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Commentaries

When phonology guides learning

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In the keynote article, Janet Werker advances the proposal that the phonological system and semantic system develop in concert, with each system exerting influences on the other during the early language learning years. Her seminal work has beautifully demonstrated that infants track information from the signal and use visual, motor, and auditory information to make sense of their linguistic world. The account articulated in the target article, along with the supporting body of research from her lab, provides the field with a foundation for exploring the bidirectional relations between the perceptual world and early language learning.

In what follows, we expand on two core themes articulated in the target article: first, we discuss how the discrimination of speech sound contrasts helps infants to identify sound categories; and second, we review research demonstrating that the developing sound system shapes early word learning and predicts later language skills. We embed our discussion in a theoretical framework, Processing Rich Information from Multidimensional Interactive Representation (PRIMIR; Werker & Curtin, 2005). This framework helped shape thinking about how infants' processing systems and representations work in concert during early language development. Further, this framework has highlighted that the developmental level of the child, as well as the input, biases, and task demands are critical in understanding how infants in monolingual and multilingual learning environments (Curtin, Byers-Heinlein, & Werker, 2011) begin to build their linguistic system. That is, to fully understand whether an infant will or will not demonstrate an ability, the task, the specific speech sound(s), and the current state of learning system have to be considered. PRIMIR takes into account indexical information (visual, motor, etc.) contained within the context in which the task is taking place, supporting the assertion that performance and learning is situationally dependent. Couched within this framework, we can begin to explore how divergent experimental results are obtained depending on the developmental level of the child, the task, and the various stimuli used.

DEVELOPMENT OF SPEECH SOUND CATEGORIES

Werker's groundbreaking work demonstrating infants' narrowing of their ability to discriminate nonnative speech contrasts set the stage for understanding the developmental time course of native language speech sound learning (Werker & Tees, 1984). Although infants are quite adept at discriminating a range of native

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speech sounds at the beginning of a word, there are cases where discrimination is difficult early in development. As Werker notes in the target article, nasal contrasts require some experience before they are easily discriminated (Narayan, Werker, & Beddor, 2010). In this section, we review research that highlights the complex nature of speech sound discrimination, noting that not all speech sounds are equally discriminable and that acoustic salience impacts discrimination. Moreover, we draw attention to the relation between speech sounds and categories. While it appears that young infants are learning about their native language sound categories, full categories (or phonemes) are not emergent until much later in development. That is, early on a sound is bound to a position, and infants require additional experience to recognize a sound across positions.

Recent research demonstrates that infants' ability to distinguish a contrast depends on the position of the contrast and highlights that additional experience with language is required to discriminate contrasts in positions other than word-initial. For example, prior to 16 months of age, Dutch- and English-learning infants do not discriminate voiceless stop consonants in the word-final (coda) position (Archer, Zamuner, Engel, Fais, & Curtin, 2016; Zamuner, 2006). While English-learning 12-month-olds discriminate voiced stops in the word-final position, it is not until several months later that they discriminate these contrasts in the word-medial coda position (Archer et al., 2016). These results suggest that experience as well as the salience of the position are integral to whether infants discriminate speech sound contrasts.

Salience is also important for infants' ability to learn similar sounding labels for objects. For example, when 15-month-olds are taught novel words differing only in their vowels, they detect a mismatch in the object–label pairing (i.e., a switch) if the vowels differ in the height dimension (e.g., /i/ and /I/), but not if they differ primarily in backness (e.g., /i/ and /u/), suggesting that some contrasts are easier to detect than others (Curtin, Fennell, & Escudero, 2009). When a minimal consonant contrast, such as /b/ and /d/, is presented in a stressed, word-medial position, then infants also detect a switch in the object–label pairing (Archer, Ference, & Curtin, 2014), again suggesting that salience of position itself may facilitate or ease the resource allocation for learning similar sounding words.

Together, these findings indicate that while infants demonstrate sensitivity to contrasts, this sensitivity is not evident across the board: where the contrasts occur and the acoustic properties of the contrasts impacts infants' detection of the speech sounds. This suggests that phonetic knowledge is positionally bound and that while infants may perform one way on a task with certain speech sounds, this does not mean that they will succeed (or fail) with other contrasts.

THE DEVELOPING SOUND SYSTEM AND EARLY WORD LEARNING

In the target article, Werker beautifully illustrates how the developing sound system sets the stage for word learning. In this section, we expand on this theme, illustrating how infants' developing phonological knowledge shapes their

acquisition of object words. In our research, we have addressed this question by focusing on one of the first steps in word learning, namely, linking a sound form with an object. Capitalizing on the Switch task (Werker, Cohen, Lloyd, Casasola, & Stager, 1998), a word–object association task that provides no contextual or referential cues, we have investigated the types of sound forms that infants are willing to entertain as possible labels in the early stages of word learning.

Our studies have demonstrated that by 12 months of age, infants show preference for particular sound forms as object labels, based on the phonological structure of the word. That is, English-learning 12-month-olds will associate objects with well-formed object labels, such as *fep* and *wug*, but will not map isolated speech sounds (e.g., /l/) or communicative sounds (e.g., *oooh* and *shhh*) to objects (MacKenzie, Graham, & Curtin, 2011). Furthermore, infants of the same age show preference for mapping these noun-like forms over forms that bear the characteristics of function-like words (i.e., syllable reduction, reduced vowels, and simplified syllable structure; MacKenzie, Curtin, & Graham, 2012a). Taken together, these findings indicate that English-learning infants have developed preferences for what constitutes an appropriate phonological pattern for content-like, and more specifically, noun-like object labels, despite extensive exposure to various speech sounds, communicative sounds, and even function words in their linguistic environment.

Infants' early object–word associations also reflect their developing knowledge about what is considered a legal phonotactic sequence for their language's object labels. That is, 12-month-old English-learning infants reject forms with illegal onset sequences, such as the Czech form *ptak*, as labels for objects (MacKenzie, Curtin, & Graham, 2012b; MacKenzie, Graham, Curtin, & Archer, 2014; see also Graf-Estes, Edwards, & Saffran, 2011). English-learning 12- and 17-month-olds will map atypical sounding forms, such as the Japanese form *sika*, to objects (MacKenzie et al., 2012b; San Juan, Lin, MacKenzie, Curtin, & Graham, 2017). Infants' acceptance of these forms, which contain legal sound sequences for English, but are phonetically atypical for English, suggests that infants will accept a certain amount of phonetic variation, perhaps due to the variability experienced in the ambient language input. They will not, however, accept forms that violate the phonotactics of the language they are learning.

These results demonstrate that infants, at the early stages of productive word learning, have preferences for particular types of word forms as object labels. We suggest that these preferences assist infants by enabling them to narrow the search space to appropriate word forms when learning new words. These preferences, however, are flexible and can be modulated based on the task at hand. That is, when provided with subtle evidence orienting them toward object labels, English-learning infants will map phonotactically illegal word forms (e.g., *ptak)* or nonnative speech sounds (e.g., [!a]) onto objects (MacKenzie et al., 2014; May & Werker, 2014; Vukatana, Curtin, & Graham, 2016). Infants' flexibility, however, is limited: even with additional contextual information, infants reject isolated consonantal sounds (e.g., /l/) or function-like words (e.g., *iv*) as object labels, suggesting that infants will not link word forms that are structurally poor (i.e., consonant, consonant–vowel, or vowel–consonant structure) to objects (MacKenzie et al., 2014).

As infants approach their second birthday, this flexibility in mapping forms narrows (Graham & Kilbreath, 2007; Namy & Waxman, 1998; Suanda & Namy, 2013; Woodward & Hoyne, 1999). The developmental course of this restriction, however, differs as a function of the type of form to be mapped. That is, 17- to 20-month-olds will no longer link objects with words with phonotactically illegal onsets (Graf-Estes et al., 2011; Vukatana et al., 2016) or words with nonnative speech sounds (May & Werker, 2014). Infants in this age range, however, will continue to map gestures to objects (Graham & Kilbreath, 2007; Namy, 2001; Suanda & Namy, 2013). By 22 to 26 months of age, however, infants will no longer map gestures to objects (Graham & Kilbreath, 2007; Namy & Waxman, 1998). There are, however, some conditions under which infants older than 24 months will map nonlinguistic sounds (Henderson, Graham, & Schell, 2015) and gestures to objects (Namy, Campbell, & Tomasello, 2004).

The research reviewed above illustrates how the infants' developing phonological knowledge helps guide their word learning efforts. Another line of research examining this relation has focused on how infants' phonological sensitivities predict their later acquisition of vocabulary. Studies in this realm have examined these developmental trajectories in both typically developing infants and infants at higher risk for developmental concerns. For example, a preference for speech over nonspeech at 12 months is related to vocabulary size at 18 months (Vouloumanos & Curtin, 2014). An early preference at 5 months for the predominant stress pattern of the language is related to vocabulary size at 12 months for typically developing infants, but not those infants who are at elevated risk for autism spectrum disorders (ASD; Ference & Curtin, 2013). Similarly, typically developing infants' ability to map novel words to objects that differ solely in their stress patterns at 12 months (Curtin, 2009) is related to their vocabulary comprehension at that age (Ference & Curtin, 2015). For infants who are at increased risk for ASD because they have an older sibling with ASD, an ability to map minimally differing stressed forms to objects predicts expressive language abilities at 24 months (Ference & Curtin, 2015).

The findings reviewed above suggest that early skills/abilities have long-term implications for other aspects of language development. However, studies with a variety of populations need to occur in order to establish the conditions under which early perceptual abilities influence different aspects of later linguistic development. For example, performance in a minimal pair word-learning task using subtle consonant contrasts (e.g., bih and dih) at 17 to 20 months of age predicted phonological knowledge and preliteracy skills up to 2.5 years later (Bernhardt, Kemp, & Werker, 2007). This finding, however, was not replicated in a tightly controlled longitudinal study with infants from more diverse socioeconomic backgrounds (Kemp et al., 2017). Thus, early tasks may predict or support different aspects of linguistic development, and understanding these relations will help us to better identify and track which abilities and skills support the complex range of linguistic skills required to successfully acquire language.

CONCLUSIONS

Werker's research on speech development and word learning has sparked numerous studies and set the stage for exploring how the phonological system and word learning influence one another. Building on the account outlined in her target article, we have highlighted how experience with the native language sound system guides infants' language learning. With experience, infants can begin to discriminate speech sound contrasts that are less salient and occur in less salient positions. Experience also impacts the mapping of appropriate word forms to referents. Infants are sophisticated learners, and without additional information (be it referential or knowledge of the task), they will limit their willingness to map forms that fall outside of their experience. Early experiences and infants' knowledge of the sound system also impacts later emerging aspects of language learning. Together, these findings suggest that infants' language learning is shaped and guided by experiences, the context, the input, and the current state of their linguistic system (Werker & Curtin, 2005).

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REFERENCES

Archer, S., Ference, J., & Curtin, S. (2014). Now you hear it. 14-month-olds succeed at learning minimal pairs in stressed syllables. *Journal of Cognition and Development*, *15*, 110–122. doi: 10.1080/15248372.2012.728544.

Archer, S., Zamuner, T., Engel, K., Fais, L., & Curtin, S. (2016). 12- and 20-month-olds' ability to perceive coda consonants: Effects of position and voicing. *Language Learning and Development*, *12*, 60–78. doi: 10.1080/15475441.2014.979490.

Bernhardt, B. M., Kemp, N., & Werker, J. F. (2007). Early word-object associations and later language development. *First Language*, *27*, 315–328.

Curtin, S. (2009). Twelve-month-olds learn word-object associations differing only in stress patterns. *Journal of Child Language*, *36*, 1157–1165.

Curtin, S., Byers-Heinlein, K., & Werker, J. F. (2011). Bilingual beginnings as a lens for theory development. *Journal of Phonetics*, *39*, 492–504.

Curtin, S., Fennell, C., & Escudero, P. (2009). Weighting of acoustic cues explains patterns of word-object associative learning. *Developmental Science*, *12*, 725–731.

Ference, J., & Curtin, S. (2013). Attention to lexical ltress and early vocabulary growth in 5-month-olds at risk for autism. *Journal of Experimental Child Psychology*, *16*, 891–903.

Ference, J., & Curtin, S. (2015). The ability to map differentially stressed labels to objects predicts language development at 24 months in 12-month-olds at high-risk for autism. *Infancy*, *20*, 242–262.

Graf Estes, K., Edwards, J., & Saffran, J. R. (2011). Phonotactic constraints on infant word learning. *Infancy*, *16*, 180–197.

Graham, S. A., & Kilbreath, C. S. (2007). It's a sign of the kind: Gestures and words guide infants' inductive inferences. *Developmental Psychology*, *43*, 1111.

Henderson, A. M., Graham, S. A., & Schell, V. (2015). 24-month-olds' selective learning is not an all-or-none phenomenon. *PLOS ONE*, *10*, e0131215.

Kemp, N., Scott, J., Bernhardt, B. M., Johnson, C. E., Siegel, L. S., & Werker, J. F. (2017). Minimal pair word learning and vocabulary size: Links with later language skills. *Applied Psycholinguistics*, *38*, 289–314.

MacKenzie, H., Curtin, S., & Graham, S. A. (2012a). 12-month-olds' phonotactic knowledge guides their word–object mappings. *Child Development*, *83*, 1129–1136.

MacKenzie, H., Curtin, S., & Graham, S. A. (2012b). Class matters: 12-month-olds' word–object associations privilege content over function words. *Developmental Science*, *15*, 753–761.

MacKenzie, H., Graham, S. A., & Curtin, S. (2011). Twelve-month-olds privilege words over other linguistic sounds in an associative learning task. *Developmental Science*, *14*, 249–255.

MacKenzie, H. K., Graham, S. A., Curtin, S., & Archer, S. L. (2014). The flexibility of 12-month-olds' preferences for phonologically appropriate object labels. *Developmental psychology*, *50*, 422.

May, L., & Werker, J. F. (2014). Can a click be a word? Infants' learning of non-native words. *Infancy*, *19*, 281–300.

Namy, L. L. (2001). What's in a name when it isn't a word? 17-month-olds' mapping of nonverbal symbols to object categories. *Infancy*, *2*, 73–86.

Namy, L. L., Campbell, A. L., & Tomasello, M. (2004). The changing role of iconicity in non-verbal symbol learning: A U-shaped trajectory in the acquisition of arbitrary gestures. *Journal of Cognition and Development*, *5*, 37–57.

Namy, L. L., & Waxman, S. R. (1998). Words and gestures: Infants' interpretations of different forms of symbolic reference. *Child Development*, *69*, 295–308.

Naryan, C. R., Werker, J., & Beddor, P. (2010). The interaction between acoustic salience and language experience in developmental speech perception: Evidence from nasal place discrimination. *Developmental Science*, *13*, 407–420.

San Juan, V., Lin, C., Mackenzie, H., Curtin, S., & Graham, S. A. (2017). *Not speaking the same language: 17-month-olds shift their perception of novel labels following brief exposure to non-native language*. Manuscript submitted for publication.

Suanda, S. H., & Namy, L. L. (2013). Young word learners' interpretations of words and symbolic gestures within the context of ambiguous reference. *Child Development*, *84*, 143–153.

Vouloumanos, A., & Curtin, S. (2014). Tuned to speech: How infants' attention to speech predicts language development. *Cognitive Science*, *38*, 1675–1686.

Vukatana, E., Curtin, S., & Graham, S. A. (2016). Infants' acceptance of phonotactically illegal word forms as object labels. *Journal of Child Language*, *43*, 1400–1411.

Werker, J. F., Cohen, L. B., Lloyd, V. L., Casasola, M., & Stager, C. L. (1998). Acquisition of word–object associations by 14-month-old infants. *Developmental Psychology*, *34*, 1289.

Werker, J. F., & Curtin, S. (2005). PRIMIR: A developmental framework of infant speech processing. *Language Learning and Development*, *1*, 197–234.

Werker, J. F., & Tees, R. C. (1984). Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. *Infant Behavior and Development*, *7*, 49–63.

Woodward, A., & Hoyne, K. (1999). Infants' learning about words and sounds in relation to objects. *Child Development*, *70*, 65–77.

Zamuner, T. S. (2006). Sensitivity to word-final phonotactics in 9- to 16-month-old infants. *Infancy*, *10*, 77–95.

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