Six questions in infant speech and language development

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1.0 Introduction

Fifty years ago, doing language development research typically meant doing diary studies (i.e., studying orthographic transcriptions of children's language productions, often recorded by the children's own parents; Darwin, 1877; Leopold, 1947). Some elicitation studies also existed (Slobin & Welsh, 1973), as did some studies involving metalinguistic judgments (Gleitman, Gleitman & Shipley, 1972). But no researcher could have dreamt of the types of tools researchers have at their disposal now. Despite their technological limitations, pioneers in the field managed to characterize many of the key elements of early language acquisition. They showed how quickly children transition from the one word to the multi-word stage (Braine, 1976). They documented how variable normal speech learning trajectories can be (Peters, 1977), as well as how variable language input can be (Snow & Ferguson, 1977). And they provided evidence that children learn grammatical rules, not just patterns of words (Berko, 1958). This early work laid down a solid foundation for the modern-day study of early language acquisition.

Today, researchers interested in early language acquisition have many more tools at their disposal. Behavioural paradigms have been developed to examine how infants perceive speech sounds in the first months of life (Jusczyk, 1997). Eyetrackers automatically track the fine-grained timecourse of children's looking behaviour and pupil dilation as the speech signal unfolds (Aslin & McMurray, 2004). Audiovisual equipment and computerized analysis programs have advanced so quickly that it is now relatively easy to build dense corpora of naturalistic parent-child interactions (Roy et al., 2015; Weisleder & Fernald, 2013). Brain imaging equipment allows researchers to safely study children's neural responses to language input (Aslin & Mehler, 2005; Mannel & Friederici, 2008), and ultrasound imaging and heart rate tracking technology allow researchers to observe fetal responses to speech even before birth (Busnel & Granier-Deferre, 1983; DeCasper et al., 1994; Kisilevsky et al., 2003).

With all of these additions to their toolbox, today's researchers have been able to ask old questions in new ways, as well as to tackle all sorts of previously unanswerable questions. Research made possible by these new tools has revealed that young infants and toddlers are more language savvy than anyone could have possibly imagined 50 years ago. As the age at which children display competencies in various aspects of language drops, many of our theories for how children are accomplishing these feats have had to undergo dramatic revision.

In this chapter, we will discuss six key questions that have been the focus of intense inquiry over the past decades. All are fundamental questions in the field of early speech and language development that researchers have made great strides towards answering in recent years. But, as is always the case in science, the answers we have today are really only approximations of the truth. As such, our discussion will both outline progress made in addressing these questions in recent decades, as well as highlight how these fundamental questions are still not fully answered (or how the answers we have obtained have simply generated additional questions).

2. How do children acquire the phoneme inventory of their native language?

Before the days of infant speech perception labs, the answer to this question appeared to be obvious. The phoneme inventory of a language includes all of those speech sounds (vowels, consonants, and tones) that signal a meaningful contrast between two words. Children were thought to learn the phoneme inventory of their native language by attending to minimal pairs (e.g., *pear* and *bear* in English). If they had two words in their lexicon with different meanings that differed by a single speech segment, then they had evidence that these two segments were contrastive in the native language. Prior to acquiring a vocabulary large enough to contain minimal pairs, children were thought to have holistic representations of words that contained little segmental detail. This view was supported by production data showing that children made frequent pronunciation errors (Ferguson & Farwell, 1975; Stoel-Gammon & Cooper, 1984; Vihman, Ferguson & Elbert, 1986), and comprehension studies suggesting that children had difficulty discriminating minimal pair words (Barton, 1976; Garnica, 1973).

More recently, this view has been turned on its head. Studies with toddlers show that they are, in fact, quite sensitive to even slight mispronunciations of familiar words (Bailey & Plunkett, 2002; Paquette-Smith, Fecher, & Johnson, in press; Swingley & Aslin, 2002; White & Morgan, 2008), although very young infants may not show this sensitivity for some of their earliest learned words (Bouchon et al., 2015; Delle Luche et al., 2016). Infant perception studies have also shown that infants are learning about the sound system of their language at an age when they have very few (if any) minimal pair words in their vocabulary (Jusczyk, 1997; Werker & Curtin, 2005). Both behavioural and electrophysiological studies show that, compared to where they start as newborns, 8-10-month-old infants do equally well or better at distinguishing between consonants that are meaningfully contrastive in their native language, but worse at distinguishing between consonants that are *not* contrastive in their native language (Kuhl et al., 2006; Narayan, Werker, & Beddor, 2010; Rivera-Gaxiola, Silva-Pereyra, & Kuhl, 2005; Werker & Tees, 1984). As a native language category is established, non-native sounds can be pulled (or assimilated) into that single native category, making them harder to tell apart (Best & McRoberts, 2003). Changes in perception occur even earlier for vowels (Cheour et al., 1998; Kuhl et al., 1992; Polka & Werker, 1994). Clearly, given that these changes in perception occur during the first year of life, children are unlikely to be relying on meaningful minimal pairs to work out the phoneme inventory of their native language.

If infants do not depend on minimal pairs to learn about the phoneme inventory of their language, then what other learning strategies might they depend on? One possibility is that infants simply track the frequency distributions of speech sounds (Maye, Werker, & Gerken, 2002). Tracking frequency distributions may be a useful way to learn about the sound categories of a language because of the way these categories are organized. The realization of phonemes is highly variable (more on this later). But if we were to keep track of the different realizations and how often they occur, we would find that the "best" versions of each phoneme occur more frequently, leading to peaks and troughs in the frequency distribution (Lisker & Abramson, 1964). This sort of distributional information could potentially provide young listeners with limited vocabularies a very strong clue to the organization of speech categories.

Of course, no matter how informative distributional cues appear to be in models of language acquisition, they would be useless if infants were not actually able to efficiently track and remember this information. Experimental work has provided some evidence that infants are able to extract this information from their speech input, supporting the notion that phoneme inventories could be bootstrapped from input distributions. We can see this in a couple of ways – first, when we manipulate frequency distributions of sounds in the laboratory, this affects infants' subsequent speech discrimination (Maye et al., 2002); second, in learning their native language, infants learn sounds that occur more often in their input earlier (Anderson, Morgan, & White, 2003), and distributions that are less clear, or "messier", are harder to learn (Bosch & Sebastian-Galles, 2003). So it seems that infants likely rely, at least in part, on distributional learning to tune their universal sensitivities to the inventory they hear around them.

However, some distributions are exceptionally difficult to sort out. For example, there is so much variability across individuals and phonological contexts in the pronunciation of vowels that if all infants did was track frequency distributions, some vowel categories would appear to significantly overlap with one another (Hillenbrand, Getty, Clark, & Wheeler, 1995). So infants must be using additional information as well. One proposal is that infants are sensitive to not just how often they hear different speech sounds, but also to the contexts (e.g., words) in which these sounds occur (even if they don't know the meanings of these words). This could help them in a number of ways. First, the occurrence of acoustically similar vowels across multiple instantiations of a particular word (e.g., the vowel /ɪ/ in multiple tokens of the word *milk*) or in minimally different words could help infants group the variable pronunciations of that vowel into a single category (Martin, Peperkamp & Dupoux, 2013). Alternatively (and perhaps in addition), infants may be less likely to mistakenly group two acoustically similar vowels into the same category when they occur in distinct words (e.g., the similar vowels /ɪ/ and /ɛ/ in the words *milk* and *bed*; Feldman et al., 2013; Feldman, Griffiths, Goldwater, & Morgan, 2013; Thiessen, 2007). Note that these strategies require only that infants track the words in which particular sounds are heard, not that they learn the meanings of minimal pairs. The use of lexical information to constrain bottom-up distributional analyses in this way is plausible, because by the end of the first year, infants have acquired a proto-lexicon of words, or at least frequently co-occurring syllables (Halle & deBoysson-Bardies, 1994; Ngon et al., 2013).

Thus, all in all, studies capitalizing on the field's methodological advances have painted an entirely different picture of how children acquire the phoneme inventory of their language. The view that children must learn a sizeable number of words before beginning to work out which sounds are contrastive in the native language is thought to be no longer tenable. However, some have questioned whether the distributions of speech sounds are as clear and as easy to learn in natural speech as they are in artificially created speech streams (Martin et al., 2015). And, as we have seen, even if children do learn about the phoneme inventory of their language via distributional statistics, we have very little sense of the full range of information that is available in the input, or the statistics that infants have the ability to compute. It is also not clear what exactly infants are learning on the basis of these statistics. Do they truly know the phoneme inventory of their language by 8 to 12 months of age? Or have they just built the foundation upon which later phonological learning will depend? How can we tell? One suggestion that the latter might be the case is evidence that children are still refining their perception of phonemes well into childhood (Nittrouer, 2002; Walley, 1993). Moreover, focusing only on statistical distributions tends to overlook some other differences in the timing and trajectory of learning about different speech segments. For example, the speed with which infants learn about different speech sounds is linked to many other factors besides statistical distributions and frequency, such as perceptual salience (Narayan et al., 2010; Polka, Colantonio, & Sundara, 2001) and perhaps even innate phonological biases (Brown & Matthews, 1997; Fikkert, 2010). Therefore, the argument that children can learn all they need to know about the phoneme inventory via distributional learning in the first 8 to 12 months of life is not an open and shut case.

3. When and how do children find words in speech?

Although we readily perceive spoken language as a string of discrete words, the speech signal does not actually contain any reliable pauses marking word boundaries. Instead, the articulations of words can blend seamlessly with the articulation of neighboring words, leading to ambiguity in where one word ends and the next begins (Cole & Jakimik, 1980). This is known as the word segmentation problem.

Adults solve the word segmentation problem in part by relying on language-specific probabilistic cues to word boundaries. For example, English content words tend to carry word-initial stress (e.g., *hello*, *magazine*, *panther*, etc.; Cutler & Carter, 1987), and voiceless plosives are aspirated in word-initial but not word-final position (e.g, the [p] in *pit* is aspirated whereas the [p] in *tip* is not). English listeners use these probabilistic patterns to identify word boundaries (e.g., they are biased to perceive stressed syllables as word onsets; Cutler & Norris, 1988). Importantly, however, the probabilistic cues that help you find word boundaries must be learned because they are different in every language (e.g., Polish stress falls on the penultimate syllable, and French word-initial plosives are not aspirated).

If adults rely in part on language-specific segmentation cues to solve the word segmentation problem, then how do children learn those cues? One simple assumption could be that parents speak to children in predominantly one-word utterances, essentially feeding children information about word boundaries. However, multiple corpus studies have shown that caregivers typically address children in multi-word utterances, with isolated words accounting for as little as 7% of the child's input (Van de Weijer, 1999; see also Brent & Siskind, 2001; Johnson, Lahey, Ernestus, & Cutler, 2013). Another possibility is that children struggle to hear word boundaries for many years until they build up a sizeable lexicon, and then they use top-down lexical knowledge to find word boundaries. However, adults have other segmentation strategies at their disposal (Cutler, 2012). Moreover, we now have abundant evidence from both behavioural and EEG studies that infants both know how words typically sound in the native language as well as segment words from speech long before their first birthday (e.g., Jusczyk, Houston, & Newsome, 1999; Kooijman et al., 2013). How can this be possible? How can infants learn how to identify word boundaries without first having substantial exposure to words produced in isolation?

One widely discussed explanation for infants' development of word segmentation abilities is that they rely on a domain-general statistical learning mechanism to extract an initial cohort of words from speech. Once an initial cohort of words is identified through such a mechanism, infants could begin bootstrapping language-specific cues to word boundaries. The most popular proposal for such a domain-general statistical learning strategy is the tracking of the transitional probabilities between syllables (Saffran, Aslin, & Newport, 1996). If the transitional probability between two syllables is high, then those syllables are likely to belong to the same word. In contrast, if the transitional probability is low, then those syllables are likely to span a word boundary. Put in more concrete terms, consider the phrase *pretty baby*. The transitional probability between *ba-* and *–by* is likely much higher than the transitional probability between –tty and –ba. Therefore, the first pair of syllables probably belong to the same word whereas the latter pair of syllables likely span a word boundary.

Infant behavioural studies have provided abundant and compelling support for this hypothesis. In just a few minutes, English-learning infants have been shown to segment words from an artificial language speech stream that contains no cues to word boundaries other than transitional probabilities between syllables (Saffran et al., 1996). This finding has been extended to other language-learning populations (Mersad & Nazzi, 2012), as well as infants as young as 5 months of age (Johnson & Tyler, 2010). Moreover, infants' ability to track transitional probabilities in an artificial language predicts scores on subsequent tests of child language abilities (Erickson & Thiessen, 2015), and infants show at least some sensitivity to high versus low transitional probabilities in natural speech (Pelucchi, Hay, & Saffran, 2009).

The evidence for infants' use of transitional probabilities to solve the word segmentation problem is so strong that many textbooks simply present this hypothesis as fact. However, just as there are some unresolved issues with how infants might use distributional statistics to learn the phoneme inventory of their native language, there are also some open questions when it comes to how fully children might rely on transitional probabilities to solve the word segmentation problem. One criticism of this hypothesis is that infants' ability to segment an artificial language using transitional probabilities might not scale up to the variability and complexity found in natural language (Yang, 2004; Johnson, 2012). For example, some studies have suggested that infants' ability to track transitional probabilities is very fragile, and falls apart when they are presented with a slightly more naturalistic language (e.g., an artificial language containing four words of variable length rather than four words of uniform length; Johnson & Tyler, 2010). Another criticism is that tracking transitional probabilities between syllables might work well for some languages (e.g., English and Italian) but not so well for other languages (e.g., Hungarian and Mandarin). Finally, many have argued that transitional probabilities are not the only language-general cue available to infants. Indeed, some have argued that major prosodic boundaries may provide a far simpler language-general segmentation solution to infants, and there is some evidence that infants rely more on prosodic boundaries than transitional probabilities when they are placed in conflict (Johnson, Seidl & Tyler, 2014; Shukla, White & Aslin, 2011). Universal constraints on the form of possible words in a human language may provide another cue (Johnson, Jusczyk, Cutler, & Norris, 2003; Yang, 2004). Clearly, additional work is needed to fully understand precisely how infants solve the word segmentation problem.

4. When and how do children begin adding entries to their lexicon?

Children typically produce their first word around 12 months of age, but both parents and researchers have long suspected that infants begin understanding words and building up a lexicon well before they begin talking. Initially, all researchers could do to gauge this understanding was ask parents to keep track of when their children showed evidence of understanding words that were spoken in their presence, like *mommy* and *bib*. Based on such parental report surveys, researchers estimated that by 11 months, children understood approximately 50 words on average (Fenson et al 1994). By the time children reached 18 months, their vocabularies were really taking off, with some estimating that children learn as many as 10 new words a week (Bloom, 2000).

But parental report, on its own, provides only one window onto children's comprehension abilities. In the past 20 years, infant-friendly eyetracking procedures have become common. These procedures provide researchers with a very useful additional window onto infants' early comprehension abilities. In these studies, children are typically presented with images on a screen while a label for one of the objects is produced (e.g., the child will see a picture of a dog and a duck and hear *Look at the dog*). If children understand the word, they will automatically look toward the labeled object. Remarkably, studies using infants' eye movements to assess their comprehension reveal that by 6 months of age, infants already understand the words *mommy* and *daddy* (e.g., they look more to a picture of their mom when they hear *mommy* and a picture of their dad when they hear *daddy*; Tincoff & Jusczyk, 1999), and that 6- to 9-month-olds understand the labels for body parts (e.g., *hand* and *feet*) and many other commonly heard nouns (Bergelson & Swingley, 2012; Tincoff & Jusczyk, 2012). By 6 to 7 months of age, under ideal conditions, children can be taught referent-object pairings in the lab (Gogate & Bahrick, 1998; Shukla et al., 2011).

Although the process of word learning might seem intuitively simple (a "teacher" points at an object and provides the label), researchers have long puzzled over its complexity – how do children pick out just the right meanings for words in a world where meanings can be anything? As the age at which we think children begin showing comprehension of words has dropped, we have had to revise our theories for how children initially learn the meanings of words (see Kucker, this volume).

The latest research suggests that children rely on different strategies at different ages, and also flexibly adjust their referential mapping strategies depending on context. We know that children well under two years of age can use social cues (Baldwin, 1993), perceptual salience (Pruden, Hirsh-Pasek, Golinkoff, & Hennon, 2006), and cross-modal synchrony (Gogate & Bahrick, 1998) to attach labels to objects. By two years of age, children also use various grammatical cues to determine the type of referent (Naigles, 1990; Paquette-Smith & Johnson, 2016; Waxman & Booth, 2001). But at six months of age, infants presumably have very limited (if any) access to most of these types of word learning strategies. For example, if an infant hasn't yet learned that the ending "ish" is often found in adjectives (e.g., "sheepish" or "selfish"), then they can't use that ending to help them zoom in on the kinds of meanings that adjectives label. So how does a 6-month-old work out the meanings of words?

One language-general word-learning strategy very young infants might rely on is to track information over time. Even if it is impossible to determine what a word means the first time you hear it, perhaps over time you can narrow in on the right meaning. In the case of concrete nouns, one way to do this is to track which object is most reliably present in the environment when a particular word is heard. For example, even though an infant might hear the word *shoe* in the presence of a variety of different objects (and in some cases, even in the absence of a shoe, as in *Where's your shoe*?), over time, shoes will tend to be the objects most reliably present. As we've seen already, infants are remarkably good statistical learners. So it might not be a surprise that by 12 months, infants (in a simplified, but still ambiguous, learning situation) can track the relationships between words and objects over time to figure out which words go with which objects (Smith & Yu, 2008).

Children still need some way to narrow the range of information they are considering. Even if a particular object is most reliably associated with a particular word, how do they know whether the word refers to the whole object, its color, its texture, the fact that it is oriented in a particular way, or any of a variety of other potential meanings? It turns out that infants have certain assumptions about what words should mean, helping them to narrow down these possibilities. For example, one of these assumptions is that words refer to whole objects (believed to be one reason infants have so many nouns in their early vocabulary; Markman, 1990). So infants are not just passively absorbing associations in the world around them – instead, they are making hypotheses about what words mean. Over time, these word-learning strategies build on one another to become more sophisticated. For example, in the process of tracking the relationship between words and objects, infants may discover that an adult's eye gaze frequently signals a reliable association, leading them to the realization that eye gaze is a highly informative cue on its own (Hollich et al., 2000). In other words, infants can use what they know to bootstrap their learning of other regularities (Smith et al., 2002).

Clearly, the use of new methodologies (e.g., eyetracking) to study early word comprehension has drastically changed our understanding of early word learning. But many questions remain. One important question is how to relate infants' behaviour (in this case, word recognition or production) to their underlying understanding. Does the fact that a child looks at the correct picture mean that they have the same understanding of words that an adult has? In particular, do infants understand that words refer, or stand for, their meanings? Or do they instead simply associate labels and objects or events, in the way we might associate the bell of an ice cream truck with a delicious treat? Indeed, some have argued that children's early object-label mappings lack the abstract nature of adults' mappings (see discussion in Waxman & Gelman, 2009; Sloutsky & Fisher, 2012).

Going beyond the meanings of individual words, we can also ask what young word learners know about the semantic relationships among words. In adults, there are extensive networks of connections between words, as demonstrated by semantic priming and eye-tracking studies (Yee & Sedivy, 2006; Moss, Ostrin, Tyler, & Marslen-Wilson, 1995). But thus far no evidence for priming exists in toddlers before the age of 18 months (Arias-Trejo & Plunkett, 2009; Delle Luche et al., 2014; Willits et al., 2013), so it is an open question whether words are connected in the same way early in development. Thus, although we now know that children begin building a proto-lexicon in early infancy, we still do not fully understand how they do it or how this early proto-lexicon transforms into the adult lexicon.

5. How do children deal with variability in the input?

Most models of language processing assume that words are made up of phonemes. But when speech scientists began looking for cues to phoneme identity in the 1950s, they were startled to discover that the acoustic cues to phonemes are not invariant, but instead differ across contexts (e.g., the acoustics of /d/ followed by /a/ are not the same as when /d/ is followed by /i/). In addition to the adjacent speech context, a variety of other factors also affect the realization of speech sounds, like a speaker's speech rate, gender, and emotion. So how do we know that a /d/ is a /d/? It is difficult enough to imagine how adults solve this problem, let alone how infants do. Over the years, there have been a variety of proposals for how listeners deal with this type of variability, ranging from the presence of individual invariant cues to certain phonetic features (Blumstein & Stevens, 1980), to the use and integration of multiple cues (Toscano & McMurray, 2010), to representations that don't strip off the variability at all (Johnson, 1997; Goldinger, 1998). Although we still don't know exactly how adults solve the lack of invariance problem, we know that they do.

So when do infants solve this problem? When we consider infants' performance in simple speech discrimination tasks involving isolated syllables, the answer appears to be that they solve it quite early. Both behavioural and electrophysiological studies reveal that very young infants are able to recognize that two speech sounds are the same when they differ in pitch or speech rate, or are produced by different talkers (Dehaene-Lambertz & Pena, 2001; Eimas & Miller, 1980; Jusczyk, Pisoni & Mullennix, 1992; Polka, Masapollo & Menard, 2014). For example, 6-month-old infants trained to turn their head when they hear a particular vowel will do so even if the pitch of the vowel changes (Kuhl, 1983). Although behavioural measures suggest that very young infants have a somewhat harder time recognizing that a consonant is the same when it occurs in different vowel contexts (Bertoncini et al., 1988; Eimas, 1999), pupillometry and electrophysiological measures demonstrate that they do this successfully by 3-6 months (Hochmann & Papeo, 2014; Mersad & Dehaene-Lambertz, 2016).

However, when infants are confronted with the same sorts of variability in the context of word recognition tasks, they do not always fare as well. For example, even though 7.5-month-olds can recognize that different versions of /pa/ are equivalent, they may not recognize that tokens of a newly trained word that differ in pitch are the same (Houston & Jusczyk, 2000; Singh, White & Morgan, 2008). Importantly, however, infants don't have this problem if the word is presented in more variable forms during the learning phase (Singh, 2008; Van Heugten & Johnson, 2012) or if the word was familiar to them before arriving in the laboratory (Singh, Nestor, & Bortfeld, 2008).

These successes and failures should be taken as important clues to how early speech perception works. If an infant sometimes struggles to recognize a newly learned word when the pitch changes, what does that mean? And why would infants' ability to cope with these sorts of variability differ depending on context? One possibility that has been advanced is that these sorts of changes can disrupt infants' word recognition because infants aren't quite sure what aspects of a word's pronunciation matter for its identity (Singh et al., 2008). So before they've worked out that pitch alone does not matter in English for distinguishing words, hearing a particular word repeatedly in a given pitch might mislead them into thinking that pitch is relevant (at least for that word). On this view, in the same way that infants track information over time for learning the meanings of words, they may also be trying to determine the most reliable acoustic-phonetic properties of the words themselves. Alternatively, it could be that even young infants encode words according to the same lexically contrastive dimensions as adults, but that this ability is fragile, and in difficult tasks infants fall back on salient features of the signal, like voice or pitch.

In addition to the abovementioned types of variation, infants must also cope with speakers who have different language backgrounds (both native speakers of other dialects and non-native speakers). This type of variation introduces a whole new level of complexity, because the mapping from sounds to words is different across accents. For example, a French-accented

/p/ sounds like a /b/ to an English speaker, because of the acoustic cues to /p/ and /b/ in the two languages. This means that once children have figured out how sounds map to words in their own accent, they can't just rigidly apply those mappings to words produced by people with different accents. Moreover, if they are being regularly exposed to more than one variant of their native language(s) in their everyday life, children must work out how the mappings work in the each of the different language varieties in their environment (Durrant, Delle Luche, Cattani, & Floccia, 2014; Fennell & Byers-Heinlein, 2014; Floccia et al., 2012; Van der Feest & Johnson, 2016).

Infants and children get better at dealing with the variability introduced by accents over development (see Cristia et al., 2012 for a review), though it's not yet clear how this improvement is linked to other aspects of children's developing phonological and lexical knowledge. For example, when listening to a native accent, 12-month-olds prefer to listen to familiar words over novel words (Hallé & Boysson-Bardies, 1994). But 15-month-olds do not show this preference when words are spoken in an unfamiliar accent (Best et al., 2009), although they do if they are given a suitable chance to adapt to the accent (van Heugten & Johnson, 2014). By 19 months, toddlers show the preference without the additional exposure. But these listening preference tasks do not necessarily reflect word recognition or comprehension. And studies using an eyetracking paradigm where children are asked to find a target object on a screen do not always reveal such competencies in toddlers. Although 19-20-month-olds recognize words produced in an artificial accent if given previous exposure to the accent (e.g., children exposed to a speaker who pronounces *dog* as *dag* can infer that that same speaker will produce *block* as *black*; White & Aslin, 2011), other studies using similar paradigms have shown that 20-month-olds still have difficulty recognizing words produced in natural unfamiliar accents (e.g., Canadian children have difficulty comprehending Australian accented-words after two minutes of exposure; Van Heugten, Krieger, & Johnson, 2015; see, however, Mulak et al., 2014).

At this point, we still have many more questions than answers about how infants (and adults!) deal with the variability present in speech. We still don't understand how, given an acoustic signal that cues so many things at the same time (e.g., speech sounds, a person's gender, age, identity, and emotion), we can apportion the signal appropriately into the parts that tell us what is being said as well as who and how they are saying it. Does the way that this process happens change over development? And how is this linked to the changes we see in children's ability to recognize words across different types of variability, including accent differences? We have a long way to go to understanding these important questions.

6. When do children start learning about function words and grammar?

Children don't begin speaking in full-fledged sentences. Rather, their first productions are typically one-word utterances such as *mommy* or *doggie*. Other words children tend to find useful, such as *more* or *up,* are also common in children's early productive vocabularies. The likelihood of verbs appearing in children's earliest productions can vary somewhat depending on what language children are learning (Tardiff, 1996). But importantly, regardless of what language a child is learning, function words (or morphemes) such as *the* and *a* are often not produced by children until much later in development (Brown, 1973; see, however, Slobin, 1982). Even once children start stringing together more than one word, these early utterances often omit function words and morphemes (e.g., *Mommy sock* rather than *This is mommy's sock*).

Historically, children's omission of function words (and morphemes) was taken to indicate that children did not begin to learn about function words or the grammatical relations they convey until long after they begin speaking. That is, even if toddlers possessed some sort of simple pivot grammar (e.g., simple word ordering regularities), without an understanding of function words (and morphemes) their grammatical competency was a far cry from what they would later possess. One explanation for children's late acquisition of function words was that they were not as perceptually salient as content words. Words such as *the* and *a* are typically unstressed and short in duration. If children couldn't hear them, how could they learn about their function? However, this view was brought into question by studies showing that toddlers understood utterances better when they contained real as opposed to fake function words (e.g., *Give me the duck* versus *Give me tev duck*; Gerken & McIntosh, 1993). Subsequent studies using both behavioural and electrophysiological measures further showed that even 10.5-month-old infants noticed when function words were omitted or mispronounced in speech (Shafer, Shucard, Shucard, & Gerken, 1998).

Today, it is well accepted that young infants do not simply ignore function words because they lack perceptual saliency. Rather, infants appear to learn about these acoustically distinct and highly frequent lexical items early in development, and even use them to segment words from speech. For example, 11-month-old English learners segment *brink* from the phrase *the brink* but not from the phrase *kuh brink*, presumably because in the former case they stripped off the known function word *the* to discover the novel word *brink* (Shi, Cutler, Werker & Cruickshank, 2006). French-learners may do so even earlier (Shi & Lepage, 2008). Some have suggested that infants' attention to the position of highly frequent function words may actually help them determine the word order of their language (Gervain et al., 2008). Other studies have shown that 18- to 28-month-olds have already begun learning about the grammatical relationship between morphemes. For example, English-learning 18-month-olds prefer to listen to passages containing the phrase *is walking* over passages containing the phrase *can walking (*Santelmann & Jusczyk, 1998*)* and French-learning toddlers know whether the masculine determiner *le* or the feminine determiner *la* should precede familiar words (Van Heugten & Shi, 2009).

Although it is now well accepted that infants pay attention to function words from early in development, and that function words (and morphemes) provide infants with a valuable tool for learning new words (and possibly even for learning about a language's typical word order), these findings do not reveal how much infants and toddlers really understand about the grammar of their language. For example, when a child listens longer to a passage that contains real function words rather than fakes ones, what does this really mean? Or when a child listens longer to a passage containing the grammatical phrase *is walking* over the ungrammatical phrase *can walking*, what does this mean? Does it indicate any knowledge of a grammatical rule, or just knowledge of statistical patterns? Certainly we know that children are very sensitive to the frequency of items in their linguistic input (Ambridge, Kidd, Rowland, & Theakston, 2015). So perhaps they just like to listen to things that sound familiar?

There are a few ways to approach this question. One is to argue that grammatical rules are extracted from statistical patterns, and that it is therefore strange to ask whether children's knowledge is grammatical or just statistical. One could point to studies showing that children's statistical learning abilities are correlated with their grammatical competency (Kidd & Arciuli, 2016) as evidence for this view. Another way to approach this question is to examine children's *comprehension* of grammatical structures (which requires a more mature understanding than a simple preference for patterns that are more likely in the native language). A growing number of studies indicate that toddlers extract a fair amount of information from the grammatical structure of utterances. In a now classic study, English-learning two-year-olds used grammatical information presented simultaneously with an action event to determine if a novel verb was transitive or intransitive (Naigles, 1990). Two-year-olds can even do this even if the grammatical information is presented alone (Yuan & Fisher, 2009). German-learning 15-month-olds have been shown to use the presence of a determiner to categorize a novel word as a noun rather than a verb (Höhle, Kiefer, Schulz, & Schmitz, 2004). Young toddlers have also displayed surprising competency in comprehending questions (Seidl, Hollich, & Jusczyk, 2003). In fact, toddlers not only extract meaning from the grammatical structure of word combinations, but by 3 years of age they can use the correspondence between grammatical categories and prosodic position to determine the category of an ambiguous word from the prosody alone (de Carvalho, Dautriche, & Christophe, 2016).

In summary, evidence for the very early but gradual emergence of grammatical competency has been slowly accumulating over the years. It appears that children are tuned into function words and the placement of content words with respect to function words from very early on. Moreover, infants and toddlers appear to use this information to learn new words and bootstrap additional information about their native language structure. However, as in other areas of language, it is unclear to what degree this knowledge resembles the adult's (Tomasello, 2000).

7. Why is there so much individual variation, and what does it mean?

As anyone who has interacted with children knows, there is considerable variability across children in their language abilities (which can cause no end of grief to parents who engage in comparisons). This is particularly obvious in children's productions. Some children talk earlier than others; some children focus for longer on single words, others move more quickly into using longer phrases; some children's speech is relatively clear, others seem more focused on the prosody of their speech, but the details suffer. Although it's harder to observe, there are also differences in children's comprehension. While some of these individual differences can be attributed to factors internal to the child, others are a result of the language-learning environment in which the child finds himself. And sometimes, the two factors are difficult to disentangle.

Most of the focus on individual differences in language, at least in infants and young children, has been at the level of vocabulary development. Perhaps this is because this is where the most dramatic (and easily observable) variability is (counting words produced is certainly more straightforward than characterizing development in some other areas of language). But another reason that vocabulary development has been the focus is that it appears to be highly sensitive to children's environment. It has long been known that children who hear more language have larger vocabularies, and that the differences in vocabulary size can be quite dramatic (Hart & Risley, 1995). Children who hear more speech also appear to process speech more efficiently (Hurtado, Marchman, & Fernald, 2008). In recent years, attention has returned to the quality, rather than the quantity, of language input that children receive. In particular, children who hear more child-directed speech tend to have larger vocabularies than children who hear less of that speech style. This difference appears to be in part due to the fact that child-directed speech encourages the child's active engagement in the conversational interaction and other behaviours, like joint attention (Hirsh-Pasek et al., 2015; Ramirez-Esparza, Garcia-Sierra, & Kuhl, 2014; Cartmill et al., 2013). Other features of child-directed speech, such as increased repetition, might be helpful as well (Newman, Rowe, & Bernstein Ratner, 2015). Hearing more child-directed speech may have facilitative effects on children's efficiency at speech processing (Weisleder & Fernald, 2013). Surprisingly, the amount of child-directed speech is correlated with vocabulary size even in cultures in which the vast majority of children's input is adult-directed speech (Shneidman & Goldin-Meadow, 2012).

Children differ not only in the amount and quality of their input, but also in the type of input they receive. One important difference in the type of input is the number of languages a child is being exposed to. Though this would seem to pose a radically different problem for the language learner, in fact, it leads to less variability in the developmental course than one might think. In speech perception and segmentation tasks, bilingual infants demonstrate some differences from monolinguals, but these tend to disappear when the input is more appropriately tailored to their circumstances or when task demands are altered (Fennell & Byers-Heinlein, 2014; Sebastian-Galles, 2010). For the most part, bilingual infants appear to progress along the same timetable as monolingual infants (in terms of their language discrimination, their speech categories, their segmentation, their early word processing), though work in this area is really just beginning (for example, we know virtually nothing about grammatical abilities in bilingual infants). However, differences between bilingual and monolingual children may emerge in childhood. For example, bilingual children's vocabulary size in each language is typically smaller than a monolingual's, and the composition of their vocabularies may differ as a result of the contexts in which each language is used. Both vocabulary and grammatical development are affected by the relative amount of exposure bilinguals have to each language, leading to more variability as compared to monolingual development, particularly in a less dominant language (Hoff et al., 2012; Hoff & Core, 2013; Bedore & Pena, 2008). These differences are important to keep in mind for the assessment of potential language delay.

In addition to these environmental factors, there appear to be individual differences in the skills underlying language development that are fairly stable over development (Bornstein &

Putnick, 2012; although it is sometimes difficult to disentangle stability in children's language environments and stability in their language abilities). Recent research has demonstrated considerable continuity between behaviour on infant speech perception tasks and later measures of language development. For example, word segmentation abilities in the first year, as assessed by both behavioural and electrophysiological measures, predict word comprehension in the lab at 16 months, productive vocabulary size at the age of 2 years, and more complex measures of language (including grammar) at 4-6 years (Junge & Cutler, 2014; Kooijman et al., 2013; Newman, Rowe, & Bernstein Ratner, 2015; Singh, Reznick, & Xuehua, 2012). And word processing efficiency at 25 months has been shown to relate to vocabulary size up to 8 years (Marchman & Fernald, 2008). It may be somewhat unsurprising that the ability to find words in speech or the ability to process words efficiently is related to later vocabulary. But even more basic speech discrimination in infancy has been shown to predict later language abilities at 2 years, including not only vocabulary, but also phrase understanding (Tsao, Liu, & Kuhl 2004). Prosodic sensitivity in the first year has been shown to predict vocabulary as well (Cristia & Seidl, 2011). One interesting aspect of these findings is that there was some selectivity in which tasks predicted later language, suggesting that those tasks may tap abilities particularly relevant for language, rather than domain-general abilities (although it's not clear whether the absence of some correlations was due to a lack of power). That's not to say that domain-general abilities don't play a role as well. Habituation speed (thought to indicate encoding efficiency), visual recognition memory, and visual sequence learning in infancy have all been associated with vocabulary development (Shafto, Conway, Field, & Houston, 2012).

Despite all of the research that has been done on the role of internal vs. environmental factors in language acquisition over the past 50 years, we still do not fully understand how much each of these factors (and the interplay between them) contribute to individual variability during first language learning. We also do not yet have a satisfactory way to track and study individual differences in young infants (Cristia et al., 2013). Indeed, the group data many researchers depend on most likely mask many crucial subtleties in normal language learning trajectories. If the field of infant speech perception is to move beyond simply charting trends in language abilities in groups of children, this is an area where researchers need to focus their energy in upcoming years. Improvements in this area will not only strengthen and broaden our theoretical understanding of normal language development, but will also open many new possibilities for identifying children at risk early in development.

8. Where to go from here

Building on the very strong foundation established by the field's pioneers, the study of language development has come a long way in the past 50 years. As the tools available to language researchers have grown increasingly sophisticated and sensitive, we have learned that infants and toddlers have a remarkable toolbox themselves, and are even more linguistically savvy than early researchers could have possibly imagined. This realization, in turn, has pushed our thinking in new directions and forced us to revamp our theories of early child language acquisition. In this chapter, we have highlighted some of these recent developments by focusing on six questions key to the field.

One important theme that has emerged is that our old notions of infants progressing along the path to language in a step-wise fashion (from sounds to words to grammar) are not viable. Rather, infants are learning about their language at multiple levels in parallel. A second theme that has emerged is that our tools, sophisticated as they are, still do not allow us to determine exactly what is in an infant's mind. Yes, infants discriminate sounds and look at pictures that match the words they hear, but what does this mean? A third theme is that, in some cases, it is not clear how the impressive abilities infants demonstrate scale up to the problem of learning language in the real world. Infants can track frequency, transitional probabilities, and the co-occurrence of words and referents across time. But how far do these abilities, demonstrated in simple lab situations, get them in the real world? There are so many other important questions that this review has not even attempted to tackle, such as the relationship between perception and production and the importance of sensitive periods for language development. As our tools continue to develop, we will undoubtedly uncover more answers (and questions!) Who knows where we'll be 50 years from now!

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