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Predictors of Language Growth in Bilingual Infants (Honorable Mention)

Stephanie Grasso
University of Redlands

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The question of whether infants' early processing abilities predict later outcomes is fundamental for understanding cognitive and language development (Borstein, Hahn, Bell, Haynes, Golding & Wolke, 2006). Language acquisition is a variable process influenced by interactions between innate capacities and exposure to environmental stimuli. In typical monolingual language acquisition, a predictable trajectory of development has been reported, across children from different cultures and language groups (Hoff, 2009). However, even in monolingual language development, there are many factors that contribute to variability, including learner characteristics intrinsic to the child, and extrinsic social contexts such as caregiver responsivity (Hoff, 2009). Factors that are intrinsic to the child include early processing abilities, which have been linked to later language outcomes (Bornstein et al., 2006; Kuhl, Conboy, Coffey-Corina, Padden, Rivera-Gaxiola, & Nelson, 2008; Marchman & Fernald, 2008). Bilingual children, who experience each language in different contexts and with different people, are expected to show even greater variability than monolingual children in both their language processing abilities and in language development (Conboy & Mills, 2006, Garcia- Sierra, Rivera-Gaxiola, Percaccio, Conboy, Romo, Klarman, Ortiz, & Kuhl, 2011; Marchman, Fernald & Hurtado, 2009). Grosjean (1989) proposed that bilinguals develop unique processing abilities in comparison to monolinguals, because both languages are always activated, and bilinguals therefore need to inhibit the activation of one language while using the other language. Research has confirmed that there are early differences between monolingual and bilingual children in nonlinguistic cognitive control skills as well as in language processing, presumably because bilingual children are constantly learning from a mixed input and so they develop specific mechanisms to allow them to control for interference. Although bilingual infants have to learn twice as much information, they pass the same developmental milestones at the same ages as their monolingual peers. Furthermore, in a study by Kovacs and Mehler (2009) bilingual infants learned two speech structures that followed either the ABA or AAB pattern, while monolingual infants only learned one. This ability suggests that bilingual infants are better at avoiding interference between two structures, and that they may have better control and selection abilities. The researchers suggest that either or both of these learning abilities are what allow bilinguals to pass the linguistic milestones at the same rate as monolinguals (Kovacs & Mehler 2009; for reviews, see Bialystok, 2010; Werker & Byers- Heinlein, 2008).

Both monolingual and bilingual toddlers exhibit rapid gains in vocabulary beginning at approximately18 months of age, making this age especially interesting for examining word processing and vocabulary growth (Hoff, 2009). In this paper, I review research with monolingual children showing that early processing abilities predict later differences in language growth, and that this relationship has been noted in bilingual as well as monolingual children. I also review the evidence that there are language processing differences between each language of bilingual children, as well as differences in the processing skills of bilingual compared to monolingual children, and propose that individual differences in the early language processing abilities of bilingual children are linked to their later language development.

It is possible that some children may come into the world with better information processing abilities than others, and that these individual differences are related to later cognitive and language outcomes. In a longitudinal study of a large group of American infants, Bornstein and colleagues (2006) tested the hypothesis that infants who habituate more quickly to a visual stimulus are more adept at paying attention to, encoding, and retrieving information, and that such basic skills predict subsequent cognitive growth. Bornstein et al. (2006) studied the latency of habituation in 4-month-old infants using a visual stimulus (a geometric pattern displayed on a video screen).The researchers hypothesized that infants' habituation efficiency (i.e., the time it took infants to lose interest in the stimulus, as measured by the time it took infants to look away from the image) reflected the time it took to encode the stimulus into memory. Bornstein et al. (2006) found that infants' habituation efficiency at 4 months of age predicted individual differences in cognitive and language skills over the next 4 years. Infants who started off with the strongest cognitive abilities tended to have the highest language and cognitive outcomes later in the preschool years, whereas infants with the weakest skills remained relatively weak at later data points. Thus, although experience and other extrinsic factors influence early development, there is some evidence that factors intrinsic to the child (in this case, basic information processing abilities present in the first few months of infancy) remain stable throughout early development and give rise to individual differences in later outcomes.

While Bornstein (2006) focused on how early innate cognitive skills predict later cognitive and language outcomes, the following studies focus on measuring receptive language skills presumed to be influenced by experience with language. Tsao, Liu and Kuhl (2004) provide evidence for the hypothesis that early processing skills predict later outcomes. The investigators used a head turn conditioning procedure to measure speech perception at 6 months, an age when infants begin to show evidence of having representations of native-language speech sounds such as the vowels "a" and "i", and used the MacArthur-Bates Communicative Development Inventory (CDI; Fenson et al., 2006) to measure language longitudinally in a group of 28 children. In the head turn procedure, infants were presented with a repeated auditory stimulus (the English vowel "a"), and conditioned to turn their heads toward a reinforcing toy when they detected a change in that stimulus (the English vowel "i"). The researchers hypothesized that infants' performance on such a standard measure of speech perception at 6 months would predict later language abilities at

13, 16, and 24 months. The researchers confirmed their hypothesis, and also found that individual differences in receptive and expressive language were stable from 13 to 16 months.

Measuring infants' discrimination of sounds, Kuhl, Conboy, Padden, Nelson and Pruitt (2005) also provided evidence that individual differences present during the first year of life predict later outcomes. Kuhl and colleagues expanded on the previous research of Tsao and colleagues by testing infants on their discrimination of both a native and a nonnative language contrast. At 7 months of age, infants are expected to begin tuning out nonnative phonetic contrasts (i.e., the acoustic differences between speech sounds that are not used in their native language) while tuning into the phonetic differences that are phonemic for their native language (e.g., the difference between the English sounds "t" and "p"). This process is known as "perceptual narrowing." The researchers tested 7 month-old-infants' speech perception by using a head turn conditioning procedure. and measured language skills at 14, 18, 24, and 30 months of age using the MacArthur-Bates CDI (CDI; Fenson et al., 2006).The researchers found that at 7 months of age, infants' native and nonnative phonetic perception skills were negatively correlated with one another, indicating that as infants tune into their native language, they also tune out information that is not relevant for that language. Furthermore, infant's native-language perception skills were positively correlated with their later speed of language acquisition, while nonnative-language perception skills were negatively correlated with language growth meaning from very early in life native-language perception skills predict later language growth.

Speech segmentation is an important ability that allows a child to separate words from the speech stream and store them for later recall. Newman, Bernstein Ratner, Juscyzk, Jusczyk, and Dow (2006) found that 7-12 month-old infants' performance on speech segmenting tasks predicted their scores on the MacArthur-Bates CDI at 24 months (CDI; Fenson et al., 2006). With a subset of the same children, the researchers measured language outcomes at 4 to 6 years of age. The researchers found that segmentation skills are related to later language outcomes, but not with generalized intelligence. Preschoolers who did well on the segmentation task demonstrated an advantage in both semantic and syntactic abilities. Word-object associations have also served as a predictor of later language development. Bernhardt, Kemp and Werker (2007) used a looking-time-based task to test word-object associations. The researchers found that performance on word-object associations at 17-20 months significantly predicted outcomes on the MacArthur Bates CDI and other standardized language tests of comprehension and production in preschoolers.

In addition to measuring infants' looking behaviors, researchers have used a measure of brain activity, called "Event-related potentials" (ERPs), to determine early processing abilities. An advantage of measuring brain activity is that it can be recorded without an overt response being required of the infant. Moreover, ERPs may be more sensitive to detecting individual differences in processing efficiency than behavioral measures such as looking times and conditioned head turns. In the ERP technique, electrodes are placed on the scalp to measure brain activity or electrocephalogram (EEG) of an individual processing stimulus (i.e., a sound or picture). ERPs provide an opportunity to study the time course of the brain's response to stimuli with great temporal resolution. ERP components are represented by the time in milliseconds of the occurrence of peaks and valleys. ERPs have been used to measure whether infants discriminate speech sounds, and whether they respond differently to words that are familiar versus unknown words. In a series of studies observing children's performance on verbal tasks, Molfese and Molfese (1985) found that 3-year-old children who showed slow development of verbal skills exhibited ERP responses at birth that did not show discrimination of two different speech sounds, such as the initial consonants of the syllables “bi” and “gi”. On the other hand, children with normal verbal skills exhibited ERP responses at birth that differentiated between speech sounds. Similarly, Molfese and Molfese (1997) measured ERPs from the temporal, parietal, and frontal regions at birth to measure the infants’ response to consonant-vowel syllables. The researchers found that children who were better at discriminating between speech sounds in infancy developed better language skills at 5 years of age. In another study, Molfese (2000) examined ERPs at birth to non-speech and speech stimuli. These ERPs discriminated between infants who eight years later were dyslexic, poor, or normal readers. Together, these studies show that basic perceptual abilities measured very early in life predict later language and literacy outcomes.

Kuhl, Conboy, Coffey-Corina, Padden, Rivera-Gaxiola, and Nelson (2008) analyzed ERP measures of 7.5 month-old monolingual infants’ perceptual narrowing of native vs. nonnative phonemes. The researchers found that 7.5 month-old infants’ native and nonnative perception skills predicted the infants’ language abilities two years later. More specifically, better perceptual skills in the native language predicted faster native language development, whereas more developed nonnative perceptual skills predicted slower native language development. Furthermore, infants’ early phonetic perception predicted language at different levels, including the number of words produced, the degree of sentence complexity, and the mean length of children’s utterances. Similarly, Rivera-Gaxiola, Silva-Pereyra and Kuhl (2005) found that 7 month old infants’ discriminatory ERP responses are not present at 11 months. However, at 11 months the infants’ remained sensitive to non-native contrasts at the neural level. Linking these findings to later language outcomes, Rivera-Gaxiola, Klarman, Garcia-Sierra, and Kuhl (2005) found that the 11 month-old infants ERPs predicted their later language scores at 18, 22, 25, 27 and 30 months of age on the MacArthur-Bates CDI (CDI; Fenson et al., 2006). These studies demonstrate the validity of ERPs to speech stimuli for predicting later language abilities.

Although there are certain intrinsic characteristics that influence language learning, many extrinsic variables also play a role (Hoff, 2006; Molfese, Modglin & Molfese, 2006). Input factors such as maternal responsivity predict the onset of crucial linguistic milestones (Tamis-Lemonda et al., 1998; Tamis-Lemonda, Bornstein & Baumwell, 2001). For example, Tamis-Lemonda et al. (2001) related child activity and maternal responsiveness to the ages at which children achieved five developmental milestones in expressive language: first words, first imitations, 50 words in production, first combinatorial speech, and first use of language to refer to the past. The researchers found that maternal responsiveness at 9 and 13 months of age predicted all five of the milestones, above and beyond children's own behavior. Children whose mothers were consistently responsive expressed their first words, achieved 50 words in production, engaged in combinatorial speech, and used language to talk about the past before children with less responsive mothers.

Research also suggests that intrinsic and extrinsic factors related to early language acquisition and development influence each other bidirectionally (Bornstein, Haynes & Painter, 1998; Bronfenbrenner, 1979; Hoff, 2006; Hurtado et al., 2008; Nelson, 1973; Vigil, Hodges, & Klee, 2005). For example, Vigil and colleagues (2005) compared the quantity and quality of parental language to typically developing children and children with language delay. The researchers found that parents of children with typical language responded more to their children and took more conversational turns than parents of children with language delay, suggesting that the language input parents provide to their children is influenced in part by the children's verbal behaviors. Hurtado et al. (2008) found that 24-month-old Spanish-learning children who experienced more input at 18 months had larger vocabularies, were faster at identifying familiar words, and made greater gains in subsequent vocabulary development between 18 and 24 months than children who received less input.

Early processing abilities are not strictly innate, but are also influenced by early experiences. Although there is evidence that children's early processing skills influence the amount of uptake of the input they receive, there is also evidence that input itself influences children's brain development and processing abilities (Conboy & Mills, 2006). Children growing up bilingually provide a natural experiment for testing this hypothesis, because maturation is held constant, while there are different levels of experience in each language (Conboy & Mills, 2006; Conboy & Thal, 2006; Grosjean, 1989; Marchman, Martinez-Sussman & Dale, 2004; Marchman et al., 2009).

Conboy and Mills (2006) studied ERPs to words in 19-22 month-old bilingual infants learning English and Spanish. The study addressed whether the organization of language-relevant brain activity was related to vocabulary size in each separate language or was linked only to total conceptual vocabulary (TCV) size and not different for the dominant and nondominant languages. The TCV measure reflects the number of concepts that the child has lexicalized with any word, regardless of the language of the word, and is therefore thought to be a valid measure of lexical development in bilingual toddlers (Patterson & Pearson, 2012). The researchers hypothesized that brain activity would be organized separately for English vs. Spanish based on the levels of experience children had in each language. Furthermore, the researchers predicted that if separate neural systems were involved in processing each language, then ERPs to words would be different for a child's dominant vs. nondominant language. The researchers averaged together each child's ERPs to known and unknown words for each language. The researchers found that the organization of brain activity was related to both separate-language vocabulary as well as TCV size, supporting both hypotheses. The timing of ERP differences to known vs. unknown words occurred earlier for the dominant vs. the nondominant language as well as earlier for the children with higher vs. TCV sizes, indicating that the two languages were processed by non-identical brain systems and that these differences were linked to language experience. Another piece of evidence in support of non-identical brain systems was seen in the ERP differences for known vs. unknown words over both hemispheres. The researchers observed differences in the timing and distribution of brain activity within individual children, which could not be attributed to maturation, because the bilingual child's brain serves as a natural control for differences in maturation. The ERP data suggests that both absolute and relative amounts of input in each of a bilingual child's languages influences the mechanisms used for language learning and processing. Moreover, the language-related brain activity of the bilingual children in this study was not identical to previously reported data from children the same ages that were raised in monolingual environments, providing some evidence that there are unique language processing mechanisms associated with bilingualism (Conboy & Mills, 2006).

In a longitudinal ERP study of bilingual infants, García-Sierra, Rivera-Gaxiola, Percaccio, Conboy, Romo, Klarman, Ortiz, and Kuhl (2011) found that bilingual infants' ERP responses to speech differed from the patterns previously reported for monolingual infants. As stated above, monolingual infants typically show perceptual narrowing for their native language's speech sound patterns between 6 and -9 months of age, and this process can be detected using ERPs. By 10-12 months, but not at 6-9 months of age, the bilingual infants studied by García-Sierra and colleagues showed comparable neural responses to those noted for the native language in 7-month-old monolingual infants studied by Rivera-Gaxiola and colleagues (Rivera-Gaxiola et al., 2005). By 10-12 months, the bilingual infants showed discrimination of both English and Spanish contrasts leading the researchers to conclude that bilingual infants remain more open to the effects of language experience, showing "neural commitment" to the features of their native languages at a later age than is seen in monolingual infants, who are acquiring only one native language. These discriminatory abilities became more enhanced with age and at the group level it was evident that these abilities were related to the input infants received in each language. The researchers also found that infants' later word production skills were strongly related to the infants' ability to discriminate between sounds at the earlier age (Garcia-Sierra et al., 2011). Furthermore, the relative differences between the early brain responses to English and Spanish and early language input in each language predicted later word production in each language. For example, if an infant had more exposure to Spanish, then he or she produced more words in Spanish several months later.

Shafer, Yu and Datta (2011) measured ERPs to phonetically similar vowels, categorized as /I/ as in bit and /e/ as in bet in monolingual and English-Spanish bilingual 3 to 36 month-old infants. The researchers found that although age and sex caused differences in the findings, the bilingual infants showed very different responses than monolingual infants in their ERP responses. Consistent with the evidence of perceptual narrowing in bilinguals, this study specifically found that the 6 month-old bilingual females appeared to be sensitive to the differences in the input. The difference in the onset of perceptual narrowing between monolingual and bilingual infants provides evidence that bilingual and monolingual brains process language in a different manner, even early in development.

In the present research, we are testing whether ERP word-processing measures taken at 20 months predict children's later language development in each language. Given that prior research showed that the efficiency of bilingual children's processing of words in each language, measured at 2 years of age using a looking-time behavioral procedure, was linked to children's current and later vocabulary skills in the same language, but not the other language (Marchman et al., 2009), we expect there to be language-specific links between children's early processing efficiency, as assessed using a measure of brain activity, and their later vocabulary skills. We are extending the work of Conboy and Mills (2006), who found that ERP measures of word processing efficiency in each language of a group of bilingual 20-month-old children were linked to the children's concurrent vocabulary sizes in each of their languages (English and Spanish), as measured using parent report inventories (the MacArthur-Bates CDIs). The use of ERPs goes beyond behavioral looking-time measures because ERPs detect differences in the distribution of brain activity that have been linked to processing efficiency. For example, Conboy and Mills (2006) reported that children with larger vocabulary (TCV) sizes had ERP effects to words that were more lateralized to the left hemisphere than children with smaller TCV sizes. In the present research, we are examining whether the 20-month ERPs of a subset of these children are also linked to later vocabulary development. Moreover, given the within-language ties between lexical and grammatical systems that have been documented in previous research with English-Spanish bilingual children this age (Conboy & Thal, 2006; Marchman, Martínez-Sussman, & Dale, 2004), we are examining whether children's earlier word processing abilities in each language are linked to their later grammatical development in each language. The use of spontaneous speech in addition to parent-report measures of lexical and grammatical development in each language is allowing us to examine children's on-line uses of language in interactive contexts, as well as their caregivers' estimation of their language skills. We predict that if brain activity reflects children's processing efficiency within each language, then it will also predict later language skills within the same language. We expect to find that language-specific ERPs to words at 20 months will predict

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