayley, 2006). The receptive communication (*RC*) scale assessed auditory acuity and preverbal behaviors related to vocabulary development, (e.g., identifying objects and pictures and responding to words). The expressive communication (*EC*) scale assessed babbling, gesturing, joint referencing, turn taking, first words, and object/picture naming. The BSID-III exhibits good reliability, with an average reliability coefficient of .91 for the *Cog* scale and .93 for the language scales. Scale convergence and discriminant validity are also high (Bayley, 2006).

Administration of the BSID-III was supervised by a doctoral-level licensed clinical psychologist with expertise in child assessment. Doctoral student examiners had a minimum of two semesters of training in the administration and scoring of standardized psychological assessment, as well as doctoral level course work in developmental psychology. They received didactic training in BSID-III test administration for the age range under study, culminating in supervised administration of all items in this range. Following training, BSID-III examiners observed and assisted the trainer in administering and scoring the BSID-III multiple times, and later were supervised from behind a one-way mirror in administration of the BSID-III, demonstrating reliability with the trainer’s ratings. Examiners were blind to maternal self-reported symptoms of depression and infant performance on the familiarization-novelty test.

Procedure

Each infant was tested in both the IDS and ADS conditions, with order counterbalanced across infants. As depicted in Fig. 1, each test consisted of an approximately 1-min videotape familiarization phase, followed by a 40-s test phase. During familiarization, one of the two videotapes (with audio) was presented on the center monitor, and the side monitors were dark. During the test phase, which followed immediately, two static, silent, smiling faces were presented on the two side monitors, and the middle monitor was dark. One face was that of the video model, and the other was that of a novel woman. After 20 s, the sides of presentation were reversed. At least 10 min, but no more than 15 min, separated the IDS and ADS video sessions. Different novel faces were used in the IDS and ADS conditions. For each infant, the IDS and ADS video models were always different people, and each was unfamiliar to the infant. There were 8 fully counterbalanced combinations of video model ($n = 2$), testing order (ID or AD test first), and on which side the familiarized face first appeared in the paired comparison tests (left or right), to which infants were randomly assigned.

Videotapes of preference tests were coded by raters who did not know the mother's level of depressive symptomatology or on which side the still image of the video model was presented. Coders estimated the durations of looking at the videos from the familiarization phase and the durations of looking at each still image from the test phase. A second rater coded 14% of the tests, with a mean inter-observer correlation of 0.96 on durations of looking during videotapes. There was 100% agreement between the two raters on the direction of preference during paired comparison tests following both ID and AD familiarization (i.e., whether the preference ratio for the familiarized face was categorized as above or below .50).

Data Analysis

Demographic information—Preliminary analyses focused on differences in relevant demographic variables in dyads with versus without a depressed mother, to identify covariates of maternal depression for subsequent analyses of infant behavior.

Familiarization phase—Analysis of covariance (ANCOVA) was used to examine mean durations of infant looking at the ID versus AD videotapes during the familiarization phase, as a function of maternal depression and its covariates. This was important to establish that the two types of videos elicited comparable levels of looking before paired comparison tests, and to demonstrate that any between-groups differences in responding to faces on subsequent test trials were not attributable to differences in ability to process or encode videotapes.

Paired comparison tests—The key dependent measures were visual preference ratios for the familiarized vs. novel faces on paired-comparison test trials for infants of depressed and non-depressed mothers. Based on previous work (Kaplan et al., 2012), we made an *a priori* prediction that infants of depressed in comparison with non-depressed mothers would have significantly lower preferences for the face of ID speakers. However, those data did not support a clear prediction about face preferences in the AD elevated vs. non-elevated conditions. Therefore, following an overall ANCOVA examining ID and AD face preferences as a function of maternal depression and relevant demographic variables, rather than an omnibus *F* test for the general interaction term, we performed a planned comparison to probe for differences in preference ratios in the ID elevated vs. ID non-elevated condition (Keppel & Zedeck, 1989, pp. 239–242). Within-subject *t*-tests assessed whether preference ratios differed from chance.

Bayley scales—A step-wise, hierarchical linear regression was performed on Bayley *Cog* scale percentiles to examine predictors of Bayley scale performance. In model 1, the effects of demographic variables alone were assessed. In model 2, maternal PDSS category was added to determine if maternal depression predicted infant Bayley scales, controlling for demographic variables. In model 3, the possibility of an interaction between infant sex and PDSS category was assessed, because prior work suggested greater risks for male infants of depressed mothers (Kurstjens & Wolke, 2001). Finally, in model 4, infant ID preference ratios were added.

RESULTS

Demographic Information

Table 1 summarizes demographic and diagnostic information. Mothers with elevated scores on the PDSS were significantly younger than were mothers with non-elevated scores on the PDSS, $F(1, 63) = 4.75, p = .05, \eta^2 = .071$, had lower educational achievement, Mann-Whitney $U = 310, z = 2.17, p = .05$, and reported lower family income, Mann-Whitney $U = 314, z = 2.07, p = .05$. However, infants of depressed and non-depressed mothers did not differ significantly in age, Mann-Whitney $U = 43, z = 1.55, p = .13$.

Video Familiarization Phase

Table 2 shows mean looking times in the two video conditions as a function of the infants' mothers' PDSS category.² A mixed 2 (elevated vs. non-elevated maternal PDSS score) $\times$ 2 (ID vs. AD videos, within-subject) ANCOVA with infant age, infant sex, and family income as covariates yielded a significant effect of infant age, $F(1, 61) = 8.86, p = .01, \eta^2 = .133$, but no significant effect of mother's PDSS category, $F(1, 61) = 0.14, p = .72, \eta^2 = .002$, or of ID vs. AD videos, $F(1, 61) = 0.19, p = .66, \eta^2 = .003$, and no significant interaction between video condition and maternal PDSS category, $F(1, 61) = 2.15, p = .15, \eta^2 = .036$. There were no significant effects for other covariates, including infant sex, $F(1, 61) = 1.36, p = .25, \eta^2 = .023$, and family income, $F(1, 61) = 0.37, p = .55, \eta^2 = .001$, and no significant interactions between video condition and infant age, $F(1, 61) = 0.72, p = .40, \eta^2 = .012$, infant sex, $F(1, 61) = 0.00, p = .97, \eta^2 = .000$, or family income, $F(1, 61) = 0.16, p = .90, \eta^2 = .000$.

Infant age was negatively correlated with the duration of looking at ID, $r(66) = -.31, p = .05$, and AD videos, $r(66) = -.34, p = .01$. Thus, although younger infants looked longer at videos than older infants, infant looking was unrelated to maternal depression or ID vs. AD videotape, providing no evidence for differential salience of ID vs. AD videos.

Paired Comparison Test Phase

Mean preference ratios were calculated for each infant by dividing the total duration of looking at the familiarized face by the total duration of looking at the familiarized plus the novel face during the test phase (see Table 3 and Figure 2). A preference ratio above 0.50 was consistent with a preference for the familiarized face, and a preference ratio below 0.50 was consistent with a preference for the novel face.

As predicted, infants of depressed mothers exhibited lower mean face preference ratios in the IDS condition than infants of non-depressed mothers. A mixed 2 (elevated vs. non-elevated maternal PDSS category) $\times$ 2 (familiarization to ID vs. AD videos) ANCOVA with infant age, infant sex, and family income as covariates showed a significant main effect of mother's PDSS category, $F(1, 61) = 4.66, p = .05, \eta^2 = .073$, and infant age, $F(1, 61) = 5.71,$

²Preliminary analyses indicated no effects on duration of looking during the familiarization or preference testing phases as a function of specific ID and AD models, testing order (ID vs. AD video first), or on which side the familiarized face first appeared in the paired comparison test. Because those variables were fully counterbalanced, and to save space, the details of those analyses are not presented here.

$p = .02$, $\eta^2 = .088$, but not of ID vs. AD video, $F(1, 61) = 0.00$. There were no significant effects of infant sex, $F(1, 61) = 0.00$, or family income, $F(1, 61) = 0.97$, $p = .76$, $\eta^2 = .002$, and no significant interactions between those variables and ID vs. AD testing conditions, $F(1, 61) = 0.18$, and $F(1, 61) = 0.55$, respectively, $\eta^2 < .003$. Likewise, there were no significant interactions between ID vs. AD tests and infant age, $F(1, 61) = 1.89$, but with a larger effect size, $\eta^2 = .031$. Infant age was significantly negatively correlated with the AD face preference ratios, $r(66) = -.28$, $p = .05$, but not the ID face preference ratios, $r(66) = -.08$, $p = .52$.

The key test for the main hypothesis under consideration was a planned comparison of face preference ratios in the ID-elevated vs. ID non-elevated conditions, controlling for covariates. Preference ratios in the ID condition were significantly higher in the non-elevated in comparison with the elevated PDSS group, $F(1, 61) = 5.23$, $p = .03$, $\eta^2 = .081$. There were non-significant effects of infant age, $F(1, 63) = 1.18$, $p = .23$, $\eta^2 = .019$, infant sex, $F(1, 61) = .011$, $p = .74$, $\eta^2 = .002$, and family income, $F(1, 61) = .085$, $p = .77$, $\eta^2 = .001$.

To examine further the effects of maternal PDSS category free of confound with infant age, we matched each of our 21 infants of depressed mothers with an infant of a non-depressed mother from this sample based on the closest possible match of age in days, considering nothing else, starting with the oldest infant (Table 4; the results were the same if we started with the youngest infant). In this analysis, the median ages of infants of depressed and non-depressed mothers were equivalent, but the differences in infant ID face preference ratios persisted. A Wilcoxin signed-rank test for matched pairs performed on these data yielded a significant effect of maternal PDSS (depression) category, $W = -146$, $z = 2.53$, $p = .01$. In a significant proportion of the matched pairs, the preference ratio was higher for the infant of the depressed in comparison with the non-depressed mother (15/21 = 74%, $z = 1.74$, $p = .05$).

One-sample t -tests performed to determine if preference ratios deviated significantly from chance (0.50) showed that preference ratios in the ID-non-elevated condition were not significantly above chance, $t(44) = 1.09$, $p = .28$, and those in the ID-elevated condition were not quite significantly below chance, $t(20) = 2.00$, $p = .06$. Preference ratios were significantly below chance in both AD conditions (elevated: $t(44) = 2.59$; non-elevated: $t(20) = 2.04$, p 's = .05).

Bayley Scales

Table 5 presents the mean age-normed BSID-III percentile scores on the Cognitive (*Cog*), and Receptive and Expressive Communication (*RC & EC*) scales as a function of the infant's mother's PDSS category and infant sex. As in some previous studies, the effect of maternal depression was seen only for male infants (Goodman, Rouse, Connell, Broth, Hall, & Hayward, 2011). A step-wise hierarchical linear regression was carried out on the *Cog* data examining effects of relevant demographic variables -- including maternal education, family income, number of children in the family, and infant sex -- followed by maternal depression, a sex-by-maternal depression interaction term, and infant ID face preference ratios.³ Table 6 presents zero-order correlations. Only ID face preference ratios positively correlated with *Cog* scale percentiles.

Model 1 showed no significant effect of demographic variables, which was also true of Model 2, where there was a significant effect of PDSS category after controlling for demographics (Table 7). However, in Model 3 the infant sex-by-PDSS category interaction term was significant, but the main effect of PDSS category was not. In Model 4, infant sex and the sex-by-PDSS category interaction term were both significant, but ID face preference ratios still accounted for a significant proportion of the variance in *Cog* scores.⁴

DISCUSSION

Schachner & Hannon (2011) demonstrated that 5-month-old infants of non-depressed mothers preferred the face of a recently encountered female ID speaker relative to a novel face, and preferred a novel face relative to a recently encountered female AD speaker. Sound tracks were critical to these effects. We examined preferences for the faces of ID vs. AD speakers in 4- to 13.5-month-old infants of depressed and non-depressed mothers. Because prior research suggested that infants of depressed mothers exhibit reduced responsiveness to IDS produced by non-depressed mothers across the first year of life (Kaplan et al., 2012), we predicted that infants of depressed mothers would exhibit a reduced relative preference for the face of a recently encountered ID speaker. This prediction was confirmed.

These results extend the generality of the non-responsiveness of infants of depressed mothers to IDS produced by non-depressed females from a conditioned-attention paradigm to the more widely used familiarization-preference paradigm. That infants of depressed mothers do not exhibit social preferences for the faces of ID speakers adds to concerns about their risk status for problems in cognitive development.

Consistent with elevated risk, maternal depression was linked to poorer performance on the (*Cog*) subscale of the BSID-III, at least in male infants. This finding is in keeping with some other studies pointing to differential risk to male infants of maternal depression, although mechanisms are not well understood (Goodman et al., 2011; Murray, Kempton, Woolgar, and Hooper, 1993). Murray et al. (1993) found that the degree of mothers' infant focus in the semantic content of their IDS at 6 weeks postpartum predicted Bayley cognitive development at 18 months, and that infant focus was especially low in depressed mothers of male infants. However, the effect of infant focus on Bayley performance remained significant after the effects of depression-by-infant sex interaction had been modeled. Similarly, here, infants' preferences for a recently encountered face of an ID (but not AD) speaker predicted their *Cog* performance, after caregivers' socio-economic status, maternal depression, infant sex, and the sex-by-depression interaction had been controlled.

Although these findings are open to several interpretations, they are consistent with the hypothesis that infants who prefer the faces of ID speakers have created for themselves greater opportunities to learn, which eventually is reflected in better performance on a standardized test of cognitive development. These findings are consistent with others

³BSID-III data were unavailable for two infants who successfully completed the familiarization-preference testing, due to subsequent fussiness. For two other infants, BSID-III testing proceeded far enough to rate the infant on the *Cog* scale, but not on the *RC* or *EC* scales, again due to fussiness.

⁴Other demographic variables that were omitted from regression models, including family income and maternal age, were not significantly related to either ID face preferences or *Cog* percentiles, and their inclusion did not change the conclusions report here.

showing that infants are active participants in what they learn, and from whom (Begus, Gliga, & Southgate, 2014; Buchsbaum, Gopnik, Griffiths, & Shafto, 2011). Unclear from this account, however, is why ID face preferences did not predict *RC* or *EC* scale performance, given the involvement of ostensive cues in IDS for promoting the processing of linguistic stimuli (Weisleder & Fernald, 2013).

The significantly lower ID face preference ratios in infants of depressed in comparison to non-depressed mothers may be attributed to consequences of non-optimal caregiver-infant interactions, which may affect infants' processing of ostensive cues. In the case of IDS, an expectation on the part of the infant that a depressed caregiver will be a contingent social partner may be violated in many cases. This coupled with the fact that the quality of depressed caregivers' ostensive cues is often low, may render infants of depressed mothers unable or unwilling to attend to and process ostensive cues. This may account for why infants of chronically depressed mothers do not respond even to "normal" IDS produced by an unfamiliar non-depressed mother (Kaplan et al., 2012).

Potentially relevant to the interpretation of these data is evidence that infants of depressed mothers may be less responsive to animated facial expressions than are controls (Bornstein, Arterberry, Mash, & Manion, 2010; Field, Pickens, Fox, Gonzalez, & Nawrocki, 1998), and that they may be less efficient at encoding environmental stimuli (Hernandez-Reif et al., 2006). However, the possibilities that infants of depressed mothers find ID faces and voices less rewarding, respond less to ostensive cues, and are less able to encode those stimuli or form associations between them, were not supported by the findings that they looked at the videos during familiarization for as long as controls.

Interpretation of the BSID-III *Cog* data should be informed by the fact that performance can be influenced by an infant's motivation and attention to the examiner and tasks, which in turn may be affected by maternal depression. For example, infants of depressed mothers may exhibit social inhibition around unfamiliar adults (Field et al., 1988). Additional research will be needed to assess this and cognition-based explanations of our findings.

Several procedural differences existed between Schachner and Hannon (2011) and the present study. For example, they used the presentation of an animated image of a looming object before each familiarization or test trial to center the infant's attention. In addition, they used soundtracks that involved spontaneous speech of pre-planned topics, leading to differences in content across speakers and between ID and AD conditions. In contrast, content was equated across speakers and for ID and AD conditions here. Finally, their testing took place in a sound-attenuating chamber. It is possible that one or more of these differences contributed to the slightly lower ID face preferences among infants of non-depressed mothers in the present study relative to their study. However, that we essentially replicated Schachner and Hannon's key finding in infants of non-depressed mothers demonstrates its robustness to small procedural variations across laboratories (see Frank et al., 2017).

There were several limitations to this study. First was the relatively small number of participants, especially in depressed mother group. This concern may be amplified by the

large age range, which spanned developmental stages. Although age did not significantly interact with maternal PDSS category, there may have been insufficient statistical power to detect such effects. Second, symptoms of depression were assessed through maternal self-report, rather than structured clinical interview. Consequently, we did not have data on chronicity of maternal depression, and were unable to explicitly test the predicted link between reduced preferences for the ID speakers' faces and the chronicity of the infant's own mother's depression. Third, with modest effect sizes the meaningfulness of differences in ID face preferences was unclear.

Unexplored here were the relative contributions to these effects of IDS *per se* separate from differences in facial expressions between the ID than AD videos. Schachner and Hannon showed that infants' preferences for the faces of ID speakers were absent when the sound tracks were omitted from videos. We assume a similar pattern of findings would have emerged here.

These findings generally confirmed those of Schachner and Hannon (2011) but went on to show that after exposure to an unfamiliar ID speaker, infants of depressed mothers preferred a novel face rather than the ID speaker's face. This suggests that infants of depressed mothers not only exhibit reduced responding to stimuli associated with their own mothers, but also may not be as open as controls to interacting with unfamiliar non-depressed women (Kaplan et al., 2012). If so, some of the infants' developmental risk associated with their mothers' depression is through a reduction in the infant's active attempts to seek out stimulating social partners. Alternatively, the fact that these infants exhibited a trend toward preference for a novel face may reflect a shift in infants' social learning strategy to focus on novel adults in search of learning experiences, as has been found following early life stress in some non-human animals (Farine, Spencer, & Boogert, 2015).

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Figure 1.

Figure 2.

Table 1**Maternal and Infant Demographic and Diagnostic Data**

Variable	Non-Elevated PDSS	Elevated PDSS
N	45	21
Age of mother (yrs)	29.0 (5.1) _a	26.3 (5.3) _b
Age of infant (days)	274.8 (80.9)	245.1 (96.4)
Infant gender (female/male)	26/19	12/9
Ethnicity		
White	30 (66.7%)	11 (52.4%)
Latina	6 (13.3%)	6 (28.6%)
African-American	5 (11.1%)	4 (19.0%)
Asian	4 (8.9%)	0 (0.0%)
Mother's education (median)	6.0 _a	5.0 _b
Family income (median)	8.0 _a	6.0 _b
Number of children	1.5 (0.7)	1.4 (0.6)
Mean PDSS score	56.5 (13.0) _a	98.7 (18.6) _b

Note: Unless otherwise indicated, numbers in parentheses are standard deviations. Means labeled with different subscripts are significantly different from one another ($p = .05$). For education, 4.0 = high school graduate, 5.0 = graduated 2-year college, 6.0 = graduated 4-year college. For family income, 5.0 = \$41,000-\$50,999, 6.0 = \$51,000-\$60,999, and 7.0 = \$61,000-\$70,999.

Familiarization Phase: Looking Times in Seconds at ID and AD Videotapes as a Function of Maternal Self-Reported Depression

Table 2

	Non-Elevated PDSS	Elevated PDSS
ID Videotape	43.4 (12.4)	42.8 (13.2)
AD Videotape	39.0 (15.4)	44.9 (21.3)

Numbers in parentheses are standard deviations.

Table 3

Test Phase: Mean Face Preference During the Paired-Comparison Test Phase

	Non-Elevated PDSS	Elevated PDSS
ID Face	.514 (.10) _a	.453 (.11) _b
AD Face	.460 (.12)	.432 (.15)

Preference ratio = looking at familiarized face divided by total looking at familiarized and novel faces in test phase. Numbers in parentheses are standard deviations. Means with different subscripts differ significantly ($p = .05$).

Table 4

Analysis of infant ID preference ratios in 21 pairs of infants matched for infant age in days as a function of their mothers' PDSS category

Elevated PDSS Score		Non-Elevated PDSS Score		
Infant Age	ID Face Preference Ratio	Infant Age	ID Face Preference Ratio	NDEP>DEP?
410	.39	392	.54	+
385	.38	386	.49	+
368	.43	377	.67	+
366	.49	367	.35	-
350	.39	345	.53	+
334	.33	339	.52	+
324	.50	334	.43	-
307	.41	295	.49	+
257	.32	247	.43	+
238	.50	247	.53	+
215	.37	215	.49	+
203	.68	215	.52	-
183	.35	203	.32	-
180	.53	173	.65	+
162	.52	172	.47	-
160	.32	165	.49	+
160	.70	163	.75	+
150	.51	160	.51	0
147	.39	152	.62	+
126	.36	133	.47	+
122	.53	125	.74	+
<i>Md</i> = 215	<i>Md</i> = .41	<i>Md</i> = 215	<i>Md</i> = .51	15/21 = 71.4%, $z = 1.74$, $p = .05$

Table 5

Mean Percentile Scores on the BSID-III as a Function of Maternal PDSS Category and Infant Sex

PDSS Category	Infant Sex	Cog	RC	EC
Non-Elevated	female	.70 (.17)	.41 (.32)	.41 (.27)
	male	.70 (.21)	.51 (.32)	.40 (.30)
Elevated	female	.75 _a (.29)	.40 (.27)	.34 (.17)
	male	.48 _b (.32)	.45 (.32)	.52 (.36)

Cog = cognitive scale; RC = receptive communication scale; EC = expressive communication scale. Numbers in parentheses are standard deviations. Means with different subscripts differ significantly (p = .05).

Table 6

Correlation matrix relating duration of looking at videos and face preference data to BSID-III performance, with relevant demographic variables.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. <i>Cog</i>	--														
2. <i>RC</i>	.18	--													
3. <i>EC</i>	.19	.64	--												
4. ID video looking	-.19	-.13	-.17	--											
5. AD video looking	.05	-.03	.06	.58	--										
6. ID pref ratio	.37	-.01	.04	-.05	.03	--									
7. AD pref ratio	.09	.01	-.02	.02	.07	.16	--								
8. PDSS category	-.22	.11	.06	-.03	.16	-.27	-.10	--							
9. Mother age	.05	-.22	-.12	.04	-.12	.17	.13	-.27	--						
10. Infant age	.14	-.18	-.04	-.31	-.34	-.08	-.28	.18	.18	--					
11. Mother's educ.	-.18	-.03	-.12	.16	-.01	-.03	.02	-.27	.48	.06	--				
12. Family income	.04	-.13	-.16	-.07	-.12	.00	-.00	-.29	.45	.38	.37	--			
13. No. children	-.26	-.24	-.27	.08	-.18	-.17	.01	.08	.28	.10	.23	.12	--		
14. Infant sex	-.21	-.03	.10	-.11	-.04	-.06	.05	.14	.05	-.15	-.07	-.16	.20	--	
15. Sex X PDSS cat	-.17	-.01	.11	.18	.11	.18	-.11	-.01	-.18	-.12	-.02	-.26	-.03	-.34	--

Hierarchical Linear Regression of Number of Children, Maternal PDSS Category, and Infant ID Face Preference Ratio on Bayley Cognitive (Cog) Scale Percentiles

<i>Variable</i>	<i>Model 1</i>		<i>Model 2</i>		<i>Model 3</i>		<i>Model 4</i>	
	B	SE B	β	B	SE	β	B	SE B
# Children	-.069	.049	-.18	-.073	.048	-.19	-.068	.046
Sex	-.046	.031	-.19	-.037	.030	-.15	-.062	.032
Mothers educ	-.036	.29	-.16	-.049	.029	-.21	-.053	.028
PDSS category				-.065	.033	-.25*	-.060	.032
Sex x PDSS							-.067	.031
ID Pref Ratio								
<i>Adjusted R²</i>								
<i>F for R²</i>								

** denotes $p = .01$