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Maternal depression and the learning-promoting effects of infant-directed speech: Roles of maternal sensitivity, depression diagnosis, and speech acoustic cues

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Abstract

The hypothesis that the associative learning-promoting effects of infant-directed speech (IDS) depend on infants' social experience was tested in a conditioned-attention paradigm with a cumulative sample of 4- to 14-month-old infants. Following six forward pairings of a brief IDS segment and a photographic slide of a smiling female face, infants of clinically depressed mothers exhibited evidence of having acquired significantly weaker voice–face associations than infants of non-depressed mothers. Regression analyses revealed that maternal depression was significantly related to infant learning even after demographic correlates of depression, antidepressant medication use, and extent of pitch modulation in maternal IDS had been taken into account. However, after maternal depression had been accounted for, maternal emotional availability, coded by blind raters from separate play interactions, accounted for significant further increments in the proportion of variance accounted for in infant learning scores. Both maternal depression and maternal insensitivity negatively, and additively, predicted poor learning.

1. Introduction

Parents increase the salience of their speech to infants by slowing its rate, exaggerating changes in pitch, hyper-articulating vowels, and repeating key words and phrases (Fernald, 1984). For young infants, infant-directed speech (IDS) is more effective than adult-directed speech (ADS) at altering infant state, eliciting infant responding, and promoting infant attention and rudimentary cognitive-linguistic processes (Cooper & Aslin, 1990; Fernald, 1984; Ma, Golinkoff, Houston, & Hirsh-Pasek, 2011). Importantly, IDS may be particularly effective at inducing social preferences: relative to a novel face, infants prefer to look at the face of a woman they had seen and heard talking in IDS intonation (Schachner & Hannon, 2011). In contrast, infants prefer a novel face to that of a woman they had seen and heard talking in ADS intonation. Thus, IDS is a powerful promoter of infant attention and learning, and stimuli correlated with it may acquire greater interest.

However, depressed mothers produce IDS that is deficient in perceptual salience, infant focus, and degree of contingency on infant behavior (Bettes, 1988; Kaplan, Bachorowski, &

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Zarlengo-Strouse, 1999; Murray, Kempton, Woolgar, & Hooper, 1993). Social factors may be particularly influential in cognitive and language development. According to Kuhl (2007) “social gating” hypothesis, parents use of IDS, and the arousal and attention generated by contingent parental responding, increases the robustness and durability of stimulus–stimulus (e.g., word-object) associations acquired during joint attentional states (see also Ma et al., 2011). Various aspects of rudimentary language development can be facilitated by contingent interaction with live partners, above and beyond mere exposure video and audio stimulation (Kuhl, Tsao, & Liu, 2003; Roseberry, Hirsh-Pasek, Parish-Morris, & Golinkoff, 2009).

Research has revealed that, in comparison to IDS produced by non-depressed mothers, IDS produced by depressed mothers is less effective at promoting a basic kind of learning in infants (Kaplan et al., 1999). But given that deficits in the salience of IDS are highly correlated with deficits in its degree of contingent delivery (Bettes, 1988), and further given evidence that maternal depression and maternal insensitivity each adversely affect the kinds of joint mother–infant attention that promotes infant learning (Raver & Leadbeater, 1995), questions remain about relative roles of low perceptual salience and low contingency as determinants of learning deficits in infants of depressed mothers. The purpose of the present research was to evaluate these alternative explanations for effects of IDS on infant learning in a conditioned-attention paradigm using a cumulative sample of infants of non-depressed and depressed mothers.

Originally motivated by evidence that IDS is particularly effective at increasing an infant’s state of arousal (i.e., sensitization and dishabituation effects; Kaplan, Goldstein, Huckleby, & Cooper, 1995), Kaplan and colleagues performed a series of experiments to test whether IDS can facilitate the acquisition of an association with a visual stimulus that soon follows it (Kaplan, Jung, Ryther, & Zarlengo-Strouse, 1996). The rationale was that the increase in central arousal elicited by IDS would persist after the presentation of the visual stimulus, and promote the formation of a stimulus–stimulus association. Analogous effects have been documented in non-human animals.

To test this hypothesis, the researchers developed a laboratory model of associative learning, a conditioned-attention paradigm, diagrammed in Fig. 1. In the pairing phase, a 10-s segment of IDS (the nominal conditioned stimulus or CS) preceded the presentation of a 10-s face reinforcer (the nominal unconditioned stimulus or UCS; forward pairings). In a control condition, a 10-s presentation of a face reinforcer preceded the presentation of a 10-s segment of IDS, such that the IDS did not predict the visual stimulus (backward pairings). To test whether the IDS segment acquired the ability to control infant attention, all infants were tested with 4 10-s presentations of a novel 4×4 checkerboard pattern. The IDS segments from the pairing phase were played simultaneously with the first and fourth checkerboard presentations, whereas the second and third checkerboard presentations occurred in the absence of sound. The extent to which the IDS stimuli increased looking at the checkerboard pattern (“positive summation”) in a forward-pairing condition, above that in a backward-pairing condition (and in other studies, random and “no CS” control conditions, Kaplan, Fox, & Huckleby, 1992), comprised the measure of associative learning. Associative learning is important because it is a phylogenetically old and ubiquitous

mechanism for infants to learn “what goes with what” in the environment (Rovee-Collier, 1986). Results showed that when an unfamiliar non-depressed mother’s IDS signaled the occurrence of a face (forward pairing condition), it acquired the ability to significantly increase looking at the checkerboard pattern in 4-month-old infants of non-depressed mothers. In contrast, when an unfamiliar non-depressed mother’s IDS occurred after the face (backward pairing condition), it had no effect on looking at the checkerboard. Similarly, an unfamiliar non-depressed mothers ADS had no effect on looking at the checkerboard pattern following either forward or backward pairings with a face (Kaplan et al., 1996). These findings showed that IDS is more effective than ADS at promoting this form of learning, possibly because of differences in IDS vs. ADS stimulus-induced sensitization (Kaplan, Zarlengo-Strouse, Kirk, & Angel, 1997).

A conditioned-attention paradigm was used in subsequent experiments to assess the learning-promoting properties of IDS produced by mothers with symptoms of depression. Although all mothers increase the mean fundamental frequency (F_0) of their IDS, clinically depressed mothers and mothers diagnosed with major depression in partial remission exhibit a significant restriction in fundamental frequency (F_0) range in their IDS (F_0 max- F_0 min, or F_0), in comparison with non-depressed mothers and with mothers diagnosed with minor depression, anxiety disorders, and major depression in full remission (Porritt, Zinser, Bachorowski, & Kaplan, 2014). Because of the demonstrated importance of F_0 modulation in eliciting infant responding (Cooper & Aslin, 1990; Fernald & Kuhl, 1987; Kaplan & Owren, 1994), it was predicted that IDS produced by depressed in comparison with non-depressed mothers would less effectively promote infant learning in this paradigm.

Indeed, groups of 4-month-old infants of non-depressed mothers for whom a segment of IDS produced by an unfamiliar, depressed mother signaled a smiling face showed no evidence of associative learning on the post-conditioning test, whereas groups of 4-month-old infants of non-depressed mothers tested with IDS produced by an unfamiliar non-depressed mother showed evidence of significant learning on the post-conditioning test (Kaplan et al., 1999). In preliminary support of the perceptual salience hypothesis, F_0 in the maternal IDS stimuli was significantly correlated with the group mean learning scores for groups of infants who were tested with those stimuli.

This initial study assessed the learning-promoting effects of unfamiliar depressed and non-depressed mothers’ IDS in infants without a history of potentially disordered interactions with a depressed primary caregiver. To test whether infants of depressed mothers would exhibit a similar pattern of findings, and further to determine if their ability to form voice–face associations might have been degraded as the result of disordered mother–infant interactions, a follow-up study compared voice–face associative learning in 4-month-old infants of clinically depressed versus non-depressed mothers. Results showed that 4-month-old infants of depressed mothers did not acquire associations in response to their own or an unfamiliar clinically depressed mother’s IDS, but did exhibit significant learning in response to an unfamiliar non-depressed mother’s IDS (Kaplan, Bachorowski, Smoski, & Hudenko, 2002). Thus, 4-month-old infants of depressed mothers did not differentiate between their own versus an unfamiliar depressed mother’s IDS, but the fact that they did exhibit an ability to learn in this paradigm in response “normal” IDS produced by an unfamiliar non-

depressed mother suggested that, at least at this age, their general associative learning abilities were intact. Perhaps depressed mothers' IDS sounded similar to ADS to these infants, or lacked the positive affect that typically characterizes IDS (Kitamura & Burnham, 1998).

As outlined above, an alternative hypothesis was that a history of prior non-reinforcement in social interactions with depressed mothers reduced the "associability" of the infant's own mother's IDS, and this "tuning-out" accounted for the poor voice-face associative learning during the conditioning test. Such an effect would be analogous to "latent inhibition" or "learned irrelevance" effects in classical conditioning studies: pre-conditioning exposure to isolated presentations of the to-be CS, or to random presentations of the to-be CS and the UCS, produce a transfer effect or "retardation" of conditioning when the pre-exposed stimulus is subsequently used to positively predict the UCS in a forward-pairing conditioning arrangement (Linden, Savage, & Overmeier, 1997). Under this view, social interactions leading up to the laboratory visit, more than the low perceptual salience of "depressed" IDS, were the proximal causes of poor infant learning in the laboratory. Here, we refer to this experience-based tuning-out of an infant's own mother's IDS "specific learned irrelevance."

Despite the preliminary support for it, several lines of evidence now cast doubt on the perceptual salience hypothesis, and are at least consistent with the learned irrelevance account. First, although there was a significant negative correlation between F_0 in maternal IDS samples and mean learning scores for *groups* of infants of non-depressed mothers who were tested with those samples (Kaplan et al., 1999), several subsequent small sample studies have failed to show significant correlations between F_0 in IDS speech samples and *individual* infant learning in infants of depressed and non-depressed mothers (Kaplan, Burgess, Sliter, & Moreno, 2009).

Second, although the learning failures in response to an infant's own depressed mother's IDS have been observed consistently in infants ranging in age from 4 to 13 months (Kaplan et al., 1999; Kaplan, Dungan, & Zinser, 2004; Kaplan et al., 2009), learning outcomes for these infants in response to "normal" IDS produced by unfamiliar non-depressed mothers have varied with the chronicity and timing of the infant's own mother's depression. In one study, the strength of the associative learning among infants of depressed mothers in response to non-depressed mothers' IDS was inversely proportion to the postpartum duration of the infant's own mother's depression (Kaplan et al., 2004). In another study, individual infants of depressed mothers were found to exhibit significant learning in response to an unfamiliar non-depressed mother's IDS at 4 months, but not at 12 months (Kaplan, Danko, Kalinka, & Cejka, 2012). Finally, 12-month-old infants of currently depressed mothers with perinatal depression onset did not exhibit significant voice-face associative learning in response to an unfamiliar non-depressed mother's IDS, whereas 12-month-old infants of currently depressed mothers with later depression onset (mean duration of 4 months) did (Kaplan, Danko, Diaz, & Kalinka, 2011). Thus, consistent with a role for an infant's experience with a depressed primary caregiver, infants of chronically depressed mothers not only failed to learn in response to their own mothers' IDS in this paradigm, but also eventually exhibited poor learning in response to normal IDS. However, infants of

chronically depressed mothers exhibit stronger-than-normal learning in this paradigm in response to an unfamiliar father's IDS (Kaplan et al., 2004; Kaplan, Danko, & Diaz, 2010).

Taken together, these findings were consistent with a progressive “tuning-out” of non-depressed mothers' IDS in infants of chronically depressed mothers, and inconsistent with the perceptual salience hypothesis. The researchers hypothesized that learned irrelevance of an infant's own mother's IDS (“specific learned irrelevance”) might eventually generalize to other similar stimuli, such as non-depressed mother's IDS (“generalized learned irrelevance”), but not to less similar stimuli, such as an unfamiliar non-depressed father's IDS.

Third, the “specific learned irrelevance” hypothesis has been supported in recent research in which the current quality of mother–infant interactions was used as a proxy measure for the general degree of contingent mother–infant interactions. Researchers (Kaplan et al., 2009) trained 5–13-month-olds on a forward pairing arrangement in which their own mother's IDS signaled a smiling female face, and separately assessed the quality of mother–infant interactions during a 10-m semi-structured play session. Videotapes of play sessions coded by blind raters using the Emotional Availability Scales (EAS; Biringen, Robinson, & Emde, 1993; Emde, 1980) showed that, relative to non-depressed controls, depressed mothers were significantly lower in sensitivity and significantly higher in (covert) hostility. Infants of depressed mothers were rated as significantly lower in responsiveness to the mother relative to infants of non-depressed mothers, consistent with the hypothesized “tuning-out.” However, only maternal sensitivity correlated with infant learning in response to maternal IDS. A hierarchical linear regression revealed that maternal depression was not significantly related to infant learning after demographic risk factors and antidepressant medication use had been taken into account, but that maternal sensitivity did significantly predict infant learning after all other variables, including F_0 in IDS, had been entered into the regression equation. This finding suggested that the quality of mother–infant interactions was more important than either maternal depression per se or speech acoustic variables in predicting infant learning in this paradigm.

The purpose of the present study was to further investigate the roles of the perceptual salience of IDS, maternal depression, and maternal sensitivity in accounting for infant learning in response to their own mother's IDS in a conditioned attention paradigm. The prior study included only a small sample of infants. The present report includes analyses of a cumulative data set, including the 55 mothers and infants in the Kaplan et al. (2009) study, plus an additional 81 mothers and infants whose data are reported here for the first time. Based on previous work, we predicted that, consistent with a specific learned irrelevance account, F_0 in maternal IDS would not predict individual infant learning. Further, we predicted that any effects attributed to maternal depression would be mediated by maternal sensitivity.

2. Method

2.1. Participants

One hundred and sixty-five mothers ($M_{\text{age}} = 30.9$ years, age range: 18–40 years) and their 4–14-month-old infants ($M_{\text{age}} = 335.9$ days, age range: 115–433 days; 95 girls and 70 boys) were recruited to the study. One hundred and six (64.2%) of the infants were white, 33 (20.0%) were Latino, 17 (10.3%) were African-American, 7 (4.2%) were Asian, and 2 (1.2%) were Native American. Median maternal education level was 6.0, where 5.0 = graduated from a 2-year college, and 6.0 = graduated from a 4-year college. Median family income was 8.0, where 7.0 = \$40,000–50,000 per year and 8.0 = \$50,000–60,000 per year.

Complete data sets were obtained for 136 of these, as 29 infants did not provide learning data due to excessive fussiness (25 infants of NDEP mothers and 4 infants of DEP mothers). Demographic data for this subsample is presented in Table 1 as a function of maternal depression diagnosis. Data for the 136 successful tests are the focus of the analyses below.

2.2. Apparatus

During conditioned-attention tests, the infant was seated in front of a large flat-black board. Infants under 6 months of age were seated in a car seat, whereas the mothers of older infants sat in an adjustable barber's chair, and infants sat in their laps. Previous research indicated that these two testing methods produced equivalent results in this paradigm (Linden et al., 1997). In both cases, the infant's eyes were level with a 4-in square translucent Plexiglas projection screen that was embedded in the board. Located 1.9 cm to the infant's left of the projection screen was an aperture through which a low-light video camera (SONY Exwave black-and white camera) recorded the infant's face. Independent observers watched full-face views of the infant on 48.3-cm video monitors. Auditory stimuli were presented using a SONY TCM 5000EV tape player. The tape player was situated 10 cm below and 33.5 cm behind the infant's head. The average distance from the infant's head to the projection screen was approximately 42 cm. Two visual stimuli, a black-and-white slide of a smiling adult female face and a black-and-white 4×4 checkerboard pattern (checks subtended 3° of visual angle), were presented using two computer-controlled slide projectors outfitted with shutters.

2.3. Speech stimuli

IDS segments were recorded during a 3-min session, using the protocol developed in prior studies (Kaplan, Bachorowski, Smoski, & Zinser, 2001). Each dyad first had a 2-min warm-up period during which mothers were asked to play freely with their infants. Then, mothers were handed a small stuffed toy gorilla and asked to interest their infants in it using the phrase "pet the gorilla." This phase lasted approximately 60 s. The first two interrogative (e.g., "Want to pet the gorilla?") and first declarative ("Pet the gorilla") utterances were selected, assembled in precise temporal sequence across mothers, and repeated once to yield a 10-s speech stimulus (e.g., "Want to pet the gorilla? Can you pet the gorilla? Pet the gorilla. Want to pet the gorilla? Can you pet the gorilla? Pet the gorilla"). Each infant was tested only with her own mother's IDS stimulus.

2.4. Acoustic analyses

Speech samples were digitized at 44 kHz with 16-bit resolution and submitted to analyses of mean fundamental frequency (F_0) and mean F_0 range (F_0) using Speech Station2 (Sensimetrics Corp., Somerville, MA) and Praat Acoustic Analysis Software (Boersma & David, 2009).

2.5. Assessment of depressive symptoms

All mothers were administered the BDI-II (Beck, Steer, & Brown, 1996; Steer, Ball, Ranieri, & Beck, 1997), a 21-item self-report measure that is a widely used instrument for assessing the affective, cognitive, motivational, and physiological symptoms associated with depression. The BDI-II has significant correlations with psychiatric ratings in clinical samples (Steer et al., 1997).

In addition, all mothers were administered the Structured Clinical Interview for DSM-IV Diagnosis (SCID; First, Gibbon, Spitzer, & Williams, 2001). Clinical diagnoses were made by Ph.D.-supervised clinical psychology graduate students. Students had received extensive training with the SCID and DSM-IV diagnosis. Interviews lasted about 1 h. Inter-rater reliability for diagnoses of Major Depression, calculated between the primary rater and a Ph.D.-level second rater yielded a kappa value of .80. Final diagnoses were based on the primary rater. We reserve the term “depressed” (DEP), for individuals diagnosed with a current DSM-IV Axis-I depression-spectrum disorder. Those without this diagnosis are called non-depressed (NDEP).

2.6. Emotional availability scales

Emotional availability scales (EAS; Biringen et al., 1993; Emde, 1980) were used to assess the quality of current mother–infant interactions. The dyad was given a basket of attractive, age-appropriate toys and told by the examiner, “Now you can just play together for a few minutes and I will come back in when the next activity is ready.” The ensuing free-play interactions were videotaped through a 1-way mirror for 10 min. Later, coders who were blind with respect to maternal diagnosis rated the videotapes on 3 scales that assessed the parent’s behavior, *Maternal Sensitivity*, *Maternal Covert and Overt Hostility*, and *Maternal Structuring/Non-Intrusiveness*, and 2 scales that assessed the child’s behavior, *Child Responsiveness to Maternal Bids* and *Child Involvement of Mother in Play*.

Emotional availability is a dyadic construct that assesses the parent and child’s ability to decipher and respond to each other’s emotional states and cues. Detailed criteria for scoring the EAS have been published (Biringen et al., 1993; Biringen, 2008). For each subscale, higher scores generally indicate more of the target construct. *Maternal Sensitivity* (10-pt scale) refers to the parent’s contingent responsiveness to the child, her ability to pick up on infant cues, to be warm and soothing during distress, to find stimulating and creative ways to play, and to have high-quality affective exchanges with the child. *Maternal Covert and Overt Hostility* (5-pt scale) involves a parent showing overt or covert discontent, impatience, or anger. *Maternal Structuring/Non-Intrusiveness* (9-pt scale) assesses the extent to which the parent provides an appropriate balance between parent- and child-directed activities, and provides “emotional containment” when necessary, but without intrusiveness, over-

stimulation or being overly controlling. Lower scores on the *Structuring/Non-Intrusiveness* scale indicate low structuring (consistent with emotional withdrawal), a score of 5 indicates optimal structuring, and higher scores indicate overly structuring/intrusive. *Child Responsiveness to Parental Bids* (9-pt scale) reflects the child's willingness to engage the parent following a parental bid, and the degree of pleasure displayed by the child in the interaction. *Child Involvement of Parent in Play* (9-pt scale) reflects the extent to which the child engages the parent in play.

Videotapes were coded by M.A.-level clinical psychologists after extensive training by an expert in EASs. Reliability videotapes and training manuals were used to train observers to a reliability of .70 or greater with the trainer on three consecutive tapes of lab visits. Intra-class correlations coefficients calculated for 15% EAS participants were .81 for *Parental Sensitivity*, .70 for *Parental Structuring/Non-intrusiveness*, .69 for *Parental Covert and Overt Hostility*, .67 for *Child Responsiveness to Parental Bids*, and .72 for *Child Involvement of the Parent in Play*.

The reliability and validity of the EAS has been established in several studies (Biringen et al., 1993; Easterbrooks, Biesecker, & Lyons-Ruth, 2000). Test-retest reliability is high through the child's second year of life (Biringen et al., 1993), and significant correlations have been shown between EAS scales and attachment classification (Pederson & Moran, 1995).

2.7. Procedure

Immediately after filling out informed consent forms and questionnaires, the IDS recording session was conducted in one room. Then, the mother and infant were videotaped in the play interaction for later EAS coding in a different room. During the videotaping, an experimenter prepared IDS segments for presentation to the infant in a conditioned-attention test (3rd room). Finally, SCIDs were administered to the mothers.

As reviewed above in Fig. 1, during the pairing phase, with the projection screen uniformly illuminated, an infant first heard a 10-s "pet the gorilla" speech segment recorded from her own mother. At the offset of the speech segment, a 10-s presentation of a black-and-white photographic slide of a smiling adult female face appeared on the projection screen. A 10-s inter-stimulus interval (ISI), during which the projection screen was uniformly illuminated and only background noise was heard, immediately followed the offset of the face. Each infant was tested only with her own mother's IDS. Infants received 6 non-overlapping speech segment-face pairings. Ten s after the offset of the sixth face, the post-conditioning summation test phase began. Infants received 4 10-s presentations of a 4 × 4 black-and-white checkerboard pattern (10-s ISIs). The speech segment from the pairing phase was presented simultaneously with the first and fourth checkerboards, whereas the second and third checkerboards occurred with only background noise (measured at 58 dB). Durations of infant looking at the projection screen during the 10-s speech, face, and checkerboard trials were recorded. Looking was signaled to a computer using a hand-held switch by 2 independent observers when the reflection of the visual stimulus was centered on the infant's pupils. A second observer was present for 87% of the tests (mean inter-observer reliability = .91, SD = .05).

2.8. Data analysis

Preliminary analyses examined effects of maternal depression on demographic variables, EAS, speech acoustic measures, and conditioned-attention performance. Next, descriptive statistics and effects of maternal depression on the EAS were analyzed. Infant voice–face associative learning was assessed during a summation test phase to determine the extent to which the IDS stimulus that had been paired with the face increased looking at a novel checkerboard pattern. Finally, relations between depression and EAS, depression and conditioned-attention performance, and EAS and conditioned-attention performance were analyzed using correlational techniques, hierarchical linear regression, and analysis of variance. The key hypothesis tested was whether EAS-based maternal sensitivity predicted infant learning after key demographic variables, speech acoustic variables, and clinical diagnosis had been taken into account.

3. Results

3.1. Demographic and diagnostic information

Table 1 provides a summary of demographic and diagnostic information for the 136 mother–infant dyads that completed all testing. Depressed mothers were more likely than non-depressed mothers to be from an underrepresented group, and had significantly lower levels of formal education. Fifty-nine mothers (43.4%) had elevated self-report scores on the BDI-II, and 20 (14.7%) received a current DSM-IV Axis-I diagnosis of major depressive disorder (MDD; $n = 16$) or depressive disorder not otherwise specified (DDNOS; $n = 4$). In addition, 17 mothers (12.5%) were diagnosed with a depressive episode in partial remission (PR), and 21 mothers (15.4%) were diagnosed with a depressive episode in full remission (FR). In comparisons between NDEP and DEP conditions below, FR and PR mothers were included in the NDEP group, unless otherwise noted.

3.2. Emotional availability scales

Mean ratings from the EAS were analyzed as a function of mother's diagnosis. A 2 (NDEP vs. DEP) $\times$ 5 (EAS subscale) MANOVA carried out on the subset of infants who also completed the conditioned-attention test ($n = 136$) showed no significant multivariate effect of EAS subscales, $F(5, 130) = 1.15$, $p = .34$, and no significant effect of depression diagnosis on any of the scales, $F(1, 134) = 1.95$, $p = .17$ for Sensitivity, $F(1, 134) = 3.00$, $p = .09$ for Hostility, and $F(1, 134) = 2.20$, $p = .14$ for Child Responsiveness.³ Similarly non-significant effects were obtained when a 4-level maternal depression variable (NDEP, FR, PR, DEP) was used.

3.3. Speech acoustics

Mean F_0 calculated across each mother's 3 "pet the gorilla" utterances did not differ for NDEP vs. DEP mothers, $M_s = 139$ vs. 130 Hz, respectively, $F(1, 134) = .39$. F_0 correlated

³A 2 (NDEP vs. DEP) $\times$ 5 (EAS subscale) MANOVA carried out on the full sample of 165 mother–infant dyads demonstrated a significant multivariate effect of depression diagnosis, $F(5, 160) = 3.13$, $p = .01$, $\eta^2 = .090$. There were significant differences between currently clinically depressed and non-depressed mothers in mean scores on the Sensitivity scale, $F(1, 163) = 6.42$, $p = .02$, $\eta^2 = .038$, the hostility scale, $F(1, 163) = 8.30$, $p = .01$, $\eta^2 = .048$, and the Child Responsiveness Scale, $F(1, 163) = 10.84$, $p = .001$, $\eta^2 = .061$.

positively with maternal education, $r = .19$, $p = .05$. When depression was entered as a 4-level variable (NDEP, FR, PR, DEP), there was a significant overall effect, $F(3, 131) = 3.49$, $p = .02$, $\eta^2 = .077$, with significant differences in F_0 between the FR ($M = 170$ Hz) and each of the other 3 conditions (never depressed, $M = 137$ Hz, PR, $M = 117$ Hz, currently depressed, $M = 130$ Hz).

3.4. Conditioned-attention tests

Pairing phase—Table 2 shows mean looking durations on the first and last presentations of the IDS speech segments (during which the projection screen was uniformly illuminated) and on the first and last face presentations in the pairing phase. As in all prior conditioned attention studies, there were no significant differences as a function of maternal depression in mean response levels during IDS segments or face stimuli, and no significant changes in responding to either stimulus across trials. The same findings were obtained here, and for the sake of brevity, those aspects of the data are not discussed further.

Summation test phase—During the post-learning test phase, speech segments were presented simultaneously with the first and fourth checkerboards (Trials 7 and 10), whereas the other two checkerboard presentations occurred alone. As seen in Table 2, averaged across the two checkerboard-alone test trials, there were no differences in duration of looking as a function of maternal diagnosis, $F(1, 134) = .40$, consistent with equivalent baseline response levels in those groups.

A 2 (mother NDEP or DEP) $\times$ 4 (test trials) split-plot repeated measures ANOVA on looking times across all 4 test trials (with Greenhouse–Geisser corrected df) revealed no significant effect of diagnostic condition, but a significant effect of trials, $F(3, 375) = 6.62$, $p = .001$, $\eta^2 = .05$. And although the maternal diagnosis $\times$ trials interaction was not significant, $F(3, 375) = 2.30$, $p = .08$, there was a significant quadratic trend in the diagnosis $\times$ trials interaction term, $F(1, 134) = 4.74$, $p = .05$, $\eta^2 = .035$. Infants of NDEP mothers showed a more pronounced U-shaped response function across test trials than did infants of DEP mothers. When the test trial data were reanalyzed using the 4-level depression variable rather than the binary depression variable, there were no significant effects.

For each infant, a difference score was calculated by subtracting the mean looking time on the two checkerboard only test trials from the mean looking on the two voice-plus-checkerboard test trials. This difference in looking reflects the extent of “positive summation,” a standard indirect assessment of associative learning (Biringen, 2008). Because previous research has shown significant positive summation after forward but not backward pairings of IDS segments and faces (Kitamura & Burnham, 1998), it has been interpreted to reflect the formation of a voice–face association. Mean difference scores, shown in Table 2, were significantly higher for infants of NDEP than DEP mothers, $F(1, 134) = 7.05$, $p = .01$, $\eta^2 = .049$. Mean difference scores were also significantly higher for infants of mothers with non-elevated in comparison with elevated self-report BDI-II scores, $F(1, 134) = 4.28$, $p = .05$, $\eta^2 = .031$. Mean difference scores for infants of the never depressed, FR, PR, and currently depressed mothers were 1.22 s ($SE = .27$, $n = 78$), 1.26 s ($SE = .59$, $n = 21$), 1.79 s ($SE = .52$, $n = 17$), and $-.12$ s ($SE = .38$, $n = 20$), respectively.

Difference scores did not correlate significantly with infant age, $r(136) = -.02$, or, for infants of depressed mothers, with the duration of the mother's current depressive episode, $r(20) = .38$, $p = .10$.

3.5. Relations between demographics, diagnostics, EAS and infant learning

As shown in Table 3, mean difference scores were significantly positively correlated with maternal sensitivity and significantly negatively correlated with maternal hostility and maternal depression (1 = currently clinically depressed; -1 = not currently clinically depressed). To follow up on these correlations and to determine the relative contributions of diagnostic, demographic, speech acoustic, and EAS variables to infant learning as measured by difference scores, a hierarchical linear regression was performed (Table 4). Significant demographic correlates of clinical depression (ethnicity and maternal education) were entered into the analysis in step 1, followed by mean F_0 in IDS segments, antidepressant medication use (1 = current use, -1 = no current use), depression diagnosis (1 = current clinical depression; -1 = no current clinical depression), maternal hostility and maternal sensitivity in steps 2–6.

Table 4 shows that maternal education and ethnicity, medication use, and F_0 did not account for significant proportions of the variance in infant learning scores. However, after effects of those variables had been controlled, current depression diagnosis accounted for a significant proportion of the variance in infant learning (R^2 change = .038). After effects of maternal depression had been accounted for, there was a significant effect of maternal hostility, $R^2 = .051$, $F(1, 129) = 7.42$, $p = .01$. Finally, there was a further significant effect of maternal sensitivity, $R^2 = .038$, $F(1, 128) = 5.76$, $p = .02$, and the effects of maternal hostility was no longer significant ($\beta = -.131$, $t = 1.42$, $p = .16$) but the effect of maternal depression was still significant ($\beta = -.170$, $t = 2.00$, $p = .05$).

Fig. 2 presents the mean difference scores as a function of depression diagnosis and maternal sensitivity category (created by a median split of the sensitivity scores). A 2 (NEP vs. DEP) $\times$ 2 (high vs. low sensitivity) ANOVA yielded a significant main effect of depression, $F(1, 132) = 7.83$, $p = .01$, $\eta^2 = .056$, and a significant main effect of sensitivity category, $F(1, 132) = 4.73$, $p = .05$, $\eta^2 = .035$, but no significant depression $\times$ sensitivity interaction, $F(1, 132) = .62$.

4. Discussion

The relative contributions of demographic variables, extent of F_0 or pitch modulation, maternal depression diagnosis, antidepressant medication use, and rated maternal emotional availability to infant voice–face associative learning were tested in a conditioned-attention paradigm. In this cumulative sample of 136 4–14-month-old infants, depression diagnosis accounted for a significant proportion of the variance in infant learning scores even after extent of pitch modulation in IDS stimuli, demographic correlates of depression, and antidepressant medication use had been taken into account. Current maternal depression, but not depression in full- or partial-remission, was linked to weaker learning. However, a significant additional proportion of variance in infant learning scores was subsequently attributable to rated maternal emotional availability. Specifically, maternal covert hostility

and maternal sensitivity were each linked to significant further increments in R^2 , although the effect of maternal hostility was no longer significant after maternal sensitivity had been entered into the regression model.

Thus, contrary to prior work, after demographic correlates of maternal depression had been factored in, maternal depression did have a significant effect on infants learning, albeit with a small effect size, and furthermore this effect persisted even after effects of maternal emotional availability had been explained. Consistent with prior work, maternal sensitivity accounted for a significant proportion of the variance in infant learning after maternal clinical depression had been accounted for, although, again, with a small effect size. In fact, an ANOVA showed significant categorical main effects for both maternal depression and maternal sensitivity.

The primary aim of this study was to further test the “specific learned irrelevance hypothesis,” according to which a history of relatively low maternal contingent responding reduces the associability of depressed mothers’ IDS for stimuli like smiling female faces. Such a reduction in associability or “tuning-out” of maternal stimulation is consistent with analogous studies from the animal conditioning literature in which stimuli that had previously been presented in isolation, or in a non-contingent arrangement with reinforcement, are subsequently “retarded” in their ability to enter into association with the reinforcer (Rescorla, 1971).

With this analogy in mind, maternal sensitivity, as measured by the EAS, was used as a proxy measure for the current, and presumably historical pattern of contingent interactions between mother and infant. Results supported the primary hypothesis. However, there is a potential, although only subtly different, alternative explanation. According to the EAS, as detailed above, maternal sensitivity encompasses the mother’s contingent responsiveness to the child, but also her ability to pick up on infant cues, to be warm and soothing during distress, to be stimulating in play interactions, and to have high-quality affective exchanges with the child. However, although these behaviors are no doubt highly correlated with one another, ratings of a mother’s sensitivity do not *only* reflect her degree of contingent responsiveness. Far from tuning out the mother, within the context of a conditioned transfer explanation, it is possible that an infant learns to associate stimuli from the mother with previously experienced emotional states. Infants of mothers with non-optimal patterns of interaction may come to associate maternal IDS with sad, frustrated, anxious, or bored feelings, which can then influence their responding to their own mother’s voice and, through a process of stimulus generalization, to the voices of unfamiliar women (“generalized learned irrelevance). Additional research will be needed to tease-apart learned irrelevance and “learned (negative) emotional states” explanations.

The fact that variations in F_0 in maternal speech samples did not correlate with variations in individual infant learning was consistent with prior studies with small samples (Kaplan et al., 2004; Kaplan et al., 2009), and ruled out an explanation of infant learning in this paradigm based on F_0 -based cues. Surprisingly, mean F_0 in IDS samples from FR mothers was significantly higher than that in never-depressed, PR, and currently depressed mothers. This is in contrast to findings from a larger sample of infants in which a non-significant

trend in this direction was obtained (Kaplan et al., 1997), and may hint at a possible rebound effect on maternal vocal stimulation from a recent depressive episode. However, learning outcomes did not differ significantly between infants of NDEP and FR mothers. Learning outcomes did differ between infants of PR and DEP mothers, even though there were no significant differences in F_0 between these two groups.

Still, it is possible that other speech acoustic cues may be able to account for the separable effects of maternal depression diagnosis on infant learning outcome. Specifically, sound energy contained in harmonics above the F_0 may affect infant responding to speech stimuli. Prior research has shown that F_0 modulation and spectral complexity combine to determine the effectiveness of IDS (Colombo & Horowitz, 1986). Furthermore, harmonics are critical in determining the location of formant frequencies, or resonance patterns, in speech. When mothers adopt the IDS speech register, not only do mothers exaggerate changes in F_0 , but they also tend to hyper-articulate vowels, as indicated by exaggerated differences in “vowel space” (i.e., the frequency locations of the first and second formants) in point vowels (but see Ref. (Benders, 2013). Although no published research has described the effects of maternal depression on spectral composition of IDS, normal IDS contains higher formant frequencies than ADS (Englund & Behne, 2005). Thus, we cannot rule out a role for spectral- or formant-based acoustic cues in infant responding to IDS.

We observed no correlation between an infant’s learning score in response to his or her own mother’s IDS in this paradigm and either the age of the infant or, for infants of depressed mothers, the duration of the infant’s mother’s current depressive episode. If the specific learned irrelevance hypothesis is correct, then infants must learn to tune-out their mother’s IDS relatively early in the first year, because poor response to maternal IDS by these infants is present as early as 4 months postpartum (Kaplan & Owren, 1994), and remains constant throughout the first year. In contrast, evidence suggests that generalized learned irrelevance, inferred based on learning failures by infants of depressed mothers in response to “normal” IDS recorded from non-depressed mothers, does not occur in infants of continuously depressed mothers until approximately 8 months postpartum (Kaplan et al., 2012). But both in the case of learning in response to the infant’s own depressed mother’s IDS, and in the case of learning in response to an unfamiliar non-depressed mother’s IDS for infants of depressed mothers, responding appears to depend on experience.

These findings suggest that maternal sensitivity is linked to the efficacy of IDS stimulus-induced facilitation of a stimulus–stimulus association. What is the significance of this kind of learning for infants? As stated previously, the ability to learn stimulus–stimulus associations is fundamental, as reflected by its ubiquity developmentally and throughout the animal kingdom. Through this kind of basic learning infants can learn “what goes with what” in their world (Rovee-Collier, 1986). Factors that adversely affect or interfere with this kind of learning will presumably slow the child’s accumulation of a knowledge base.

Unfortunately, the evidence that stimulus–stimulus learning, as measured through conditioned-attention performance, is associated with important outcomes in infant cognitive and language development is limited. There is evidence that mean F_0 in maternal IDS “pet the gorilla” utterances itself correlates significantly with MCDI productive vocabulary

scores (Kaplan et al., 1997), suggesting that the speech acoustic cues which were not predictive of associative learning here may nonetheless play some role in rudimentary language acquisition. In addition, difference scores from conditioned-attention tests with 12-month-olds in which an unfamiliar non-depressed mother's IDS signaled a smiling face correlated significantly with concurrent MacArthur Communicative Development Inventory (MCDI; Fenson et al., 2000) receptive vocabulary scores (Kaplan et al., 2011); a floor effect may have prevented detection of an effect on MCDI productive vocabulary scores). To date, though, no evidence has linked deficits in conditioned-attention performance to general cognitive development. In this context, the small effect sizes we obtained linking maternal depression, maternal sensitivity, and infant learning are concerning. Additional research will be needed to establish links between this kind of associative learning and more global measures of infant cognitive development.

In contrast, a growing body of data shows that maternal sensitivity and contingent responding predict advances in many aspects of child socio-emotional and cognitive development (Bornstein & Tamis-LeMonda, 1997). These relations have been attributed in part to contingent mothers fostering the expectation in infants that their behavior will affect the environment and those around them (Watson, 1985). The learned irrelevance hypothesis embodies the negation of this expectation, although with stimulus–stimulus rather than response–outcome associations.

Our findings suggest that low levels of maternal sensitivity in day-to-day interactions may not only reduce arousal, but may also produce active infant learning, as a result of which the ability of IDS to attract infant attention, serve as a reinforcer, and enter into association with ensuing visual, and possibly other, stimuli is diminished (Kaplan et al., 2004). Put another way, infants may be "...designed to find the human face, voice, and touch interesting and pleasurable but will stop responding to them positively if the mother does not tailor her ministrations to the baby's capacity to receive them" (Bornstein, Suwalsky, & Breakstone, 2012, p. 120). Sensitive caregivers may promote particularly durable associations in part through this kind of general-process learning mechanism.

Our research suggests that IDS in a sense carries with it something of the history of mother–infant interactions, possibly through an underlying associative learning mechanism, and this history affects ("gates?") the learning-promoting effects of IDS. The fact that infants of insensitive mothers become unresponsive even to "normal-sounding" IDS recorded from unfamiliar non-depressed mothers (Kaplan et al., 2011; Kaplan et al., 2012), and "hyper-responsive" to IDS recorded from unfamiliar, non-depressed fathers (Kaplan et al., 2010), suggests that the acquired significance and non-significance of IDS for infants in their day-to-day interactions transfers to subsequently encountered IDS, and may in some situations override its acoustic salience in determining infant responding.

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References

- Beck, AT., Steer, RA., Brown, GK. BDI-II: 2nd edition manual. San Antonio, TX: The Psychological Corporation; 1996.
- Benders T. Mommy is only happy! Dutch mothers' realization of speech sounds in infant-directed speech expresses emotion, not didactic intent. *Infant Behavior & Development*. 2013; 36:847–862. <http://dx.doi.org/10.1016/j.infbeh.2013.09.001>. <http://www.ncbi.nlm.nih.gov/pubmed/24239878>. [PubMed: 24239878]
- Bettes B. Maternal depression and motherese: Temporal and intonational features. *Child Development*. 1988; 59:1089–1096. <http://dx.doi.org/10.2307/1130275>. <http://www.ncbi.nlm.nih.gov/pubmed/3168616>. [PubMed: 3168616]
- Biringen, Z. The emotional availability (EA) scales. 4. Boulder, CO: Published by emotionalavailability.com; 2008.
- Biringen, Z., Robinson, JL., Emde, RN. Manual for scoring the emotional availability scales infancy to early childhood version. Boulder, CO: 1993.
- Boersma, P., David, W. Praat: Doing phonetics by computer (Version 5.1.05) [Computer program]. 2009. Available from: <http://www.praat.org/> (retrieved 01.05.09)
- Bornstein MH, Tamis-LeMonda CS. Maternal responsiveness and infant mental abilities: Specific predictive relations. *Infant Behavior & Development*. 1997; 20:283–296. [http://dx.doi.org/10.1016/S0163-6383\(97\)90001-1](http://dx.doi.org/10.1016/S0163-6383(97)90001-1).
- Bornstein MH, Suwalsky JTD, Breakstone DA. Emotional relationships between mothers and infants: Knowns, unknowns, and unknown unknowns. *Developmental Psychopathology*. 2012; 24:113–123. <http://dx.doi.org/10.1017/S0954579411000708>. <http://www.ncbi.nlm.nih.gov/pubmed/22292998>.
- Colombo J, Horowitz FD. Infants' attentional response to frequency modulated sweeps. *Child Development*. 1986; 57:287–291. <http://www.ncbi.nlm.nih.gov/pubmed/3956313>. [PubMed: 3956313]
- Cooper RP, Aslin RN. Preference for infant-directed speech in the first month after birth. *Child Development*. 1990; 61:1584–1595. <http://dx.doi.org/10.2307/1130766>. <http://www.ncbi.nlm.nih.gov/pubmed/2245748>. [PubMed: 2245748]
- Easterbrooks M, Biesecker G, Lyons-Ruth K. Infancy predictors of emotional availability in middle childhood: The roles of attachment security and maternal depressive symptomatology. *Attachment & Human Development*. 2000; 2:170–187. <http://dx.doi.org/10.1080/14616730050085545>. <http://www.ncbi.nlm.nih.gov/pubmed/11707909>. [PubMed: 11707909]
- Emde, RN. Emotional availability: A reciprocal reward system for infants and parents with implications for prevention of psychosocial disorders. In: Taylor, PM., editor. *Parent–infant relationships*. Orlando, FL: Grune & Stratton; 1980. p. 87–115.
- Englund K, Behne D. Infant-directed speech in natural interaction – Norwegian vowel quantity and quality. *Journal of Psycholinguistic Research*. 2005; 34:259–280. <http://dx.doi.org/10.1007/s10936-005-3640-7>. <http://www.ncbi.nlm.nih.gov/pubmed/16050445>. [PubMed: 16050445]
- Fenson L, Pethick S, Renda C, Cox JL, Dale PS, Reznick S. Short-form versions of the MacArthur Communicative Development Inventories. *Applied Psycholinguistics*. 2000; 21:95–116. <http://dx.doi.org/10.1017/S0142716400001053>.
- Fernald, A. The perceptual and affective salience of mothers' speech to infants. In: Feagans, L. Garvey, C., Golinkoff, R., editors. *The origins and growth of communication*. Norwood, NJ: Ablex; 1984. p. 5–29.
- Fernald A, Kuhl PL. Acoustic determinants of infant perception for motherese speech. *Infant Behavior & Development*. 1987; 10:279–293. [http://dx.doi.org/10.1016/0163-6383\(87\)90017-8](http://dx.doi.org/10.1016/0163-6383(87)90017-8).
- First, MB., Gibbon, M., Spitzer, RL., Williams, JBW. User's guide for the Structured Clinical Interview for DSM-IV-TR Axis I disorders – Research version. New York: Biometrics Research; 2001.
- Kaplan PS, Owren MJ. Dishabituation of visual attention in 4-month-olds by infant-directed frequency sweeps. *Infant Behavior and Development*. 1994; 17:347–358. [http://dx.doi.org/10.1016/0163-6383\(94\)90027-2](http://dx.doi.org/10.1016/0163-6383(94)90027-2).

- Kaplan PS, Fox KB, Huckleby ER. Faces as reinforcers: Effects of facial expression and pairing condition. *Developmental Psychobiology*. 1992; 25:299–312. <http://dx.doi.org/10.1002/dev.420250407>. <http://www.ncbi.nlm.nih.gov/pubmed/1624058>. [PubMed: 1624058]
- Kaplan PS, Goldstein MJ, Huckleby ER, Cooper RP. Habituation, sensitization, and infants' responses to motherese speech. *Developmental Psychobiology*. 1995; 28:45–57. <http://dx.doi.org/10.1002/dev.420280105>. <http://www.ncbi.nlm.nih.gov/pubmed/7895923>. [PubMed: 7895923]
- Kaplan P, Jung PC, Ryther JS, Zarlengo-Strouse P. Infant-directed versus adult-directed speech as signals for faces. *Developmental Psychology*. 1996; 32:880–891. <http://dx.doi.org/10.1037/0012-1649.32.5.880>.
- Kaplan PS, Zarlengo-Strouse P, Kirk LS, Angel CL. Selective and nonselective associations between speech segments and faces in human infants. *Developmental Psychology*. 1997; 33:990–999. <http://dx.doi.org/10.1037/0012-1649.33.6.990>. <http://www.ncbi.nlm.nih.gov/pubmed/9383621>. [PubMed: 9383621]
- Kaplan PS, Bachorowski J-A, Zarlengo-Strouse P. Child-directed speech produced by mothers with symptoms of depression fails to promote associative learning in four-month old infants. *Child Development*. 1999; 70:560–570. <http://dx.doi.org/10.1111/1467-8624.00041>. <http://www.ncbi.nlm.nih.gov/pubmed/10368910>. [PubMed: 10368910]
- Kaplan PS, Bachorowski J, Smoski MJ, Zinser M. Role of clinical diagnosis and medication use in effects of maternal depression on IDS. *Infancy*. 2001; 2:537–548. http://dx.doi.org/10.1207/S15327078IN0204_08.
- Kaplan PS, Bachorowski J-A, Smoski MJ, Hudenko WJ. Infants of depressed mothers, although competent learners, fail to acquire associations in response to their own mothers' IDS. *Psychological Science*. 2002; 13:268–271. <http://dx.doi.org/10.1111/1467-9280.00449>. <http://www.ncbi.nlm.nih.gov/pubmed/12009049>. [PubMed: 12009049]
- Kaplan PS, Dungan JK, Zinser MC. Infants of chronically depressed mothers learn in response to male, but not female, IDS. *Developmental Psychology*. 2004; 40:140–148. <http://dx.doi.org/10.1037/0012-1649.40.2.140>. <http://www.ncbi.nlm.nih.gov/pubmed/14979756>. [PubMed: 14979756]
- Kaplan P, Burgess A, Sliter J, Moreno A. Maternal sensitivity and the learning promoting effects of depressed and non-depressed mothers' infant-directed speech. *Infancy*. 2009; 14:143–161. <http://dx.doi.org/10.1080/15250000802706924>. <http://www.ncbi.nlm.nih.gov/pubmed/20046973>. [PubMed: 20046973]
- Kaplan PS, Danko CM, Diaz A. A privileged status for male infant-directed speech in infants of depressed mothers? Role of father involvement. *Infancy*. 2010; 15:1–24. <http://dx.doi.org/10.1111/j.1532-7078.2009.00010.x>.
- Kaplan PS, Danko CM, Diaz A, Kalinka CJ. An associative learning deficit in 1-year-old infants of depressed mothers: Role of depression duration. *Infant Behavior & Development*. 2011; 34:35–44. <http://dx.doi.org/10.1016/j.infbeh.2010.07.014>. <http://www.ncbi.nlm.nih.gov/pubmed/21071090>. [PubMed: 21071090]
- Kaplan PS, Danko CM, Kalinka CJ, Cejka A. A developmental decline in the learning-promoting effects of infant-directed speech for infants of mothers with chronically elevated symptoms of depression. *Infant Behavior & Development*. 2012; 35:369–379. <http://dx.doi.org/10.1016/j.infbeh.2012.02.009>. <http://www.ncbi.nlm.nih.gov/pubmed/22721737>. [PubMed: 22721737]
- Kitamura, C., Burnham, D. The infant's response to vocal affect in maternal speech. In: Rovee-Collier, C. Lipsitt, LP., Hayne, H., editors. *Advances in infancy research*. Vol. 12. Stamford, CT: Ablex; 1998. p. 221–236.
- Kuhl PK. Is speech learning 'gated' by the social brain? *Developmental Science*. 2007; 10:110–120. <http://dx.doi.org/10.1111/j.1467-7687.2007.00572.x>. <http://www.ncbi.nlm.nih.gov/pubmed/17181708>. [PubMed: 17181708]
- Kuhl PK, Tsao H-M, Liu F-M. Foreign-language experience in infancy: Effects of short-term exposure and social interaction on phonetic learning. *Proceedings of the National Academy of Sciences*. 2003; 100:9096–9101.
- Linden DR, Savage LM, Overmeier JB. General learned irrelevance: A Pavlovian analog to learned helplessness. *Learning & Motivation*. 1997; 28:230–247. <http://dx.doi.org/10.1006/lmot.1996.0963>.

- Ma W, Golinkoff RM, Houston D, Hirsh-Pasek K. Word learning in infant-and adult-directed speech. *Language Learning & Development*. 2011; 7:185–201. <http://dx.doi.org/10.1080/15475441.2011.579839>.
- Murray L, Kempton C, Woolgar M, Hooper R. Depressed mothers' speech to their infants and its relation to infant gender and cognitive development. *Journal of Child Psychology and Psychiatry*. 1993; 34 <http://dx.doi.org/10.1111/j.1469-7610.1993.tb01775.x>. <http://www.ncbi.nlm.nih.gov/pubmed/8245134>.
- Pederson DR, Moran G. A categorical description of infant-mother relationships in the home and its relation to Q-sort measures of infant-mother interaction. *Monographs of the Society for Research in Child Development*. 1995; 60(2–3):111–132. <http://dx.doi.org/10.2307/1166174>.
- Porritt LL, Zinser MC, Bachorowski J-A, Kaplan PS. Depression diagnoses and fundamental-frequency-based acoustic cues in maternal infant-directed speech. *Language Learning & Development*. 2014; 10:51–67. <http://dx.doi.org/10.1080/15475441.2013.802962>. <http://www.ncbi.nlm.nih.gov/pubmed/24489521>. [PubMed: 24489521]
- Raver, CC., Leadbeater, BJ. Factors influencing joint attention between socioeconomically disadvantaged adolescent mothers and their infants. In: Moore, C., Dunham, PJ., editors. *Joint attention: Its origins and role in development*. Hillsdale, NJ: Erlbaum; 1995. p. 251-272.
- Rescorla RA. Summation and retardation tests of latent inhibition. *Journal of Comparative and Physiological Psychology*. 1971; 75:77–81. <http://dx.doi.org/10.1037/h0030694>. <http://www.ncbi.nlm.nih.gov/pubmed/5559222>. [PubMed: 5559222]
- Roseberry S, Hirsh-Pasek K, Parish-Morris J, Golinkoff RM. Live action: Can young children learn verbs from video? *Child Development*. 2009; 80:1360–1375. <http://dx.doi.org/10.1111/j.1467-8624.2009.01338.x>. <http://www.ncbi.nlm.nih.gov/pubmed/19765005>. [PubMed: 19765005]
- Rovee-Collier C. The rise and fall of infant classical conditioning research: Its promise for the study of early development. *Advances in Infancy Research*. 1986; 4:139–159.
- Schachner A, Hannon EE. Infant-directed speech drives social preferences in 5-month-old infants. *Developmental Psychology*. 2011; 47:19–25. <http://dx.doi.org/10.1037/a0020740>. <http://www.ncbi.nlm.nih.gov/pubmed/20873920>. [PubMed: 20873920]
- Steer RA, Ball R, Ranieri WF, Beck AT. Further evidence for the construct validity of the Beck Depression Inventory-II with psychiatric outpatients. *Psychiatric Reports*. 1997; 80:443–446. <http://www.ncbi.nlm.nih.gov/pubmed/9129364>.
- Watson, JS. Contingency perception in early social development. In: Field, TM., Fox, NA., editors. *Social perception in infants*. Norwood, NJ: Ablex; 1985. p. 157-176.

Highlights

- Predictors of infant voice–face associative learning were studied in a conditioned-attention paradigm in a cumulative sample of 4- to 14-month-old infants of non-depressed and depressed mothers.
- Maternal depression diagnosis and maternal sensitivity each had main effects on IDS-facilitated infant learning, but the two did not significantly interact.
- Extent of pitch modulation in maternal IDS was unrelated to infant learning.
- Results reinforce the conclusion that infants' social experiences with their mothers affect the learning-promoting properties of maternal IDS.

Conditioned Attention Paradigm

Phase 1: Pairing Phase (6 pairings over 180 s)

Forward Pairings: IDS followed by Face

Backward Pairings: Face followed by IDS

Phase 2: Summation Test Phase (4 checkerboards over 70 s)

Fig. 1.
Schematic diagram of the conditioned-attention paradigm.

Fig. 2.

Mean difference scores (mean looking at checkerboard plus voice, i.e., test trials 1 and 4, minus mean looking at checkerboard alone, i.e., test trials 2 and 3), calculated from summation test phase data as a function of the infant's mother's clinical diagnosis and her EAS-based sensitivity category.

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

Variable	NDEP	DEP
<i>N</i>	116	20
Age of mother (years)	30.9 (5.3)	29.0 (5.1)
Age of infant (days)	342.4 (62.8)	321.6 (62.3)
Ethnicity		
White	83 (71.6%)	6 (30.0%)
Latina	17 (14.7%)	10 (50.0%)
African-American	10 (8.6%)	3 (15.0%)
Asian	4 (3.4%)	0 (0.0%)
Native-American	2 (1.7%)	0 (0.0%)
Mother's education (median)	6.0 _a	4.8 _b
Number of children	1.8 (0.9)	1.8 (0.8)
BDI score	10.2 (8.0) _a	24.0 (7.6) _b

NDEP = not currently clinically depressed mother, DEP = currently clinically depressed mother. 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.

Table 2

Mean looking times in response to voice and face during pairing and summation test phases.

Phase	Stimulus	DEP	NDEP
<i>Pairing</i>			
Trial 1	Voice	4.96 (3.17)	4.57 (3.67)
Trial 6	Voice	4.68 (3.30)	4.36 (3.35)
Trial 1	Face	6.12 (3.77)	6.60 (2.98)
Trial 6	Face	6.04 (2.60)	5.65 (3.18)
<i>Summation test</i>			
Trial 7	Voice + checkerboard	5.85 (3.13)	6.82 (2.88)
Trial 8	Checkerboard	6.03 (2.62)	5.02 (3.05)
Trial 9	Checkerboard	4.34 (2.98)	4.68 (2.76)
Trial 10	Voice + checkerboard	4.60 (3.62)	5.47 (3.22)
Difference score		0.04 (1.68)	1.30 (2.32)

Table 3

Correlations between measures of infant learning, demographic variables, depression diagnosis, and EAS ratings.

	1	2	3	4	5	6	7	8
1. Learning (Diff) score	–	–.04	.08	–.10	–.22*	–.05	.29*	–.24*
2. Minority status	–	–	–.38*	–.20*	.22*	–.05	–.07	.12
3. Maternal education	–	–	–	.19*	–.27*	–.08	.14	–.07
4. F_0	–	–	–	–	–.05	.16*	.06	–.12
5. Depression diagnosis	–	–	–	–	–	.16*	–.12	.15
6. Antidepressants	–	–	–	–	–	–	.02	–.04
7. Maternal sensitivity	–	–	–	–	–	–	–	–.46*
8. Maternal hostility	–	–	–	–	–	–	–	–

*
 $p = .05$.

**
 $p = .01$.

Table 4

Demographic speech acoustic, depression, medication, and EAS variables on infant difference scores from summation tests.

Step	Variable	R ² change	F change	df1	df2	Sig. F change
1	Minority status/education	.006	.43	2	133	.65
2	Mean F ₀	.014	1.92	1	132	.17
3	Antidepressant meds	.010	1.36	1	131	.25
4	Depression diagnosis	.038	5.26	1	130	.02
5	Maternal hostility	.051	7.42	1	129	.01
6	Maternal sensitivity	.038	5.76	1	128	.02