CHAPTER 12

Early development of the prosody-meaning interface

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This chapter reviews evidence on how infants up to 18 months of age develop the ability to use prosody as a sign of the expression of pragmatic meanings, from both a comprehension and a production point of view. Developmental research reveals that pre-lexical infants use prosodic information not only to comprehend emotions in the speech of their communicative partners, the intentional value of the partners' speech, and their speech act motivation, but also to express these same pragmatic meanings when they communicate with others. In essence, before the emergence of lexical and grammatical skills, infants use prosody to communicate intentionally with the world around them.

Introduction

Human languages resort to a variety of linguistic strategies for the expression of meaning, including not only grammatical and lexical encoding but also prosody. Prosodic patterns in human speech convey a set of pragmatic meanings that a young child must learn to comprehend. Research on the prosody-meaning interface has traditionally distinguished between two types of information that can be expressed through prosodic patterns: on the one hand, attitudes and emotions (what has been traditionally called paralinguistic or affective meaning) and, on the other hand, speech act information, information structure, and speakers beliefs (what has been called linguistic meaning) (e.g., Gussenhoven, 1984; Ladd, 1996; see Prieto, 2015, for a review). Traditionally, prosody has been separated into two types, emotional/affective prosody and linguistic/pragmatic prosody. More recent accounts, however, have rejected this simple dichotomy on the grounds that prosody is used by speakers to convey a wider range of dimensions

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of meanings than just these two (such as emotions and affect, politeness, speech acts, agreement or disagreement between interlocutors, epistemic positioning, or information structure), and, furthermore, these dimensions are not mutually exclusive to each other anyway (Portes, Beyssade, Michelas, Marandin, & Champagne-Lavau, 2014; Prieto, 2015; for a claim that emotions can be seen as pragmatic and epistemic actions, see Wilutzky, 2015). In the present chapter we will refer to all of such dimensions as meanings or pragmatic meanings indistinguishably, since the debate about whether they are all linguistic or not lies beyond the scope of this chapter.

The central question we will address here is when and how infants start to develop the ability to understand and express meanings through prosody. Much of the answer must lie in the human environment with which a newborn has first contact. Indeed, through the exaggerated prosodic properties of infant-directed speech, caregivers make the relationship between prosodic form and communicative function uniquely salient to children (see Saint-Georges et al., 2013, for a review), thus paving the way for infants to start learning the prosody-meaning correspondences of their mother tongue. Over the last few decades, developmental research has focused heavily on how infants use sensitivity to prosody as a tool to discriminate among the rhythmic patterns, pitch cues, and accentual patterns that are typical of the language that surrounds them (e.g., Bhatara, Boll-Avetisyan, Höhle, & Nazzi, this volume). This early sensitivity to prosody has been claimed to function as a bootstrapping mechanism for early speech segmentation as well as word learning (e.g., Bhatara et al., this volume; de Carvalho, Dautriche, Millotte, & Christophe, this volume; Thorson, this volume; Teixidó, François, Bosch, & Männel, this volume). However, work on children's use of this early sensitivity to prosody to access the pragmatic meaning dimension is still relatively sparse, and little is known about how children exploit the various meanings conveyed by prosody, especially in the early stages of language development.

Being able to map incoming speech to meaning is a fundamental skill in early language acquisition because it is crucial for successful social interactions. From the moment they are born, infants show social skills that act as important precursors and predictors of their later linguistic and cognitive abilities. Newborns prefer to look at human faces more than other types of stimuli (e.g., Johnson, Dziurawiec, Ellis, & Morton, 1991), and they prefer to listen to their mother's voice over the voices of other females or other people in general (DeCasper & Fifer, 1980). Thanks to these early social abilities, infants know when they are being addressed, have expectations about what will come next in social interactions, and begin to infer relevant and generalizable information about communicative acts (Csibra & Gergely, 2009).

Around the middle of the first year of life, infants develop communicative skills that are crucial for the emergence of intentional communication. They start to engage in joint attentional frames, following a communicative partner's gaze or gesture towards an event or an action or directing the other person's attention towards it by using gaze or gesture strategies themselves (e.g., Bruner, 1975). Infants as young as 5 months also notice that actions can have different goals (Woodward, 1998), and by the end of their first year of life they can attribute a goal to an action even if the action is not completed (e.g., Meltzoff, 1995). In order to process and express meanings in interaction, infants use contextual information such as the physical presence of the objects being referred to or the social actions that preceded the interaction (e.g., Clark, 2004, among many others).

This chapter will review evidence that reveals how infants (from 0–18 months) use prosody as a tool to comprehend and express pragmatic meanings in interactions. The evidence will be drawn from a set of studies that show infants' abilities to successfully map prosody to pragmatic meaning in three separate areas, namely (a) the comprehension and expression of emotion-related meanings, (b) the distinction between intentional and non-intentional speech, and (c) the expression and comprehension of speech act motives. The motivation for this three-way division comes from the fact that, although these areas interact with and feed off each other, previous research has traditionally studied them separately. On the one hand, some studies have investigated when and how infants learn that actions are goal-directed (i.e., intentional, as opposed to accidental), and on the other hand, other studies have examined when infants learn to produce and comprehend actions with specific social motivations (in speech, these would be regarded as speech acts). In essence, the existing evidence indicates that infants use prosody as a tool to infer and express pragmatic meaning well before they can use lexical and grammatical tools for these purposes.

The prosody-meaning interface in infancy: Comprehension

There is a vast literature on language development showing that babies are sensitive to the prosodic features of speech such as pitch and duration, even before birth (see Bhatara et al., this volume; de Carvalho et al., this volume). Four-month-old infants prefer to listen to infant-directed speech (i.e., speech with exaggerated prosodic features such as higher pitch range, higher mean pitch, and slower speech tempo) than to adult-directed speech (e.g., Fernald, 1985). Similarly, babies can discriminate between languages which display timing differences such as utterance-final lengthening or languages which belong to distinct rhythm classes (e.g., Nazzi, Bertoncini, & Mehler, 1998), and they can also

distinguish between different stress patterns in the ambient language. Infants between 4 and 9 months of age prefer to listen to the rhythmic and prosodic patterns of their ambient language and can use this information to segment the speech stream into words (e.g., Höhle, Bijeljac-Babic, Herold, Weissenborn, & Nazzi, 2009).

Infants' sensitivity to pitch direction also emerges very early in life. Infants between 4 and 9 months of age discriminate between rising and falling intonation patterns in the case of intonational languages like Portuguese or English (Frota, Butler, & Vigário, 2014) and several different tonal shapes in the case of tonal languages like Mandarin or Cantonese (Yeung, Chen, & Werker, 2013). These studies suggest that language-specific perceptual sensitivity emerges earlier for prosodic patterns (e.g., pitch and stress) than for segmental patterns (e.g., vowels and consonants). However, less is known about how young infants use this early sensitivity to prosodic cues in social contexts to infer pragmatic meanings expressed by their interlocutors. The following sections discuss the current findings on how infants develop the ability to map prosodic cues to social meaning, focusing on how prosody is used by infants to understand a communicative partner's (a) emotional and affective state, (b) goal to act intentionally, and (c) motivation for a particular speech act.

Infants' early understanding of others' emotional states through prosody

The sensitivity to the emotional valences expressed by prosodic cues develops very early in infants. By 5 months of age, infants are found to react differently to different affective vocal expressions (for instance, smiling in response to approval vocalizations), can discriminate between sad or angry vocalizations if the vocalizations are accompanied by facial expressions, and can match positive and negative affective vocalizations with the appropriate facial expression (e.g., Fernald, 1993; Vaillant-Molina, Bahrick, & Flom, 2013). These behavioral findings have been confirmed by evidence coming from electrophysiological and brain imaging studies. Electrophysiologically measured responses have revealed that newborns are sensitive to threat-related emotions, with different activations of the frontocentral scalp region being found for angry and fearful voices respectively (Zhang et al., 2014). Similarly, evidence coming from near infrared spectroscopy (NIRS) (e.g., Grossmann, Oberecker, Koch, & Friederici, 2010) and from ERP responses (e.g., Blasi et al., 2011) has shown that 7-month-old infants react differently to semantically-neutral words depending on whether they are produced with a happy, angry, or neutral tone of voice (see Teixidó, François, Bosch, & Männel, this volume, for more information about infants' brain responses to prosody for speech segmentation and word learning).

Before their first birthday, infants develop a strong understanding of emotional states based on their analysis of prosodic cues. Mumme, Fernald, and Herrera (1996) asked mothers to produce vocal cues of positive, negative, or neutral affect directed towards a referent located in front of their 12-month-old infant. In the positive affect condition, the mothers were asked to say 'Oh, how delightful!', the *Oh* being high-pitched and smooth, and the *how delightful* being produced in a relaxed voice with a rise-fall pitch. In the negative affect condition, the mothers said 'Oh, how frightful!', the *Oh* here produced with a gasping inhalation, and the *how frightful* produced rapidly with a tense voice slightly high in pitch. In the neutral affect condition, the mothers said 'Oh, how insightful!', the entire utterance being produced in a monotone voice. The results revealed that the infants showed negative-affect behaviors towards the referent after mothers had expressed vocal cues of negative affect, but not when they had expressed vocal cues of positive or neutral affect. Interestingly, they also revealed that not all affects seem to have the same impact, since vocal cues of positive affect did not induce positive-affect behaviors in the infants.

Despite the fact that Mumme et al.'s (1996) results showed that infants could infer an adult's emotions by relying on vocal cues, the experimental design left it unclear as to whether it was the lexical or prosodic content of the vocalization (or both) that induced this effect. Although at such a young age the infants presumably did not yet understand words like *frightful* or *delightful,* the possibility that lexical knowledge might have influenced their responses cannot be completely ruled out. More recent studies have managed to isolate prosody as a variable, with results showing that 15-month-old infants are able to associate pitch values in a communicative partner's speech with the emotions (s)he is intending to convey. Hoicka and Wang (2011) presented 15-month-old infants with an experimenter producing either humorous or 'sweet' vocal cues, the only difference between the two being pitch mean values (the humorous cues having a higher pitch mean than the 'sweet' ones). After being exposed to the vocal cues, infants observed the experimenter producing either a matching behavior or the opposite one (i.e., either a humorous action or a sweet action). Importantly, the experimenter maintained a neutral facial expression in all conditions in order to prevent infants from using facial cues to drive their inferences. Infants looked longer at the behavior if it mismatched the vocal cues than if it matched them, revealing that they had developed expectations about the adult's behavior given a specific prosodic feature. These results show that already at 15 months of age infants can make prosody-meaning associations independently of situational context and lexical cues.

The studies reviewed so far show an early mapping of prosodic cues to emotional states. This early comprehension, however, continues to develop in later stages up to adolescence. Preschool children can match speech bearing different

acoustic cues of emotion to the appropriate facial expressions (Berman, Chambers, & Graham, 2016), and by the time they enter school children will rely on prosodic cues for the comprehension of an interlocutor's emotion when these cues compete with lexical information or situational context, such as in ironic speech (see Armstrong & Hübscher, this volume, for a review of the research on the expression of affect through prosody at these later stages).

Early understanding of prosody as a marker of intentional communication

The set of cognitive abilities that enable infants to comprehend a communicative partner's intentions is called Theory of Mind. Theory of Mind, also known as 'mind-reading' or perspective-taking, is the capacity to understand that other people have beliefs, intentions, and desires, and that these may differ from one's own (Premack & Woodruff, 1978, and many others thereafter). Research has shown that Theory of Mind emerges only gradually in development, the simplest forms being observed in early infancy and the most complex ones during the school years (see Liszkowski, 2013, for a review). At the outset, infants have flexible expectations about other people's actions depending on the preceding shared actions or the situational context in which these actions occur. Seven-month-old infants, for instance, are surprised when an event does not fulfill their own and someone else's expectations (Kovács, Téglás, & Endress, 2010), and toddlers make predictions about another person's beliefs (Onishi & Baillargeon, 2005). Only much later do other more complex forms of Theory of Mind emerge. During the preschool years, for example, children develop the ability to hold first-order representations, that is, an awareness that somebody else can hold a belief that may differ from their own (Baron-Cohen, Leslie, & Frith, 1985). By about 5 to 7 years of age, or even later, children are capable of holding second-order false belief representations, the realization that one person may hold a belief that contrasts with another person's belief about something (e.g., Miller, 2009; Sullivan, Zaitchik, & Tager-Flusberg, 1994).

Intentional communication typically emerges around 9–12 months of age, and studies have shown that by around their first birthday infants know that speech is used to refer to abstract intentions (Martin, Onishi, & Vouloumanos, 2012; Vouloumanos, Onishi, & Pogue, 2012). In these studies infants were exposed to act-preceding contextual information shared between the interlocutors, and this helped them to interpret the speech as meaningful. Although most of the existing research on the mechanisms by which young infants infer an interlocutor's intentions highlight the role played by information that the infants extract from the context prior to the shared action (e.g., Tomasello, Carpenter, & Liszkowski, 2007), there is also recent evidence that infants rely heavily on act-accompanying signals like prosody and gesture to understand that the other person's speech is

intentional. In order to test whether infants detect intentionality from speech cues alone, Carpenter, Akhtar, and Tomasello (1998) designed a study in which intentional and non-intentional actions were preceded by the same shared action context and only speech features differed between the two conditions. The authors tested 14- to 18-month-old infants using an action imitation paradigm. They found that infants imitated an action more if it was followed by a verbal sign of intentionality (the expression 'There!' with appropriate prosody) than if followed by a verbal sign indicating that the action was accidental (the expression 'Whoops!' with appropriate prosody). Since the two actions were performed by the experimenter in identical fashion with the only difference between them being the verbal message (even the facial expressions were neutralized as much as possible), the authors concluded that at the beginning of their second year of life infants can use prosodic properties in speech to infer that an action is intentional.

In order to tap into the specific role of prosody in infant's detection of intentional and non-intentional actions, Sakkalou and Gattis (2012) tested whether 14- and 18-month-old infants could detect the intentional nature of an action by relying on the prosodic cues of the word accompanying the action. Using Carpenter et al.'s (1998) methodology, infants were first exposed to intentional actions that were accompanied by the word 'There!', produced with high amplitude and long duration, and accidental actions that were accompanied by the word 'Whoops!', produced with low amplitude and short duration; in a second experiment, the authors removed the lexical information by testing L1 English-learning infants with the Greek equivalents for 'There!' and 'Whoops!'. In both experiments the authors found that infants imitated the intentional actions more often than the accidental ones, and they observed an age-related effect when lexical cues were removed (i.e., older infants performed better than younger infants). Since infants could only have based their imitative behavior on the prosody accompanying the action, it was concluded that infants comprehended the pragmatic value of prosodic cues and were able to relate them to speech intentionality at 14 months of age. These findings were confirmed and further explored in a later study examining individual differences (Sakkalou, Ellis-Davies, Fowler, Hilbrink, & Gattis, 2013). Interestingly, the authors found that the infants who at 13 months imitated intentional actions most frequently where the ones who were better at detecting intentional actions on the basis of prosody at 14 months of age.

Early understanding of prosody as a marker of speech act information

In communicative interactions, interlocutors detect not only that the speaker is communicating intentionally but also the specific intention behind the communicative act (i.e., they can differentiate between informative/assertive, requestive/directive, and expressive speech acts). Caregivers use a different set of linguistic patterns,

including distinct melodies, depending on whether they are uttering a statement, greeting someone, asking a question, making a request, or refusing something (e.g., Armstrong, 2012; Esteve-Gibert, Liszkowski, & Prieto, 2016). Esteve-Gibert et al. (2016) analyzed the speech of caregivers as they played with infants. The experiment was designed to elicit pointing actions on the part of the caregiver either to ask the infant to give them an object (imperative condition), share interest in the object with the infant (expressive condition), or inform the infant about a specific feature of that object (informative condition). Their results showed that in each of the three conditions caregivers accompanied their lexical message with a specific combination of prosodic patterns (intonation contour, pitch range, and mean syllable duration) and gesture features (hand shape, gesture duration) in order to distinguish the intention they wished to transmit.

Again, most of the previous research on infants' early comprehension of speech acts has focused on how infants use the contextual cues in which these acts are embedded to comprehend other people's intentions. Although 12-month-old infants do use social contextual cues to understand whether an adult has produced an attention-directing action (such as pointing) in order to request an object, inform about its presence, or express interest in it (see Liszkowski, 2014, for a review), often times social contextual cues are ambiguous or underspecified. Since prosody and gesture constitute another marker of adults' pragmatic intentions, it is possible that young infants can resort to them to infer an interlocutor's intended meaning. This hypothesis was tested in a subsequent study in which prosodic features (alongside pointing gesture cues) were the only cues that infants could use to infer the motivation behind a communicative partner's speech act. Esteve-Gibert, Prieto, and Liszkowski (2017) carried out two experiments to determine whether 12-month-old infants were capable of successfully associating specific prosodic patterns (and hand gestures) with the speaker's underlying speech act intention. The first experiment had the goal of testing the role of prosody in conjunction with lexical and gestural cues, and the second one was intended to test exclusively the role of prosody and gestures, without lexical input. Infants saw an adult who produced gestures to direct the infant's attention towards an object with either an imperative, expressive, or informative intent. The measure of interest was whether, for each condition, the infants reacted in a way that was consistent with the adult's intention by either giving the object to the adult in the imperative condition, sharing interest in the object with the adult in the expressive condition, or discovering the feature of the object that they had been informed about in the information condition. Importantly, the situational context was the same across the three possible conditions to rule out the possibility that infants would use contextual information to infer the motive behind the adult's speech act. The results of the first experiment showed that infants could use

lexical information, prosody, and gesture as a whole to understand the speaker's intention behind the attention-directing action. The results of the second experiment showed that when the lexical information was neutralized across intentions (by having the adult say 'Hey, this, this!' in all three conditions), infants could still understand the adult's intention and react accordingly.

In sum, evidence to date shows that a few months after being born and within their first year of life infants develop a fine perceptual sensitivity to the differences in prosodic cues in speech that can be used to understand a communicative partner's affective internal state and the intentional value of their speech. Later on, around 12–15 months of age, they seem to be able to associate specific variations in the prosodic cues (pitch, duration, and intonation) of their caregiver's speech with specific speech act meanings.

The prosody-meaning interface in infancy: Production

In this section, we review the literature on the pathways followed by infants in their early expression of pragmatic meaning through prosodic cues. As mentioned above, babies are very closely attuned to the prosodic patterns of the ambient language(s) during their first year of life. There is evidence that newborn's early production of prosodic cues like intonation is not random but instead progressively linked to the patterns they are exposed to in their target language (e.g., Mampe, Friederici, Christophe, & Wermke, 2009; Wermke et al., 2016). Mampe et al. (2009), for instance, found that the intonation pattern of newborns' cries is tuned to the most common pattern of the language to which they have been exposed while still inside their mother's womb. The authors tested French and German newborns only a few hours after being born, and found that French newborns produced rising contours when crying, while German newborns' cries had a falling contour. This difference reflects the most frequent tonal pattern of each language, since French is mostly a rising-intonation language and German a falling-intonation one. Some months later, infants' babbling has also been found to reflect the prosodic correlates of stress – namely higher F0, intensity, and duration values – of their ambient language (Davis, MacNeilage, Matyear, & Powell, 2000), as well as the pitch range values of the ambient language (Snow, 2006). Similarly, the form of infants' first words is found to be constrained by the structure of prosodic words and phrases in the language they hear around them (Kehoe, this volume). Again, this raises questions about when and how infants start to produce the target prosodic features of the language to express their emotional and intentional states. The following sections explore this issue.

Infants' early use of prosody to mark their emotional status in speech

In general, studies of infants' emerging control of prosody for the expression of affective and emotional meaning show that from 2 months of age onwards, infants start to differentiate positive and negative emotions in their vocalizations on the basis of acoustic parameters (e.g., Lindová, Špinka, & Nováková, 2015; Oller, Buder, Ramsdell, Warlaumont, & Chorna, 2013; Papousek, 1992; Scheiner, Hammerschmidt, Jürgens, & Zwirner, 2002). Oller et al. (2013), for instance, investigated the relation between the speech sounds produced by 3- to 4-month-old infants and the emotional meanings they seemed to express with them. The authors found that infants used cries to express mostly a negative emotion and laughs to express a positive emotion, and, interestingly, that other types of speech sounds (squeals, vowel-like sounds, and growls) were used indistinguishably to express positive, negative, and neutral emotions. This functional flexibility had also been observed in previous studies focusing on the acoustical properties of infants' emotional vocalizations. One study reported, for example, that 2-month-old infants use variations in pitch height, pitch range, and duration in a flexible way to indicate positive or negative emotions (Scheiner et al., 2002), while an earlier one noted that these acoustic properties increase with increasing negative arousal (Papousek, 1992).

The flexible use of early vocal sounds is claimed to signal an infant's first step towards an adult linguistic system. Crucially, from a very early stage, infants carry out this de-functionalization by controlling the prosodic properties of speech. This early control of prosodic parameters is the precursor of later more sophisticated prosodic patterns in infants' vocalizations which allow them to convey intentionality and make basic speech act distinctions. In the next section we review the literature that addresses these issues.

Early production of prosody as a marker of intentional communication

Goldstein, Schwade, and Bornstein (2009) tested 5-month-old infants in a task where an experimenter interacted normally with infants and then suddenly stopped responding to the infants' vocalizations. When the experimenter interrupted the interaction in this fashion, the infants increased their vocalization rate. This showed that as early as 5 months infants use speech as a social tool to try to modify their environment. As we will see in the following paragraphs, the prosody of such early vocalizations reflects whether or not an infant's speech is intentional and goal-directed.

Beaumont and Bloom (1993) asked adults to judge 3-month-old infants' vocalizations as being an attempt to interact socially or not. The authors selected two types of vocalizations for the judgment task, consonant-vowel syllabic sounds with

pitch variation, and vocalic sounds with uniform pitch. Results showed that raters judged syllabic vocalizations as being more intentional and socially favorable, and thus demonstrated that adults assign intentionality to infants' vocalizations on the basis of how infants modulate prosodic features (and specifically, pitch variation). However, the fact that at 3 months of age infants have not yet developed the ability to engage in joint attentional frames and produce goal-directed actions (e.g., Woodward, 1998, 1999) suggests that the intentionality perceived in infant vocalizations may be simply an adult mental construction reflecting adults' propensity to automatically project intention on infant behavior rather than true evidence that infants can modify prosodic features to achieve a specific goal.

Some months later, between 7–12 months of age, infants start to engage in patterns of joint attention and are able to produce goal-directed actions (as we saw in previous sections of this chapter), a sign that they can communicate intentionally with others. In this time period, infants have been shown to control prosodic features like pitch range and duration in their own productions to differentiate among emotionally expressive vocalizations, goal-directed vocalizations, and vocalizations which have no specific goal. Papaeliou, Minadakis, and Cavouras (2002) examined whether 7- to 11-month-old infants used different duration, fundamental frequency (F0), and intensity values during vocalizations to express intentionality. Infants at all ages were found to control these prosodic features, with emotional vocalizations being longer and showing a higher F0 and lower intensity than vocalizations with pragmatic intent. The results of an interesting follow-up study by Papaeliou and Trevarthen (2006) revealed that intentional vocalizations (defined as those produced in a playing-together situation) were shorter and had a higher pitch range than non-intentional vocalizations (defined as those produced in a playing-alone situation). The expression of emotional and intentional speech (as well as the ability to establish and maintain a state of joint attention) constitutes the pragmatic antecedent of speech act distinctions, which will be discussed in the next subsection.

Early production of prosody as a marker of speech act information

There is evidence that young infants are able to specify the intention of their communicative acts to their interlocutors. Most of the results come from studies examining non-speech communicative acts by young infants. Bates, Camaioni, and Volterra (1975) were among the first to propose that before the emergence of their first spoken words infants express proto-versions of speech acts by using deictic gestures. Since then abundant evidence has been gathered showing that 12-month-old infants point with a specific pragmatic intention in mind, be it to ask for information (interrogative pointing), request an object or action (requestive pointing), share their interest in something (expressive pointing), or inform another person

about something that might be relevant (informative pointing) (e.g., Tomasello et al., 2007).

In this context, various recent studies have shown that, like deictic gestures, prosodic features such as pitch and duration are used by young infants to signal speech act distinctions (see Cameron-Faulkner, 2014, for a review of research on the development of speech acts in infancy). For example, Esteve-Gibert and Prieto (2013) examined the prosodic markers of speech act motivation in video recordings of more than 2,000 vocalizations by pre-lexical infants at 7, 9, and 11 months of age. To do so, the pitch range and duration values of the vocalizations were analyzed. After classifying vocalizations as being either intentional or non-intentional, the authors then further classified intentional vocalizations as either expressing emotions like discontent or satisfaction, or signaling a speech act like response, statement, or request. The study yielded two main results. First, the types of pragmatic meaning changed with age: while at younger ages there were a high number of non-intentional productions, intentional vocalizations became more frequent as the infants grew older. Notably, it was found that the proportion of non-intentional vocalizations decreased significantly between 9 and 11 months of age. Furthermore, at younger ages the expressions of discontent and satisfaction were the most frequent pragmatic functions, but by the time the infants were 11 months of age the frequency of statements, requests, and responses had substantially increased. Second, the results showed that non-intentional vocalizations were much longer and more monotonic (with a narrower pitch range) than intentional vocalizations, and that expressions of discontent and requests showed a significantly wider pitch range and longer duration than responses and statements.

The direction of the intonation contour is also used by pre-lexical infants to signal speech act information. Here the evidence comes from studies analyzing the intonation contours that accompany pointing gestures. For example, Grünloh and Liszkowski (2015) tested 14-month-old Dutch-learning infants by eliciting imperative (requestive) and declarative (expressive and informative) pointing acts in laboratory-controlled situations and then analyzed the prosodic and gestural characteristics of the infants' behavior. They found that infants produced flat intonation (defined as having less than 2 semitones of difference between a high and a low F0 target) with requestive pointing gestures, and rising contours with declarative (i.e., expressive and informative) pointing gestures. Murillo and Capilla (2016) explored a longitudinal corpus in which 9- to 15-month-old L1 Spanish-learning infants were recorded during semi-structured play. They found that, at the age of 15 months, infants produced flat intonations for declarative functions and rising contours for imperative functions. Although these two studies did not detect the same patterns, this might be explained by age differences in the respective

subject populations, language-specific effects (given that Spanish and Dutch have a different distribution of intonation contours per pragmatic function), or even methodological issues (since it is more difficult to identify the possible social intention of pointing gestures when they are produced spontaneously compared with when they occur in a controlled shared-action context). In any case, what the two studies reveal is that, beyond the social cues, the prosodic features of vocalizations (together with the pointing gestures used) give clues to pre-lexical infants' underlying intentions.

Infants continue to gain competence in the use of prosodic features (and specifically, intonation contours) to signal speech act type and pragmatic meaning as their lexical and socio-cognitive skills develop further. Prieto, Estrella, Thorson, and Vanrell (2012) analyzed the intonation patterns produced by four Catalan-speaking children and two Spanish-speaking children between 11 and 28 months. Their results revealed that the children's use of intonation was largely independent of grammatical development, and it emerged well before the appearance of two-word combinations. Both Catalan- and Spanish-speaking children produced the basic pragmatically appropriate and phonologically differentiated intonation contours (i.e., the contours used to signal vocatives, statements, requests, and expressive intentions) of their respective ambient languages between 12 and 15 months of age, that is, during the period when some infants go from the onset of word production to having a small lexicon of 25 words (see Armstrong & Hübscher, this volume; Chen, this volume; Frota & Butler, this volume).

All in all, the results reported in this section reveal that infants start to command the prosodic properties of speech very early on, well before they produce their first words. Evidence suggests that pre-lexical infants use prosody to express their emotional states, and some months later they can use it to communicate intentionally with the world around them and even signal the specific intention they want to transmit.

Conclusions and future directions

The mapping between prosody and meaning constitutes a central ability in early language acquisition, an ability which is important for successful social interactions. The overview presented in this chapter has revealed that infants' sensitivity to prosodic features emerges very early in their lives and that these early perception skills are employed to begin mapping prosodic patterns onto the pragmatic meanings intended by others.

An important conclusion from the studies reviewed in this chapter is that very young infants use prosodic patterns to express and comprehend meaning well

before they use lexical and grammatical marking. We do not yet know, though, whether higher pragmatic prosodic skills in infancy will be predictive of lexical and grammatical skills later in development, in other words, whether pragmatic prosody is paving the way for lexical and grammatical acquisition in later stages or not. If this were the case, it would suggest that prosody may have a bootstrapping effect on the development of pragmatics (see Hübscher, Esteve-Gibert, Igualada, & Prieto, 2017, for a proposal in this regard). Indeed, while the role of prosody as a facilitator of syntactic bootstrapping has been highlighted in language acquisition research (see de Carvalho et al., this volume), the role of prosody as a pragmatic decoder has been neglected. On a related note, researchers interested in gestural development have already found evidence that children's use of gestures seems to favor their acquisition of linguistic skills (e.g., Iverson & Goldin-Meadow, 2005; see Goldin-Meadow & Alibali, 2013, for a review).

An important research topic which merits further study is the relationship between the emergence of prosodic abilities and infants' later development of linguistic and grammatical skills, and, more specifically, whether the acquisition of prosodic meaning can serve as a predictor of later language abilities. Despite the evidence of considerable variability at the individual level, there have been several attempts to relate the emergence of phonological and communicative strategies to children's subsequent linguistic abilities. Igualada, Bosch, and Prieto (2015), for instance, found evidence that the multimodal ability of 12-month-old children to appropriately combine pointing gestures with speech to express an assertive speech act is predictive of later lexical and syntactic abilities at 18 months. For their part, McGillion et al. (2017) found that babble onset predicted the emergence of first words and infants' expressive vocabulary at 18 months of age, and that the onset of pointing predicted infants' receptive vocabulary at 18 months of age. Future studies could try to correlate the emergence of infants' ability to use and understand prosodic cues with their later communicative skills, with the goal of assessing the possible role of prosody in predicting later linguistic and cognitive impairments. In this regard, one line of research that could be strengthened is the study of atypical populations, in which specific cognitive or linguistic abilities are impaired (see Peppé, this volume, for a review of the research on prosodic development in such populations).

From a developmental perspective, the evidence points to a tight relation between the pragmatic meanings that infants can access through prosody at a certain developmental stage and the cognitive skills that emerge at that point in time (see Matthews, 2014, for a review). Thus, at a very early stage infants are able to interpret prosody in adult speech only to distinguish between basic emotions such as fear, anger, or happiness. Some months later, once they have learned that actions can be goal-directed and that people act intentionally towards objects and events, infants can comprehend the intentional value of somebody else's action (that is,

they can tell whether it is intentional or accidental) by processing the prosodic cues of that person's speech. And as soon as infants can comprehend that actions can have specific and varying goals (e.g., pointing at an object can have different purposes), they show evidence that they associate specific prosodic patterns with certain simple speech acts like making a request, offering information, or expressive a feeling. However, 12-month-olds are still not able to understand and produce speech acts that involve complex mental skills. As we have noted, first-order false-belief representations (the realization that somebody can hold a belief that may differ from one's own) emerge during the preschool years (Baron-Cohen et al., 1985), and second-order false belief representations (the realization that somebody can hold a false belief of someone else's false belief about something) do not appear until age 5 or later (Miller, 2009). It stands to reason that only when children have developed these more complex mental skills can they make use of prosody to understand and signal belief states (see Armstrong & Hübscher, this volume).

Furthermore, the directionality of the relation between cognitive and linguistic development is still not fully understood. Some results certainly suggest that cognitive skills are a precursor of and/or a prerequisite for linguistic skills. As we have noted, for example, Sakkalou et al. (2013) found that infants with higher cognitive skills at 13 months of age are the earliest to use prosody to map intentions with actions at 14 months of age. However, other accounts propose an inverse causal relationship, suggesting it is linguistic skills that impact and determine infants' development of cognitive abilities, especially at later stages of language development (see De Villiers, 2007, for a discussion of this debate). The studies reported so far indicate that at least at the pre-lexical stage the emergence of cognitive skills coincides with or slightly precedes the emergence of pragmatic prosody. Further studies could assess the potential correlations between individual differences in cognitive skills (and also Theory of Mind abilities related to an understanding of mental states) and the development of pragmatic prosody.

The evidence outlined in this chapter has also suggested a parallel temporal development between infants' early comprehension and production of pragmatic prosody. First, around 5 months of age infants react by smiling to prosody conveying positive affect, such as when a mother expresses approval (Fernald, 1993). At around the same age, infants begin to produce vocal cues to express emotions in a flexible way, so that the same vocal cues can be used to express different emotions (Oller et al., 2013). Later on, around their first birthday, infants understand that prosody (and speech in general) is used by their interlocutors as a sign of intentional communication (Carpenter et al., 1998; Sakkalou & Gattis, 2012; Vouloumanos et al., 2012). Simultaneously, as they gain control over prosodic cues like duration and pitch range, they begin to employ it for this purpose

themselves (Esteve-Gibert & Prieto, 2013; Papaeliou et al., 2002; Papaeliou & Trevarthen, 2006). At about the same time (12 months), infants learn to decode prosodic signals to distinguish between informative, requestive, and expressive attention-directing acts (Esteve-Gibert et al., 2017), and they begin to signal such simple forms of speech acts in their own prosodic output (Esteve-Gibert & Prieto, 2013; Grünloh & Liszkowski, 2015; Murillo & Capilla, 2016).

Broadening the experimental procedures and methodologies employed in the acquisition of the prosody-meaning interface is essential to make progress in the field. On the one hand, more production studies should be conducted in laboratory-controlled settings, where shared-action contexts and act-preceding interactions can be precisely controlled and infant subjects' social intent thus more clearly determined. Larger sample sizes with more infants should be tested, thereby identifying potential individual effects, and bi- and multilingual populations could be further explored. On the other hand, online processing techniques like eye-tracking or neuroimaging can tap into infants' implicit language and cognitive skills before they are able to demonstrate them explicitly (see Teixidó et al., this volume, for a review). Using such techniques will be crucial to investigate the point at which infants start to make the connection between the suprasegmental cues they perceive and their intended meanings. All in all, a variety of empirical techniques can be deployed in a complementary fashion to assess infants' understanding of prosody as their linguistic and cognitive capacities unfold.

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