J. Child Lang. **38** (2011), 56–60.
doi:10.1017/S0305000910000516

Stepping backwards in development: integrating developmental speech perception with lexical and phonological development – a commentary on Stoel-Gammon's 'Relationships between lexical and phonological development in young children'*

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Within the subfields of linguistics, traditional approaches tend to examine different phenomena in isolation. As Stoel-Gammon (this issue) correctly states, there is little interaction between the subfields. However, for a more comprehensive understanding of language acquisition in general and, more specifically, lexical and phonological development, we must consider relations between multiple subfields. That is, by examining the interactions between these subfields, a greater understanding of lexical and phonological development can emerge. For instance, the interaction between phonology, syntax and semantics is demonstrated in recent work looking at how phonological patterns can provide a basis for inferring a word's lexical category (such as nouns and verbs) (Christiansen, Onnis & Hockema, 2009; Lany & Saffran, 2010).

Stoel-Gammon provides an extensive overview of data from developmental speech production to establish the relationship between lexical and phonological development. Numerous studies demonstrate that phonological patterning is one factor that determines which words are produced and learned by children. A range of findings provide evidence for this factor, such as studies examining the connection between children's prelinguistic and later word productions (Vihman, 1992) and studies comparing phonological distributions in children's early lexicons to children's production accuracy (Stoel-Gammon, 1998). A wealth of knowledge can be gathered from the studies that Stoel-Gammon reviews. Speech production studies in particular, have provided linguists with a solid foundation of how the phonological system develops in conjunction with the acquisition of words. However, to fully understand lexical and phonological acquisition, it is essential that we also take a step back in development. We also need to consider findings in related fields such as infant speech perception and look

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at what is acquired at the very earliest stages of language learning because of the potential interplay between early speech perception and later language development (Curtin & Werker, 2007; Kuhl, Conboy, Padden, Nelson & Pruitt, 2005; Saffran & Graf Estes, 2006). That is, it is critical to know what knowledge about the sound patterns and sound structures of a language is acquired by learners before they establish a lexicon, and how learners integrate this knowledge throughout development. Why might this be informative? As Stoel-Gammon points out, lexical and phonological development are mutually facilitative. By taking a step back and considering earlier stages in development (and subsequently different methodologies), we can better understand the learning mechanisms, the nature of early representations, different levels of representation and how early knowledge may form a foundation for phonological and lexical development as this knowledge is incorporated into emerging language representations (Ramus, Peperkamp, Christophe, Jacquemot, Kouider & Dupoux, 2010).

A framework for these relations can be captured in the PRIMIR model of developmental speech perception (Processing Rich Information from Multidimensional Interactive Representations; Werker & Curtin, 2005). PRIMIR is able to capture continuity across development, because representations are multidimensional and because different levels of representations can interact. Thus, representations that are built in early speech perception are incorporated into later lexical and phonological representations. According to PRIMIR, the earliest sound representations that emerge are on the General Perceptual Plane. These consist of phonetic and indexical categories which are based on similarity clusters or exemplar-based distributions. These representations can range from stress-based patterns to frequently occurring phonotactic sequences. Representations are also context-sensitive, and can capture phonetic differences in the way phonemes are realized in different prosodic positions, 'for example, the distribution of [p^h] in syllable initial position has different values than do word-final or word medial [p] distributions' (Werker & Curtin, 2005: 214–15.) Representations on the General Perceptual Plane are established before the learner has acquired a lexicon. In turn, word forms are extracted from these clusters on the Word Form Plane, resulting in the emergence of lexical neighbourhoods. Phonemes emerge on the Phonemic Plane, from generalizations across the other levels. PRIMIR can provide a promising framework for capturing the relationship between representations that are established during early speech perception and how they are tied to later language production.

Zamuner (2009b) tested predictions based on PRIMIR by examining the phonological organization of children's early productive lexicons. One finding coming from a variety of studies is that an infant's ability to discriminate contrasts and/or categorize stimuli varies across prosodic or

word domains (for a review, see Fais, Kajkawa, Amano & Werker, 2009). In studies that directly compare positional factors, infants are, in general, more sensitive to patterns in word-initial position than word-final position (Jusczyk, Goodman & Bauman, 1999; Zamuner, 2006). Based on the relationship between representations at the General Perceptual Plane and Word Form Plane, this predicts that positional sensitivities seen in early speech perception should be mirrored in the lexical neighbourhoods in children's early lexicons. More words should overlap in word-initial position than in word-final position. This prediction was borne out in an analysis of English-learning children's lexicons between 1;4 and 2;6. Thus, representations that are established before learners acquired a productive lexicon or phonology appear to have an influence on which words children acquire (Zamuner, 2009b). Children's early production patterns can be linked to, or seen as stemming from, an even earlier stage in language development, before children have started producing language. By considering this early stage in development, a new insight is garnered into the continuity across lexical and phonological development.

Converging results are seen in early language production patterns. Children acquire segments in word-initial position before segments in word-final position (Levelt, Schiller & Levelt, 1999). Within the PRIMIR framework, this finding can be characterized in a similar way. Production patterns could stem from representations on the General Perceptual Plane, where word-initial representations are richer or more developed than word-final representations. Production patterns may also be related to lexical representations on the Word Form Plane, where more lexical items overlap in word-initial position than in word-final position. Another example of this relationship is seen in children's production accuracy. Zamuner (2009a) found a relationship between Dutch children's production accuracy in word-initial position and vocabulary size, but not in word-final position. This may be related to learners' early speech perception abilities and to the structure of children's emerging vocabularies. Dutch infants show a perceptual advantage for word-initial position, and early vocabulary analyses of Dutch find more words that overlap in word-initial position than word-final position. It is worth stressing that more research is needed from other languages, as Stoel-Gammon argues. Disentangling these intertwined possibilities will only be possible with more cross-linguistic data. This is not only because languages have both similar and different structures, but also because learners' initial language abilities develop depending on the lexical and phonological patterns of the target language. Thus, research on other languages will help tease apart which factors contribute to learning at different stages of development.

Take another case from the acquisition of phonotactics. Infants begin to demonstrate knowledge of language-specific phonotactics at around age 0;9,

showing a preference for word lists composed of legal phonotactics over illegal phonotactics (Friederici & Wessels, 1993). Continuity across development is seen in later lexical learning, where older infants aged 1;7, show better learning of non-words composed of legal phonotactic patterns than illegal phonotactic patterns (Graf Estes, 2007). Similarly, children are better at producing non-words with legal phonotactic patterns than illegal phonotactic patterns (Messer, 1967). Other studies have found associations between infant phonetic discrimination and later language development, and identified factors to potentially connect them, such as phonotactic pattern learning (Kuhl *et al.*, 2005). These links across development, taken from research on infant speech perception, later lexical development and production, illustrate how integrating findings from early speech perception can provide insights into how we view language development. If a preference or advantage is seen for sound patterns in early infancy (for example, better speech discrimination abilities in word-initial position), and this trend continues across early lexical and phonological development, we need to ask what the nature of this relationship is and how can we account for it (Peperkamp, 2003). These relationships may reflect general processing abilities, more specialized linguistic knowledge or a combination of many factors.

To understand the relationship between lexical and phonological acquisition, Stoel-Gammon argues that research on lexical and phonological acquisition needs to integrate multiple subfields and sources of data. It is essential that we add to this consideration evidence from developmental speech perception to better understand the relationship between lexical and phonological development. Obviously, there is more to language acquisition than perceiving speech but, as research shows, infant speech perception can provide new perspectives on how the lexicon and phonology are acquired.

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