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Prenatal Motherese? Newborn Speech Perception May Be Enhanced by Having a Young Sibling

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Abstract

Prenatal experience with infant- and child-directed speech (IDS/CDS) may affect newborns' speech perception. We examined this possibility using an existing neonatal database from a recent cross-language study (Moon, Lagercrantz, & Kuhl, 2011). Seventy-three American and Swedish neonates ($M_{\text{age}} = 32.58$ hr, $SD = 13.58$ hr) were retrospectively coded as either having High ($n = 32$) or Low ($n = 41$) prenatal IDS/CDS exposure based on whether there were any children younger than 4 years old in the household during pregnancy. We compared the mean sucks for contingent presentations of prototypes and nonprototypes of vowel stimuli (native or foreign) among groups. A mixed 3-way ANOVA revealed a significant interaction: Neonates responded to prototypes and nonprototypes differently in the High IDS/CDS group, whereas there was a lack of differential responses in the Low IDS/CDS group. Future research with well-controlled measurement of prenatal speech is warranted.

When talking to infants and young children, people in virtually every language environment naturally adopt a form of speech that researchers believe is a match with youngsters' developing capacities for speech and language (Ferguson, 1964; Snow, Ferguson, & Social Science Research Council, 1977). Infant-directed speech (IDS) and child-directed speech (CDS) consist of utterances that are shorter, more repetitious, and higher and more varied in pitch in comparison to adult-directed speech (ADS; Fernald & Simon, 1984; Snow, 1977). IDS and CDS are also characterized by vowels that are longer in duration and more "stretched" in acoustic space (Englund & Behne, 2005; Kuhl et al., 1997; Liu, Tsao, & Kuhl, 2009).

There is some experimental evidence showing the functional purpose of IDS/CDS in helping infants to learn their languages. In a vowel discrimination task, 6–7 month-old infants performed significantly better when speech sounds were synthesized to approximate the pitch contour of IDS (Trainor & Desjardins, 2002). Thiessen, Hill, and Saffran (2005) have also demonstrated that IDS helped 6-month-olds to segment words from syllable streams. In another type of test, the clarity of mothers' speech, defined by the level of stretched vowel

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This study is a *post hoc* analysis on a pre-existing database from a recent study done by Moon, Lagercrantz, & Kuhl (submitted).

space, was positively correlated with infants' (6–8 months and 10–12 months old) performance in a consonant discrimination task (Liu, Kuhl, & Tsao, 2003). The results from these experiments suggest that adults' efforts to modify speech for infants and young children serve the purpose of helping the youngsters identify and process important segments in the speech stream in the initial period of development.

Although research has demonstrated the benefits of clearer and more exaggerated speech for infants as early as 6 months of age (e.g., Liu et al., 2003), human hearing begins much earlier than birth. Fetal ear structures are developed by the 20th week of gestation, and some fetuses have responded to sound beginning around the 19th week of gestation (Hepper & Shahidullah, 1994). Therefore, fetuses may experience as much as 20 weeks of hearing prior to birth. When presented with synthesized speech sounds, human fetuses (24–36 weeks) exhibited a decrease in fetal heart rate and an increase in heart rate variability, which are indications of fetal attentional responses to auditory stimuli (Zimmer et al., 1993). It is therefore plausible that neonates may already have some experience with the phonetic units of a language at the time of birth. Indeed, results from a recent cross-language experiment showed that neonates produced a higher sucking response rate for the prototype of a foreign, but not a native vowel (Moon, Lagercrantz, & Kuhl, 2011). A prototype is a category member that is the best example of the category and has been shown to be privileged in both perception and memory (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976); in the context of the study mentioned previously (Moon et al., 2011), the prototype is the vowel exemplar that best represents the category (Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992). Moon and colleagues (2011) adopted an operant-choice procedure (Aldridge, Stillman, & Bower, 2001) to investigate how neonates from the U.S and Sweden responded to variations of an English vowel /i/ (as in “fee”) and a Swedish vowel /y/ (as in “fy”). Neonates younger than 72 hr heard 17 variations of either the English or the Swedish vowel. Researchers compared the mean sucks for the prototype and nonprototypes for each vowel between groups. Within hours after birth, neonates already sucked significantly more for the prototype of the vowel that belonged to a foreign language. This differential response indicates discrimination between different versions of a vowel and salience of the novel prototype.

To date, no study has investigated whether having prenatal exposure to IDS/CDS could influence neonates' speech perception. We examined the relation between infants' probable prenatal exposure to IDS/CDS and their vowel perception at birth. We retrospectively divided newborns from the existing database of the study described previously (Moon et al., 2011) into two groups based on the whether the mother had at least one child at the age of four or younger in the household during pregnancy. The rationale behind this procedure was that having one or more infants or toddlers at home during pregnancy would alter the composition of the speech input for the fetus. We assumed that, in this case, IDS and CDS would comprise a larger portion of the pregnant mothers' daily speech with consequent transmission to the intrauterine acoustic environment. Therefore, we identified some of the neonates as likely to have been exposed to a larger amount of IDS/CDS (High IDS/CDS) and others as unlikely to have experienced the acoustically distinct vowels in IDS/ CDS (Low IDS/CDS). We hypothesized that the main finding of the cross-language study (Moon et al., 2011) would be enhanced in the neonates with High IDS/CDS. That is, they would

produce more sucks during the foreign prototype presentation in comparison to foreign nonprototypes as well as to the native prototype, whereas this pattern would be weaker in Low IDS/CDS neonates.

Method

Participants

All subjects' information came from the database of the previous research that investigated newborns' perception of native and foreign vowels (Moon et al., 2011). The original database consisted of information from 80 neonates recruited and tested in hospitals in Tacoma, Washington and Stockholm, Sweden. The inclusion criteria of the original study were apparently healthy newborns without pregnancy or birth complications, less than 72 hr of age. For 20 infants in each country, the stimuli were in the native language and for the other 20, stimuli were in the foreign language.

We evaluated the probability of exposure to IDS/CDS during pregnancy of all the neonates in the database. The age of the mother and her parity (number of pregnancies and live births) were the main factors taken into consideration for coding the likelihood of mothers' use of IDS/CDS. Therefore, we excluded 7 neonates from further analysis due to missing information on parity. The number of participants for the post hoc analysis was 73, including 39 American neonates and 34 Swedish neonates ($M_{\text{age}} = 32.58$ hr, $SD = 13.58$ hr). The two IDS/CDS exposure groups did not differ statistically in average age in hours since birth ($M_{\text{Low IDS/CDS}} = 33.66$, $M_{\text{High IDS/CDS}} = 31.19$), gestational age in weeks since conception ($M_{\text{Low}} = 39.75$, $M_{\text{High}} = 39.41$), birth weight ($M_{\text{Low}} = 3472.07$, $M_{\text{High}} = 3458.53$), total number of sucks ($M_{\text{Low}} = 113.63$, $M_{\text{High}} = 122.59$), and male neonate percentage ($M_{\text{Low}} = 26.83\%$, $M_{\text{High}} = 37.5\%$) all t s < 1.1 , all p s > 0.2 .

Stimuli

We adopted all auditory stimuli from a study investigating the influence of linguistic experience on 6-month-old infants' phonetic perception (Kuhl et al., 1992). The prototypes of the American /i/ and Swedish /y/ were first computer generated based on native adult speakers' evaluation of the best examples of those vowels. Researchers subsequently created 16 variations of each prototype by manipulating the first two formant frequencies of the vowels, forming two concentric rings in F1/F2 vowel space circling the prototype. All 16 variations of one vowel were the nonprototypes.

Equipment

The stimuli were delivered by a Dell computer to the newborns through Grado 225 headphones placed close to both ears. The loudness of the sound stimuli averaged 72 dB (Bruel & Kjaer Sound Level Meter Model 2235, Scale A). A pacifier with an air pressure sensor was offered to the newborn and, if the infant sucked with sufficient intensity and rhythmicity, stimulus presentation began. The pressure sensor provided input to a computer with custom software that delivered speech stimuli when the sucking pressure reached a threshold, adjusted for each infant so nearly every suck produced sound in the headphones.

Design and Procedures

The original study used a mixed design (Moon et al., 2011). For the independent variable of language type, half of the infants in each country heard the prototype and 16 variants of their native vowel and the other half heard the foreign prototype and its 16 variants. For the independent variable of vowel type (prototype vs. nonprototype), each newborn heard all 17 versions of a given vowel prototype plus variants. Upon initiation of sucking, one of the 17 stimuli was activated in the headphones and repeated until there was a pause in sucking of at least 1s. When sucking resumed, a new stimulus was presented. All the sessions were 300s long, and all the neonates were able to cycle through all 17 vowel variants at least once in a randomized order. The dependent measure was the number of sucks for each vowel stimulus in the first presentation cycle, reflecting the level of arousal in the neonates by each speech stimulus without any previous exposure to the stimuli.

For the present study, we retrospectively coded 32 neonates as having had high probability (High IDS/CDS) and 41 as having had low probability of prenatal exposure to IDS/CDS (Low IDS/CDS). We assumed that first-born infants and infants with siblings older than 5 years of age were unlikely to have experienced IDS/CDS prenatally whereas the infants with siblings within 4 years of age during pregnancy were likely to have had high level of prenatal IDS/CDS exposure.

Results

The number of sucks to all 16 nonprototypes was averaged for each newborn for comparison to the sucks to the prototype. The mean sucks for prototypes and nonprototypes were then calculated among newborns. The independent variables in this analysis were Prenatal Exposure to IDS/CDS (High vs. Low), Language Type (Native vs. Foreign), and the Vowel Status (Prototype vs. Nonprototype). Figure 1 displays the results for High and Low IDS/CDS groups, respectively. A mixed three-way $2 \times 2 \times 2$ ANOVA was conducted to examine whether prenatal exposure to IDS/CDS impacted neonatal perception of native and foreign vowels at birth. Results revealed a significant interaction among the three variables, $F(1, 69) = 7.34, p = .009, \eta^2 = 0.096$ (Figure 1). Further analysis showed that the High IDS/CDS group sucked significantly more for the foreign prototype than to the foreign nonprototypes, $F(1, 14) = 5.63, p = .032, \eta^2 = 0.287$; and less for the native prototype compared to the native nonprototypes, $F(1, 16) = 5.25, p = .036, \eta^2 = 0.247$. In the low IDS/CDS exposure group, this pattern was not present. There were no differences in sucking to prototype versus nonprototypes in either the native or the foreign language.

A supplementary two-way ANOVA was conducted to examine the effect of prenatal IDS/CDS exposure on neonates' perception of the prototype of native or foreign vowels. This analysis showed a significant interaction, $F(1, 69) = 5.57, p = .021, \eta^2 = 0.075$ (see Figure 2): Neonates in the foreign language group sucked significantly more to activate the prototype compared to infants in the native language group but only when they had high level of prenatal exposure of IDS/CDS.

Discussion

Our study demonstrated that newborns 33 hr after birth exhibited differential response patterns to native versus foreign vowel variants depending on their level of prenatal exposure to infant-directed and child-directed speech (IDS/CDS). Newborns with a high probability of prenatal IDS/CDS exposure responded differently to prototypes versus nonprototypes: Sucks to the prototype were more frequent when the stimuli were foreign and less frequent when the stimuli were native vowel variants. On the other hand, newborns with little prenatal IDS/CDS exposure exhibited no response differences to the vowel prototypes versus variants in either language.

We offer speculations regarding the results of both High and Low IDS/CDS groups. For the High IDS/CDS group, first, prenatal experience with distinct vowels emphasized by IDS/CDS directs newborn attention to some, as yet unidentified, characteristics of vowels that are prototypes. Future research is needed to identify characteristics that set prototypes apart from nonprototypes for newborn infants. Second, a novel foreign prototype may elicit a higher level of arousal whereas a native prototype may result in a momentary orienting response in which the infant is preparing to take in more information and consequently stops sucking (Sokolov, 1963, Stekelenburg & van Boxtel, 2002). For the Low IDS/CDS group, the lack of differential response to the foreign vowel prototype suggests infants' inability to discriminate. However, it is also possible that these infants, with relatively little experience with different vowels may be able to discriminate, but unable to make a selective response.

Although the differences between experienced and inexperienced newborns were statistically significant, the analysis was exploratory in nature for generating further hypotheses; no causal relations should be inferred. An important direction for future research is using a more systematic and accurate way to measure IDS/CDS exposure. One way to approach this issue would be to develop a maternal questionnaire that directly asks about the prenatal sound environment, especially the mother's daily conversation partners. Another, more reliable but labor-intensive approach would be to employ a device that can record the daily sound environment of neonatal research participants before birth for more strict control of IDS/ CDS exposure.

In summary, our results are consistent with the notions that different styles of maternal speech may affect vowel perception in newborns (Liu et al., 2003) and that the prenatal period may also be very influential. By carefully measuring the prenatal sound environment, researchers may be able to learn more about typical learning process of speech sound and how it is influenced by the environment. Eventually, we may be able to better understand and support the very early basic processes involved in language acquisition and also devise early intervention strategies for atypical development at the point when the brain has optimal plasticity.

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Biography



Tian (Christina) Zhao graduated from Pacific Lutheran University in Tacoma, Washington with a bachelor's degree in psychology, with minors in biology and music. There, she was first involved in research through working with Dr. Christine Moon, studying how infants

perceive speech. Upon graduating from college, she started her PhD program at the Department of Speech and Hearing Sciences at University of Washington. The research questions that interest her most are concerning the interaction between music and speech perception and how experience in a particular sound environment shapes one's perception of sounds. Particularly, she is interested in the neural mechanism that underlies auditory perception in the aforementioned domains.

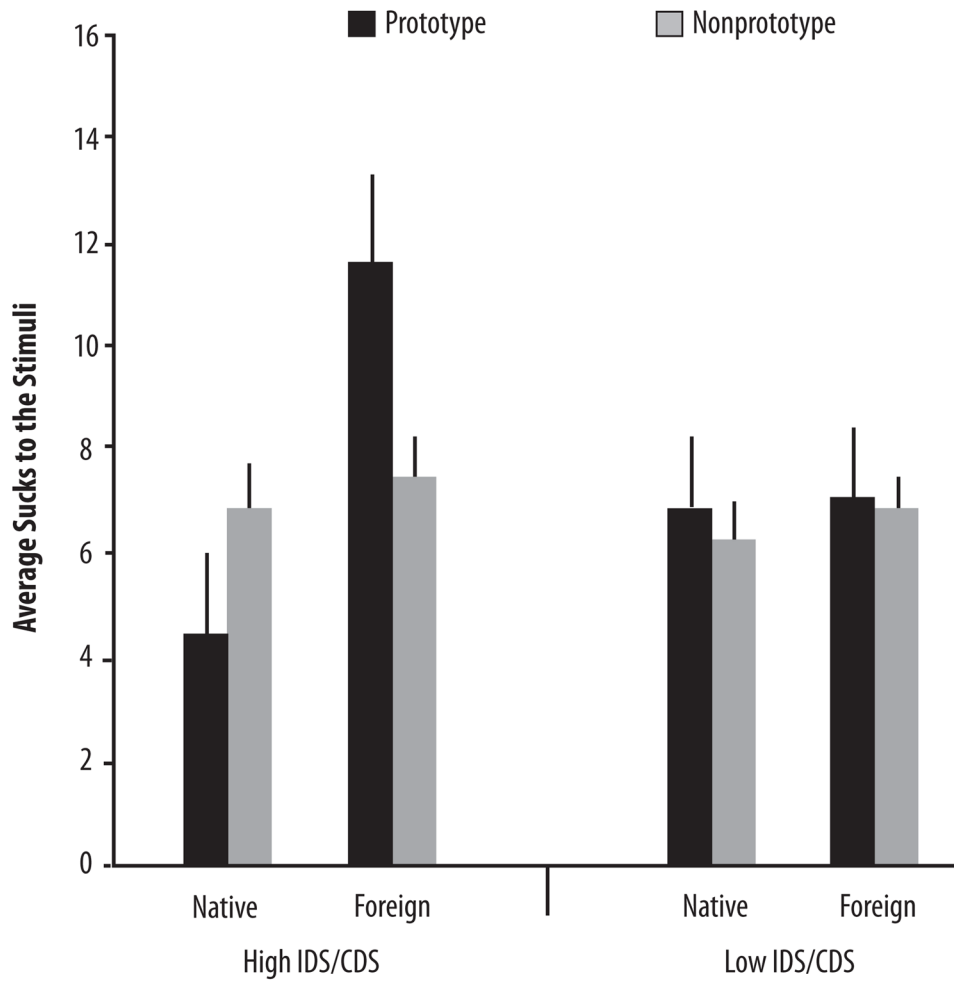


FIGURE 1. Neonates with a High versus Low probability of prenatal IDS/CDS exposure: Responses to prototype versus nonprototype of native and foreign language groups.

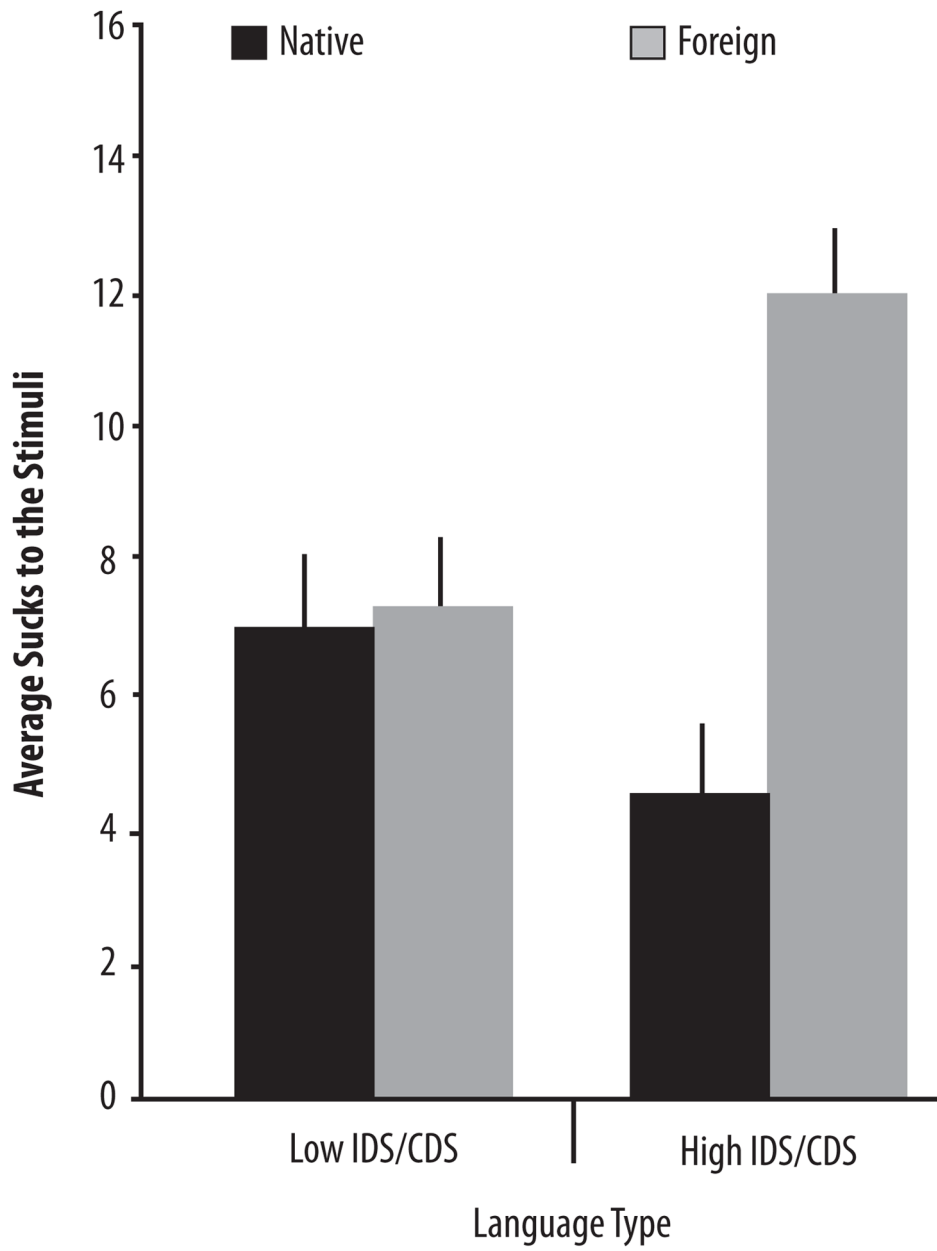


FIGURE 2. Average sucks to the prototypes by different groups: Neonates with high prenatal IDS/CDS exposure responded differentially to native versus foreign prototype whereas no difference observed in the Low exposure group.