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Cognitive Control Factors in Speech Perception at 11 Months

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The development of speech perception during the 1st year reflects increasing attunement to native language features, but the mechanisms underlying this development are not completely understood. One previous study linked reductions in nonnative speech discrimination to performance on nonlinguistic tasks, whereas other studies have shown associations between speech perception and vocabulary growth. The present study examined relationships among these abilities in 11-month-old infants using a conditioned head-turn test of native and nonnative speech sound discrimination, nonlinguistic object-retrieval tasks requiring attention and inhibitory control, and the MacArthur-Bates Communicative Development Inventory (L. Fenson et al., 1993). Native speech discrimination was positively linked to receptive vocabulary size but not to the cognitive control tasks, whereas nonnative speech discrimination was negatively linked to cognitive control scores but not to vocabulary size. Speech discrimination, vocabulary size, and cognitive control scores were not associated with more general cognitive measures. These results suggest specific relationships between domain-general inhibitory control processes and the ability to ignore variation in speech that is irrelevant to the native language and between the development of native language speech perception and vocabulary.

Keywords: speech perception, vocabulary, language development, cognitive control, inhibitory control

Attunement of speech perception to the properties of the native language is an important step in language development, but the mechanisms underlying this process are not entirely understood (for recent proposals, see Anderson, Morgan, & White, 2003; Best & McRoberts, 2003; Kuhl et al., 2008; Werker & Curtin, 2005; Werker & Tees, 1999). Changes in speech perception during the first year involve an increasing ability to ignore acoustic variations in speech that are irrelevant for the native language while focusing on language-relevant information (Jusczyk, 2002; Kuhl et al., 2008). Of interest is whether these changes are related to similar abilities in nonlinguistic domains of information processing. The relevance of domain-general abilities for language processing is indicated by deficits in executive function and attention in children with language disorders (e.g., Hoffman & Gillam, 2006; Stevens, Sanders, & Neville, 2006) and evidence from bilingual children that high demands for attentional flexibility and inhibitory control in bilingual processing sharpen such abilities in nonlinguistic domains (e.g., Bialystok, 1999). The present research addressed whether infants' levels of cognitive control during nonlinguistic tasks are related to their responses to language-relevant (native) versus irrelevant (nonnative) phonetic information in syllable pairs and whether these abilities are associated with a measure of language development, vocabulary size.

One previous study investigated the relationship between infants' speech perception and nonlinguistic cognitive abilities (Lalonde & Werker, 1995). Infants 8–10 months of age who failed to discriminate a nonnative speech contrast performed better on visual classification and the A-not-B task than did infants who discriminated the nonnative contrast. All infants discriminated a native contrast, indicating that cognitively advanced infants were not generally less compliant for speech-discrimination tasks. The authors concluded that increases in the ability to integrate disparate sources of information promote the reorganization of speech perception. Given that the A-not-B task (Piaget, 1954) requires infants to inhibit a prepotent response while maintaining information in memory, Diamond, Werker, and Lalonde (1994) further suggested that the ability to inhibit irrelevant information influences nonnative discrimination.

The present study expanded on this research by investigating relationships between infants' native *and* nonnative speech discrimination, receptive vocabulary skills, and performance on two tasks of goal directedness and inhibitory control. Using continuous measures of speech discrimination, rather than pass/fail criteria as in previous research, we asked whether degrees of sensitivity to native and nonnative contrasts were related to cognitive control skills. We also asked whether vocabulary skills were related to performance on speech discrimination and nonlinguistic tasks. To explore functional relationships among abilities, we also examined

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associations with two general measures that reflect cognitive ability (rate of conditioned learning) and nonlinguistic communicative skills (gesture use). We hypothesized that specific functional relationships between speech discrimination, vocabulary learning, and cognitive control skills would be reflected in differential patterns of association across measures and that there would be a lack of association between these skills and the other two more general measures.

We tested the speech-discrimination skills of 11-month-old infants from English-speaking homes using stop-initial minimal pair syllables for which voice onset times (VOT) crossed category boundaries for phonemes in English or Spanish (see Figure 1). Thus, one pair of syllables (short-lag/long-lag) represented a native contrast and the other (prevoiced/short-lag) a nonnative contrast. Discrimination of the prevoiced/short-lag contrast should be difficult for monolingual English infants this age because it involves two consonants that are assimilated into the same phoneme (voiced) category in English (Best & McRoberts, 2003). Although listeners may use additional acoustic cues besides VOT for voiced–voiceless discrimination, it is known that infants' perception is influenced by VOT cues (Burnham, 1986; Eilers, Gavin, & Wilson, 1979; Maye, Werker, & Gerken, 2002; McMurray & Aslin, 2005; Rivera-Gaxiola et al., 2007; Rivera-Gaxiola, Silva-Pereyra, & Kuhl, 2005). For the present study, the critical difference between contrasts is that one represented a *native* and the other a *nonnative* contrast for the infants. On the basis of previous research, including a study that used the same stimuli and testing procedure (Conboy, Rivera-Gaxiola, Klarman, Aksoylu, & Kuhl, 2005), we expected better discrimination for the native than for the nonnative contrast at the group level and that this differential discrimination would be linked to receptive vocabulary scores.

We tested cognitive control abilities using tasks that have previously shown variability across infants of this age in the ability to ignore irrelevant information while focusing on cues relevant to attaining a goal.[1] We used a means-end task (ME) that required infants to obtain a toy out of reach using an intermediary (cloth or string). Behaviors were rated as goal-directed and planful when infants ignored the potentially distracting intermediary and focused on the toy (Sommerville & Woodward, 2005). We also used a detour-reaching object-retrieval task (DR), in which a toy was placed inside a transparent box with its opening positioned to one side, and infants were required to inhibit the prepotent response of reaching directly for the toy through the closed front side of the box, rather than through the open side (Diamond, 1991). On the basis of the findings of Lalonde and Werker (1995), we predicted that better cognitive control skills on these tasks would be linked to poorer discrimination of the nonnative contrast, reflecting a domain-general ability to resist interference from irrelevant and misleading information.

Method

Participants

Participants were 18 typically developing infants from monolingual English-speaking homes (12 girls, 6 boys) tested at 47 weeks. Three additional infants (1 girl, 2 boys) did not complete head-turn testing. Infants were recruited from a university-maintained list if they had no known physical, sensory or mental disorders; had no more than three middle ear infections; normal hearing at the time of testing; gestational age at birth of 40 ± 3 weeks; birth weight of at least 6 pounds (2.7216 kg); and no exposure to Spanish. Information regarding participants' race/ethnicity, income, and parental educational levels was not available.

Double-Target Head-Turn Speech-Discrimination Task

Stimuli. Stimuli were three syllables produced by a female adult bilingual (English and Spanish) speaker (fundamental frequency = 180 Hz) and manipulated using Praat software (Boersma & Weenink, 2008) to obtain close matches in duration (229.65 ± 0.3 ms), intensity, and average root mean square power (see Figures 1 and 2; for complete description of stimuli, see Rivera-Gaxiola, Silva-Pereyra, & Kuhl, 2005). Native and nonnative contrasts were formed using English /da/ - /ta/ and Spanish /ta/ - /da/. In pilot testing, the background stimulus [ta] was identified as /da/ by adult native English speakers and /ta/ by adult Spanish speakers, the native target [t^ha] was identified as /ta/ by English speakers, and the nonnative target [da] was identified as /da/ by Spanish speakers. Pilot testing also confirmed that adult English speakers discriminated the English but not the Spanish contrast, whereas Spanish speakers easily discriminated the Spanish contrast (Rivera-Gaxiola, Silva-Pereyra, & Kuhl, 2005).

Procedure. Infants were tested using a double-target conditioned head-turn procedure (Conboy et al., 2005). Each infant sat on the parent's lap in a sound-attenuated booth while stimuli were played at 65 dB sound pressure level from a loudspeaker to the left. An assistant silently manipulated toys to the right to attract infants' attention. Infants were trained to turn away from the assistant and toward a reinforcer (mechanical toy adjacent to the loudspeaker) when they detected a change from the repeating background sound, [ta], to either target sound. An experimenter judged the head turns from a video monitor in a separate room. Correct head turns were reinforced with activation of the mechanical toy.

The procedure consisted of two conditioning phases (for each contrast) followed by a test phase (see Figure 3). Infants were conditioned separately to each contrast on the same day and were then tested on both contrasts in a single session on a separate day within 1 week. (One infant required 2 days to complete conditioning.) All infants received conditioning for the native contrast first.[2] To control bias, we implemented the following: (a) contingencies and trial selection were under computer control, (b) the parent and assistant listened to masking music under headphones, and (c) the experimenter's headphones, which allowed monitoring of the experimental room, were deactivated during trials. Sensitivity was calculated using the formulas d'native [$= z$ (hit-native) $- z$ (false alarm-pooled)] and d'nonnative [$= z$ (hit-nonnative) $- z$ (false alarm-pooled)]. A d'-difference score was also calculated: [d'native $- d'$nonnative]. The number of trials to complete the first

[1] An adaptation of the A-not-B object-search task was also administered, but because of a high attrition rate and lack of statistical power, those results are not reported.

[2] Conditioning phases were counterbalanced in a previous study (Conboy et al., 2005). Results indicated that infants conditioned to the native contrast first had overall better performance on both the native and nonnative contrasts during test but performed significantly better on the native than on the nonnative contrast during testing, regardless of order of conditioning.

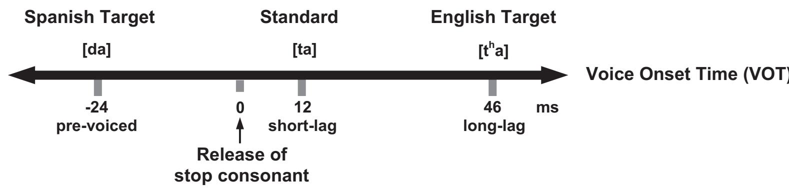

Figure 1. Stimuli used in double-target head-turn task.

level of the initial conditioning phase (with the intensity cue) was recorded as a general measure of conditioning rate.[3]

Vocabulary and Gesture Measures

The MacArthur-Bates Communicative Development Inventory: Words and Gestures (CDI; Fenson et al., 1993) was completed by parents within 1 week of testing. Receptive vocabulary size and gesture use were scored using a computerized system (Marchman, 1999).

Cognitive Control Measures

Infants were tested on a separate day within 1 week of head-turn testing. Each infant sat in a high chair or on the parent's lap, in front of a table (90 × 50 cm, 74 cm high) with two equal-sized black table surfaces, one mounted above the other on drawer sliders. At the beginning of each trial, the top level of the table was pulled out of the infant's reach (open position), and the target object was placed upon it. Then the top level was pushed toward the infant so that it was exactly aligned with the lower level (closed position) and the object came within reach.

ME. The experimenter sat at a 90° angle to the infant's right. Warm-up began by allowing the infant to play with a toy (10 × 8 × 5 cm) until comfortable with the situation. Then the experimenter placed the toy on the open table, pushed the table closed, and said, "Get it!" Test trials were initiated after three successful retrievals of the toy on warm-up trials. On both warm-up and test trials, the infant was handed the toy if she or he failed to reach for it within 30 s. Verbal praise followed each retrieval. If the infant did not seem interested in the toy, a different toy the same size was substituted. The task was discontinued if the infant failed to act on the toy within 30 s on three or more consecutive trials.

There were eight test trials. On the first four trials, the experimenter placed a flannel cloth (25 × 40 cm) on the open table, placed the toy on the far end of the cloth so that the cloth would be within the infant's reach but the toy out of reach when the table was closed, then pushed the table closed and said "Get it!" On each trial, the same toy was used with a different cloth (two solid, two patterned). For the next four trials, two solid-color and two patterned strings (34 cm long) were tied to four different toys (approximately 8 × 8 × 8 cm). The experimenter placed the string-toy unit on the open table with the string extended so that the string would be within the infant's reach but the toy out of reach when the table was closed, then pushed the table closed and said "Get it!" Each trial ended when the infant retrieved the toy or 30 s elapsed. Each trial was coded offline from a video recording by two separate raters, using an adaptation of the scoring system developed by Sommerville and Woodward (2005). A trial was rated *planful* if the infant focused on the toy prior to reaching for the intermediary (cloth or string), maintained visual fixation on the toy while pulling the intermediary, and grasped the toy within 3 s of the toy coming within reach. A trial was coded *unplanful* if all of these criteria were not met. Interrater agreement was 89.71% (disagreements were resolved by discussion between raters and a third rater).

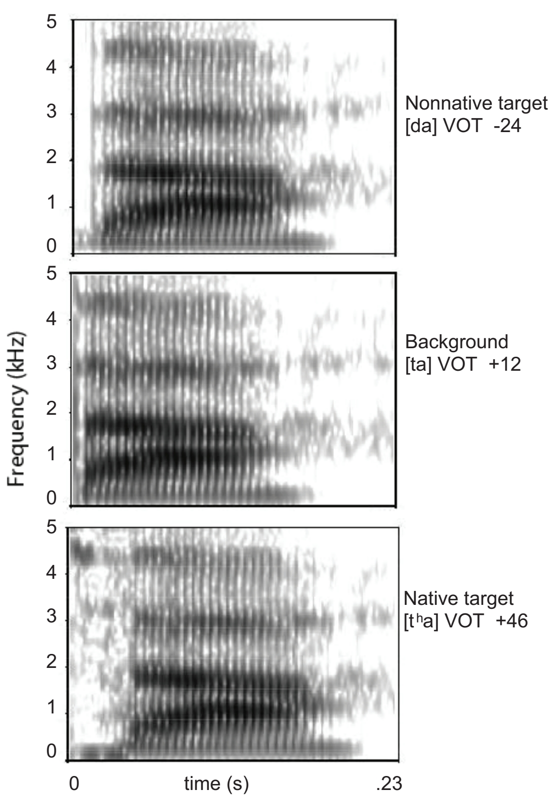

Figure 2. Spectrograms of stimuli used in double-target head-turn task. VOT = voice onset time. From "Brain Potentials to Native and Non-Native Speech Contrasts in 7- and 11-Month-Old American Infants," by M. Rivera-Gaxiola, J. Silva-Pereyra, and P. K. Kuhl, 2005, *Developmental Science, 8*(2), p. 165. Copyright 2005 by Blackwell Publishing. Adapted with permission.

[3] During this first phase, infants do not yet know that they will be conditioned to focus on changes in a phonetic element of the speech stimulus versus the intensity of the stimulus. We expected that the number of trials to complete this initial phase would be relatively independent of levels of attunement to native language properties and would instead reflect general learning and/or attentiveness to the highly salient intensity cue.

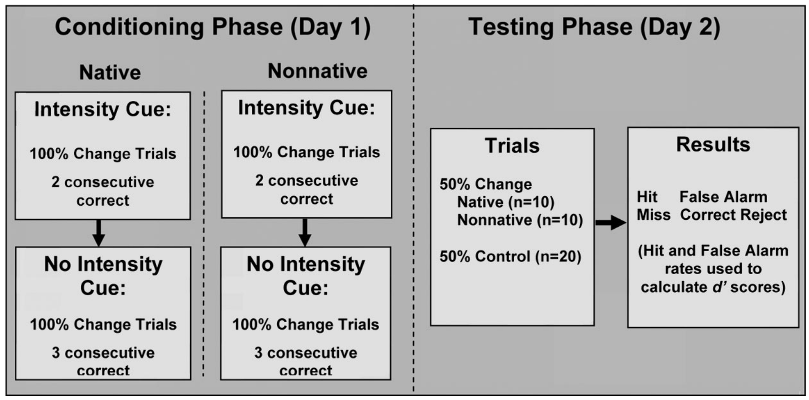

Figure 3. Double-target head-turn task procedure: On each conditioning trial, the background sound changed to the target for three repetitions, and the mechanical toy was activated for 5 s to allow the infant to learn the association between target sound and reinforcer. During the initial portion of each conditioning phase (native and nonnative), the target sound was presented with a 4 dB intensity cue. Following two consecutive correct head turns to the target, trials were administered without the intensity cue until three consecutive correct head turns were achieved. In the test phase, change and control (no sound change) trials occurred with equal probability (50%), and consecutive trials of one type were restricted to three. Correct head turns on change trials were reinforced and recorded as "hits," and incorrect head turns on control trials were recorded as "false alarms."

DR. The experimenter sat directly across from the infant. A clear plexiglass box (13 × 10 × 10 cm) was placed out of the infant's reach on the open table, with the box's opening to the right or left. While the infant was looking at the box, the experimenter hopped a small toy (7 × 5 × 4 cm) along the table and into the box, then pushed the table closed, holding the box in place, and said, "Get it!" The trial ended when the infant retrieved the toy or 30 s elapsed. We terminated trials at 10 s if the infant did not act on the box to avoid frustrating or fatiguing the infant. On each of the four trials, the side of the opening was switched (right, left, right, left). Each trial was coded offline from a video recording by two separate raters. A trial was scored *planful* if the infant touched the toy or clearly attempted to reach into the side of the box to touch the toy and was coded *unplanful* otherwise. Interrater agreement was 93%.

For each infant, the percentage of trials rated *planful* was calculated for each task. We *z*-normalized these percentage scores and averaged *z*-scores to obtain an ME-DR composite score.

Results

Associations among head-turn scores, cognitive control scores, and CDI scores are provided in Table 1.[4] In addition, *t* tests and repeated-measures analyses of variance (ANOVAs) for each relationship are summarized in the sections that follow. All *p*s are two-tailed unless otherwise noted. Effect sizes are reported for significant effects (η_p^2 for ANOVA; Cohen's *d* and 95% confidence intervals for the difference between means [CI_d] for *t* tests).

Speech Discrimination and Vocabulary Size

As expected, sensitivity for the group as a whole was higher for the native (mean $d' = .63$, $SD = .74$) than for the nonnative contrast (mean $d' = .29$, $SD = .67$), $t(17) = 2.29$, $p = .04$, $CI_d = .03, .66$, $d = .48$. The sample was divided into two equal groups, based on a median split of CDI vocabulary scores (under/over 25 words). Mean vocabulary sizes were 15 ($SD = 5.17$) and 59 words ($SD = 39.28$) for the lower and higher groups, respectively. Native and nonnative d' scores were examined using repeated-measures ANOVA, with language of contrast as the within-subjects variable and vocabulary group as the between-subjects variable. There was a main effect of contrast, $F(1, 16) = 7.7$, $p = .01$, $\eta_p^2 = .33$, and an interaction between contrast and vocabulary group, $F(1, 16) = 9.0$, $p < .01$, $\eta_p^2 = .36$. Infants in the higher group showed greater sensitivity to the native contrast (mean $d' = .98$, $SD = .80$) than did those in the lower group (mean $d' = .29$, $SD = .52$), $t(16) = 2.15$, $p < .05$, $CI_d = .01, 1.36$, $d = 1.02$, but there was no group difference in sensitivity to the nonnative contrast (see Figure 4). A *t* test of the d'-difference score indicated a greater difference between discrimination of the native and nonnative contrasts in the higher group ($M = .71$, $SD = .62$) than in the lower group ($M = -.03$, $SD = .41$), $t(16) = 2.99$, $p < .01$, $CI_d = .22, 1.26$, $d = 1.41$. There were moderate-strong positive correlations between vocabulary and native d' and d' difference but not nonnative d' scores (see Table 1). The d' scores were not associated with the CDI gesture score nor the number of head-turn first-level conditioning trials (see Table 1).

Speech Discrimination and Cognitive Control

Seventeen infants completed speech-discrimination and cognitive testing. Results are described separately for each task. Infants were grouped on the basis of planful behaviors (see below). Pass/fail groupings for the ME and DR scores were positively related but did not completely overlap (Fisher's exact test, $p = .04$, one-tailed). Seven infants passed both tasks, 6 infants failed both tasks, and 4 other infants passed either the ME or DR task but

[4] Kendall's tau values are reported because of the small sample size. Pearson's and Spearman's correlations were also conducted and yielded the same patterns of findings and, in several cases, stronger associations.

Table 1
Patterns of Correspondence Across Scores (Kendall's Tau, N = 17)

Variable	d' native	d' nonnative	d' difference	No. of conditioning trials, first level	CDI gestures
CDI words understood	$.43^{*}$	.11	$.36^{*}$	.05	.06
DR percentage score	−.12	$-.55^{**}$	$.35^{\dagger}$	.08	.00
ME percentage score	−.21	$-.39^{*}$	.03	.19	.21
DR-ME composite	−.20	$-.51^{**}$	.25	.19	.08
No. of conditioning trials, first level	.08	.06	−.26	—	−.01
CDI gestures	−.21	−.24	.05	—	—

Note. CDI = the MacArthur-Bates Communicative Development Inventory: Words and Gestures (Fenson et al., 1993); DR = detour-reaching object-retrieval task; ME = means-end task.
$^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$.

failed the other task. Native and nonnative d' scores were examined using repeated-measures ANOVA, with language of contrast as the within-subjects variable and ME or DR group as the between-subjects variable.

ME. Infants were divided into roughly equal groups on the basis of a pass/fail criterion (ME-pass = at least 75% of the eight trials were planful, $n = 9$; ME-fail = fewer than 75% of trials were planful, $n = 8$). Repeated-measures ANOVA indicated a main effect of contrast, $F(1, 15) = 5.08$, $p = .04$, $\eta_p^2 = .25$, and an ME group effect approaching significance, $F(1, 15) = 2.63$, $p = .13$, $\eta_p^2 = .15$, but no interaction. Planned comparisons indicated lower nonnative discrimination scores for the ME-pass group (mean $d' = -.05$, $SD = .44$), compared with the ME-fail group (mean $d' = .60$, $SD = .73$), $t(15) = 2.27$, $p = .04$, $CI_d = .04, 1.27$, $d = 1.08$ (see Figure 5). The ME-pass group did not differ from the ME-fail group in native discrimination, $t(15) = .81$, $p = .43$, $CI_d = -.49, 1.1$.[5] The ME-pass group had higher d'- difference scores (mean $d' = .53$, $SD = .65$) than did the lower group (mean $d' = .28$, $SD = .63$), but this difference did not reach significance, $t(15) = 1.75$, $p = .28$, $CI_d = -1.02, .32$. There was a moderate negative association between the percentage of planful ME trials and nonnative d' scores (see Table 1).

DR. Infants were divided into roughly equal groups on the basis of a pass/fail criterion (those who showed planful behavior on at least one of the four trials, $n = 9$, and those with no planful trials, $n = 8$). Repeated-measures ANOVA indicated a main effect of contrast, $F(1, 15) = 5.54$, $p = .03$, $\eta_p^2 = .27$, and a main effect of DR group, $F(1, 15) = 4.57$, $p < .05$, $\eta_p^2 = .23$. The DR Group × Contrast interaction approached significance, $F(1, 15) = 3.29$, $p = .09$, $\eta_p^2 = .18$. Planned comparisons indicated lower nonnative discrimination scores for the DR-pass group (mean $d' = -.15$, $SD = .30$), compared with the DR-fail group (mean $d' = .71$, $SD = .68$), $t(15) = 3.49$, $p < .01$, $CI_d = .34, 1.4$, $d = 1.64$. As with the ME group analysis, the DR groups were not significantly different on the native contrast, $t(15) = .89$, $p = .39$, $CI_d = -.46, 1.13$ (see Figure 6). The DR-pass group had marginally higher d'-difference scores (mean $d' = .61$, $SD = .58$) than did the DR-fail group (mean $d' = .08$, $SD = .64$), $t(15) = 1.82$, $p = .09$, $CI_d = -.09, 1.16$, $d = .87$. There was a moderate-strong negative association between the percentage of planful DR trials and nonnative d' scores and a trend for the association between the DR percentage score and the d'-difference score (see Table 1).

Cognitive Control and Vocabulary, Gesture, General Learning Measures

Infants were divided into roughly equal groups on the basis of their ME-DR composite scores (8 infants $z < 0$; 9 infants $z > 0$). Vocabulary sizes were slightly higher for infants with higher ME-DR scores ($M = 47.22$, $SD = 44.9$) than for those with lower scores ($M = 24.63$, $SD = 20.65$), but this difference did not reach significance, $t(15) = 1.30$, $p = .21$, $CI_d = -14.37, 59.57$, $d = .65$.[6] ME-DR scores were not associated with the CDI gesture score nor the number of head-turn conditioning trials (see Table 1).

Discussion

The present findings showed that 11-month-old infants who discriminated a linguistically relevant contrast while disregarding one irrelevant for their language were more advanced in both vocabulary development and cognitive control abilities than were those who discriminated the two contrasts at equivalent levels. Cognitive control and vocabulary scores were not significantly associated with the gesture score or the number of first-level conditioning trials on head turn, suggesting that their associations with discrimination scores reflect specific functional relationships, rather than more general development across domains. Native speech perception was positively associated with vocabulary size but not with the ME/DR tasks, whereas nonnative speech perception was negatively associated with ME/DR but not vocabulary size. Different processes appear to have driven each of these relationships.

We suggest that the specific cognitive ability linked across the ME/DR tasks and discrimination of nonnative contrasts is inhibitory control. All the infants in this study successfully responded to the nonnative target during the head-turn conditioning phases, but given the more demanding testing situation in which they had to monitor both targets, their responses favored the native over the

[5] The native d' score was numerically higher for the ME-pass group, but this was driven by a single infant with a particularly high d' score.

[6] Because this difference may have been driven by a single infant with a very large vocabulary score (152 words), we conducted a Fisher's exact test on the ME/DR pass/fail group and vocabulary group (above or below 25 words), and it yielded a similar result ($p = .11$, one-tailed).

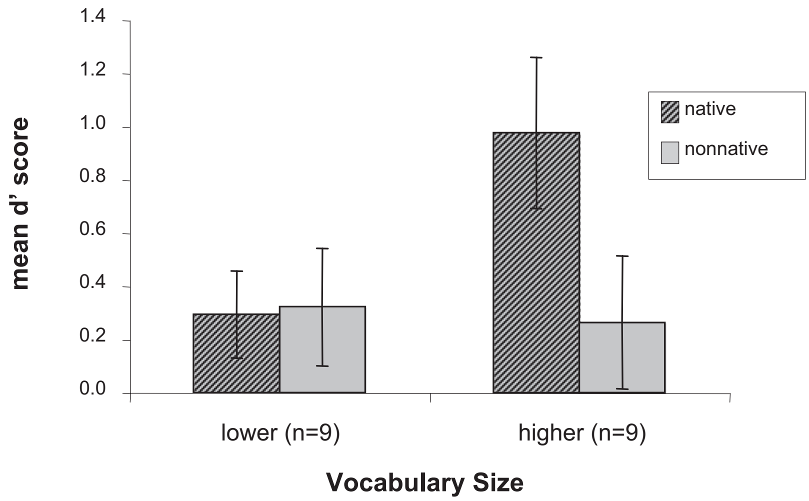

Figure 4. Discrimination performance on the native and nonnative speech contrasts, by MacArthur-Bates Communicative Development Inventory: Words and Gestures (Fenson et al., 1993) receptive vocabulary scores.

nonnative. This replicates previous work showing that nonnative discriminative ability is not completely lost but is, instead, reduced by perceptual reorganization processes (Kuhl et al., 2006; Tsao, Liu, & Kuhl, 2007; Werker & Tees, 1984). The results are consistent with previous work that used different tasks and procedures with slightly younger infants (Lalonde & Werker, 1995). Together, the present and previous research suggest that negative associations between nonnative discrimination and cognitive control skills reflect infants' increasing domain-general abilities to perceptually sort out relevant from irrelevant information and disregard the latter (see also Diamond et al., 1994).

The positive association between native discrimination and vocabulary size seen in the present and previous research may reflect language experience influencing both phoneme category formation and the learning of particular word forms, and/or more direct bidirectional influences between phonemic and lexical levels of language learning (see Kuhl et al., 2008; Werker & Curtin, 2005). The present study was not designed to test such influences; future research involving longitudinal designs and cross-lag correlation analyses would be illuminative.

The weak, nonsignificant association between inhibitory control skills and vocabulary size could be due to the small sample size. Alternatively, it could be due to the nature of early word representations. To develop a lexicon, infants must pay attention to relevant acoustic information in word forms while disregarding irrelevant differences that do not change a word's meaning. The former may precede the latter. Although infants this age can recognize word forms and detect mispronunciations of familiar words (e.g., Vihman, Nakai, DePaolis, & Hallé, 2004; Swingley, 2005), under certain testing conditions, they treat minimal pairs as tokens of the same word (see Werker & Yeung, 2005). The vocabulary measure used in the present work was based on a binary response from parents regarding their infants' word knowledge and, thus, would not be sensitive to varying levels of word representations. Thus, it may be that inhibitory control skills are linked to the degree to which infants form phonetically specific

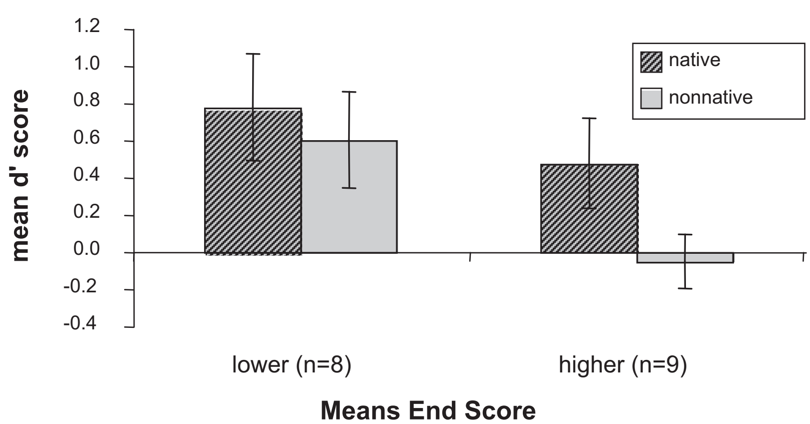

Figure 5. Discrimination performance on the native and nonnative speech contrasts, by means-end scores.

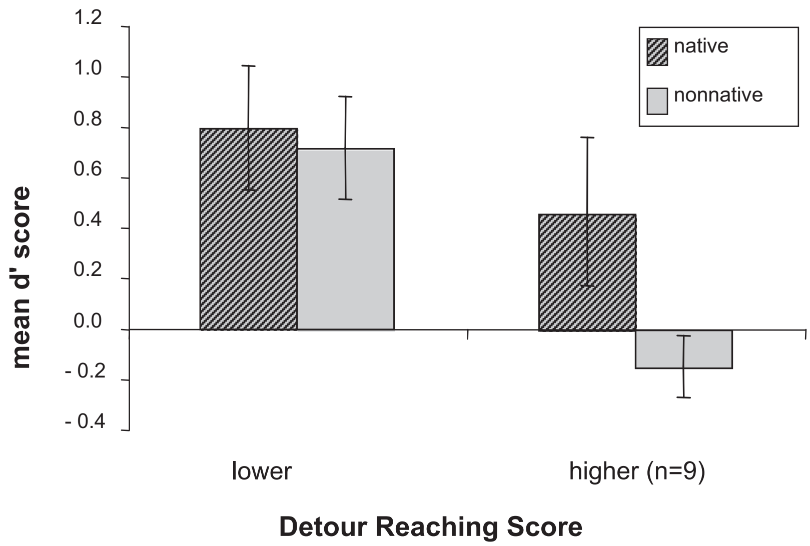

Figure 6. Discrimination performance on the native and nonnative speech contrasts, by detour-reaching scores.

word representations but not more general knowledge of words tapped by the CDI receptive score.

If correct, the preceding explanation could also account for the lack of a negative association between nonnative discrimination and vocabulary size. Previous studies have shown associations between nonnative speech discrimination during the first year and *later* expressive vocabulary growth, during the second and third years, whereas concomitant links between receptive vocabulary and speech discrimination at 11 months have only been reported for native discrimination (Conboy et al., 2005). Kuhl and colleagues (Kuhl, Conboy, Padden, Nelson, & Pruitt, 2005; Kuhl et al., 2008) showed that better discrimination of a nonnative contrast at 7.5 months, measured using either head-turn or a neural mismatch response, was negatively linked to expressive vocabulary growth from 14 to 30 months. Using the same stimuli as in the present study, Rivera-Gaxiola, Klarman, Garcia-Sierra, & Kuhl (2005) found that infants who showed similar neural responses to nonnative and native contrasts at 11 months produced fewer words a year later than did those who processed the nonnative sound differently. In these studies, speech-discrimination measures taken during the first year predicted how many words parents recognized their infants saying at later ages; these were probably fairly consistent word forms for parents to have recognized them.

The lack of a relationship between native discrimination and performance on the ME/DR tasks showed that infants were not generally more or less attentive or compliant across tasks. The ME/DR tasks may have tapped resistance to irrelevant information more so than selective attention to relevant cues; the latter might be more important for fine tuning perception of native phonemes. It is also possible that the native contrast was already well learned by this age and that associations between cognitive control abilities and native discrimination would only be observed with a more difficult contrast, or at an earlier stage in learning.

In sum, the results support the hypothesis that domain-general abilities allow infants to resist interference from irrelevant information in the speech signal. The results are less clear with regard to whether resistance to irrelevant information is linked to infants' ability to selectively focus on relevant information in the speech signal and how either skill promotes vocabulary development. Further research is needed to determine the specific linguistic and nonlinguistic influences on this early learning process.

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