What paves the way to conventional language? The predictive value of babble, pointing and SES.

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Abstract

A child's first words mark the emergence of a uniquely human ability. Theories of the developmental steps that pave the way for word production have proposed that either vocal or gestural precursors are key. These accounts were tested by assessing the developmental synchrony in the onset of babbling, pointing and word production for 46 infants observed monthly between the ages of 9 and 18 months. Babbling and pointing did not develop in tight synchrony and babble onset alone predicted first words. Pointing and maternal education emerged as predictors of lexical knowledge only in relation to a measure taken at 18months. This suggests a far more important role for early phonological development in the creation of the lexicon than previously thought.

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The hallmark of human communication is the use of linguistic conventions: words and grammatical structures that function as inter-subjectively shared symbols. Although infants begin to show sensitivity to the association between common words and their referents around six months of age (Bergelson & Swingley, 2012), most children do not produce words until after their first birthday. Only then can we say that the infants can use conventional language to direct others' attention. There are large individual differences in the age at which infants make this transition to word production. Proposals as to why infants begin producing words when they do tend to focus on infant readiness in terms of either gestural or vocal precursors, and reflect theoretical proposals about the evolutionary origins of language. Thus, while some would argue that the phylogenetic and ontogenetic origins of language are vocal (MacNeilage & Davis, 1993), others have argued that the gestural domain is more important (Tomasello, 2008). Very little has been done to pit such theories against each other and weigh up the relative contributions of vocalisation and gesture as predictors of word onset. Indeed, regardless of whether ontogeny recapitulates phylogeny, there have been calls in the developmental literature for a more integrated approach to the study of predictors of word learning (Hall & Waxman, 2004).

There are several problems with this state of affairs. First, an infant's vocal and gestural abilities might in fact reflect a single underlying construct of communicative readiness (Bates & Dick, 2002; McNeill, 2000). Indeed, pointing and babble do co-occur from early in development and both are lateralised in the left hemisphere (Cochet & Vauclair, 2010; Franco & Butterworth, 1996; Iverson & Fagan, 2004; Masataka, 1995; Willems & Hagoort, 2007). By this account, the development of babble and pointing should be

correlated, with children who are communicatively advanced developing both abilities earlier. In this case, neither modality would necessarily be a better predictor of early word learning.

Second, if the two modalities are found to follow different developmental trajectories, the question is whether theoretical accounts emphasizing gestural or vocal origins are supported when the two types of precursors are weighed up simultaneously. Work on either side of the debate has tended to measure only the particular precursor of interest rather than considering its contribution alongside development in the other modality (e.g., Goldin-Meadow, 2007; Stoel-Gammon, 1998). Besides its theoretical importance, joint consideration of the two modalities has practical consequences for the early identification of risk factors for language development (e.g., Oller et al., 2010).

Third, early vocal and gestural abilities may be affected by the caregiver, whose mode of interaction may be responsible for any observed relations between precursors and the onset of word production. Caregiver education has been shown to be positively correlated with the quantity of infant-directed speech and the quality of parental responses to their infant's attention, gestures and vocalisations (Bornstein, Haynes, & Painter, 1998; Hoff, 2003a, 2003b; Hoff-Ginsberg, 1991; McGillion et al., 2013; Mundy et al., 2007). This latter difference in responsiveness is thought to be especially important when explaining variance in early lexical development since, at this stage, learning is more likely to occur if the caregiver talks about what the infant is already attending to (Hoff, 2003b; McGillion et al., 2013). It is, therefore, vital to control for this factor when assessing the relation between infants' pre-linguistic skills and their word learning. However, despite much recent research on the effect of caregiver education on language development, the focus has been on explaining what mediates or moderates this predictive relation, with very little work weighing

up this influence alongside the infant's own early communication skills (Demir & Küntay, 2014).

The goals of this study were to establish 1) whether early gestural and vocal behaviours emerge in synchrony; 2) whether either modality is more important for predicting the onset of word production. In addressing the latter question, we controlled for the level of education of the primary caregiver as a proxy for infant directed speech. Our primary focus was on the age at which children produced their very first words (i.e., the transition to conventional language) and the number of words children were reported to produce at 18 months. To establish whether the predictors of word production were the same as for word comprehension, we also analysed parental reports of the number of words they thought their child understood at 18 months. We chose the vocal and gestural predictor that each literature suggests is most important for predicting word onset. In the vocal domain this was the stable production of consonants; in the gestural domain it was the onset of index finger pointing.

Vocal precursors to word production: Babble

Phonological ability, both perceptual and expressive, is a key ingredient of later language success (Kuhl, 2004; Stoel-Gammon, 1998; Vihman, 2014). In order to be able to understand and produce words, the infant must be able to perceive and produce the component speech sounds of their native language. From a production perspective, although typically developing infants vocalise from birth, speech-like sounds begin to emerge gradually only late in the first year life, as a result of anatomical and neuro-motor maturation (Vihman, 2014). Many consider the appearance of reduplicated or canonical babble (repeated adult-like syllables containing a consonant, e.g., ([bababa], [dadada]) between 6 and 8 months to be an especially important precursor of language, both onto- and phylogenetically (MacNeilage & Davis, 1993; Lieberman, 2002; Oller, 2000). Early babble of this form can be

viewed as a milestone of motor development – a type of rhythmic vocalisation related to other forms of motor development in the first year of life (Campos et al., 2000; Iverson & Fagan, 2004; Kent, 1984; Thelen, 1981; Thelen, Ulrich, & Wolff, 1991). However, babble can also be considered a language milestone reflecting the infant's sensitivity to, and use of, the sounds of their native language (Jusczyk, 1997). In addition to physical maturation the production of babble is contingent on at least some exposure to the ambient language (Oller & Eilers, 1988). The phonological patterning, prosody, and consonant shape in babble have all been shown to be influenced by the infant's language environment (Oller et al., 2010). Moreover, the appearance of consonants in pre-linguistic vocalisations has been related not only to word production (McCune & Vihman, 2001) but also to their phonological shape. That is, the consonants used in babble are typically the ones used in first words (Vihman, Macken, Miller, Simmons, & Miller, 1985). In recent studies, the measure used to capture the onset of babble is the age at which infants first demonstrate the stable use of two supraglottal consonants (DePaolis, Vihman & Keren-Portnoy, 2011; Majorano, Vihman & DePaolis, 2013), and we adopt that measure here.

Gestural precursors to word production: Pointing

Pointing, specifically index finger pointing, is often considered the first true means of triadic referential communication available to the infant, setting it apart from other gestures, such as showing, which arguably has a more phatic function (Liszkowski & Tomasello, 2011). The prototypical pointing hand shape, index finger extended with the remaining digits curled inwards, emerges as early as 3 months of age (Fogel & Hannan, 1985). However, it is not until the infant extends both arm and finger, between 9 and 15 months, that this behaviour is associated with a system of shared intentionality and communicative intent on the part of the infant (Carpenter, Nagell, Tomasello, 1998; Tomasello, Carpenter, & Liszkowski, 2007). In contrast to the above accounts proposing vocalisation as the gatekeeper to language, it has

been argued that this latter developmental step, producing declarative pointing gestures, provides the foundation on which linguistic communication rests, both developmentally and from an evolutionary perspective (Butterworth, 2003; Goldin-Meadow, 2007; Tomasello, 2008). This claim has been borne out in a growing number of studies in which pointing, specifically index finger pointing, has been robustly associated with later vocabulary (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979; Colonnesi, Stams, Koster, & Noom, 2010; Desrochers, Morissette, & Ricard, 1995; Iverson & Goldin-Meadow, 2005; Özçaliskan & Goldin-Meadow, 2005). What underpins this relation is not well understood, however. Some argue that the onset of pointing reflects the emergence of new social-cognitive abilities and social motivations that are required for subsequent word production (Tomasello, Carpenter & Liszkowski, 2007). Thus, Tomasello (2001) has argued that, while children can make speech sounds and associations well before the first birthday, it is only with the advent of new social cognitive skills emerging in the 9-12-month period that they are capable of fully appreciating what a word is: an 'intersubjectively understood linguistic symbol used to direct and share attention with other persons' (Tomasello, 2001, p. 1120). A second (non-mutually exclusive) possibility is that the infant's referential gestures prompt caregivers to respond by producing words in a context that is optimal for learning (Goldstein & Schwade, 2008; Kishimoto, Shizawa, Yasuda, Hinobayashi, & Minami, 2007). That is, when infants point to things, parents can translate this gesture into conventional language at a moment when the infant is jointly attending to both the word and whatever it is denoting. On both accounts, early onset of pointing should predict early onset of word production (so long as the child has the minimal phonetic repertoire needed to produce words).

The Current Study

This study sought to establish whether early gestural and vocal behaviours emerge in synchrony (and are thus potentially reflections in different modalities of the same communicative readiness construct) and, if not, whether either modality is more important for predicting the onset of word production and levels of expressive and receptive vocabulary at 18 months. To achieve this we analysed a densely sampled set of video recordings of 46 infants interacting in naturalistic play sessions with their primary caregiver (their mother in each case), between the ages of 9 and 18 months. This data set allowed us to establish the month in which infants were reliably observed to produce consonants, to point, and to produce their first words.

Method

Participants

Participants were drawn from a larger sample of 59 parent-infant dyads who had previously participated in a longitudinal study of early phonological development (Vihman, DePaolis, & Keren-Portnoy, 2009). These families were recruited in the North of England via advertisements in the local press and infant-focused community groups. Eleven dyads were ineligible for inclusion in the current study (as caregivers did not give consent for use of their data in other research); one more infant was excluded due to a developmental disorder and a final dyad was excluded because the primary caregiver did not participate in play recordings. Thus, the final sample for the present study included 46 parent-infant dyads. Twenty-one of the infants were boys, 21 were first born, and all came from monolingual English-speaking families where the mother was the primary caregiver. All infants were full-term and had no

known hearing or developmental disorders. Seventy per cent of mothers and 50% of fathers had a university degree.

Procedure & Transcription

Dyads were video-recorded in their homes engaging in 30 minutes of naturalistic play when the infant was between 9 and 18 months old. A research assistant remained with the dyad for the duration of the recording, moving the video camera to ensure that the infant remained in shot. Initially, recordings were made weekly, then bi-weekly (when the infant turned 13 months), dropping to once per month when the infant demonstrated consistent use of 2 supra-glottal consonants (or Vocal Motor Schemes; McCune & Vihman, 2001). A demographic questionnaire administered on the first home visit at 9 months measured, amongst other information, birth order and parental education. A parental report of expressive and receptive vocabulary, the Oxford Communicative Development Inventory (OCDI; Hamilton, Plunkett, & Schafer, 2000), a modified, UK version of the MacArthur Bates Communicative Development Inventory (Fenson *et al.,* 1994), was collected monthly. Participants were given £10 per visit to thank them for participating.

Infant vocalisations were phonetically transcribed by three trained research assistants (including the first author) using EUDICO Linguistic Annotator software (ELAN; Sloetjes & Wittenburg, 2008).

Measures

Babble onset was characterised as the stable production of two supra-glottal consonants (excluding glottal and glides). A consonant was considered to have reached stable production status if it fulfilled one of two criteria: (1) A minimum of ten tokens were produced in three out of four consecutive half-hour sessions (McCune & Vihman, 2001); or

(2) a total of 50 or more tokens of the given consonant were produced in one recording session (DePaolis, Vihman, & Keren-Portnoy, 2011). Stable consonant production was dated to the first home visit where the infant's production met either criterion. The onsets of first and second consonants were positively correlated ($r = 0.756$; $p < 0.01$). Age at onset of the second stable consonant is preferred here as a measure of babble, primarily because age of acquisition of the first stable consonant correlated with infant age at first home visit ($r = 0.299$; $p = 0.044$), but also because this measure of second consonant production has previously been found to correlate with referential word learning (McCune & Vihman, 2001).

Pointing onset was coded according to amended criteria from Matthews, Behne, Lieven, and Tomasello (2012). We coded index finger pointing uniquely as it has been identified both theoretically (Butterworth, 2003) and empirically (Colonnesi et al., 2010) as the most important pre-linguistic pointing behaviour. Recordings were viewed, in order, by a trained research assistant until the infant was observed to spontaneously make an index-finger point. That is, whilst looking at the object or event of interest, the infant produced a point with their left or right hand, or both, such that that the index finger was clearly and visibly separate from the other fingers, which were partially or entirely curled back. To check the reliability of this point measure, we compared it with parental reports of onset, where available. At each home visit, caregivers were asked to complete a diary commenting on any new communicative behaviour their child had begun to engage in. Although parents were not specifically asked to report pointing behaviour, 50% ($n = 23$) did so spontaneously, remarking that their infant had begun to point since the previous home visit. For this subset of parents, we calculated the correlation between parent-reported age of point onset (median = 312 days) and our estimated age of pointing onset from video coding (median = 385 days). The two measures were significantly correlated ($r = .452$, $p = .03$). To further check the reliability of the video-coded measure of pointing onset, we asked a research assistant blind

to the hypotheses of the study to watch video recordings selected just before and just after we had originally estimated infants to have started pointing for the presence of pointing behaviour. To check that infants hadn't started pointing before our estimated onset date, we randomly selected 20% (n = 9) of the recordings from the month preceding the observed pointing onset. No infant was observed to point in these sessions. To check whether, once infants started to point, they would reliably do so in subsequent sessions, we coded pointing gestures in the sessions following that in which we had first observed each infant pointing (n = 45; one infant was first observed to point in their final session). Half the infants (n = 23) were observed to point in the session that immediately followed their first observed point. A further 27% (n = 12) were next observed to point two sessions after they were first observed to do so with the remaining 22 % either pointing within two further sessions or reaching 18 months of age (when recordings stopped).

Maternal and paternal education was coded on a 5-point scale based on a modified version of Hobbs and Vignoles' (2007) classification system: Level 1: No qualifications; 2: vocational qualifications; 3: GCSE or equivalent (UK exams typically taken at 16 years of age); 4: A levels or equivalent (UK exams typically taken at 18 years of age); 5: University Degree. Maternal and paternal education levels were positively related ($r = 0.538$, $p < 0.01$), thus only maternal education was included in analyses as the mother was the primary caregiver for all dyads.

The infant's age at the first session in which they spontaneously produced four different words was identified as the *4-word point,* using Vihman and McCune's (1994) word identification procedure. This procedure considers both the phonetic shape of vocalisations and contextual criteria to identify words. Word candidates are scored on 1) their phonological similarity to the presumed adult target, 2) the availability of a plausible referent in the

immediate context, and 3) the consistency with which the same form is used for the same referent.

The OCDI (Hamilton *et al.,* 2000) was used to measure the infant's *expressive and receptive vocabulary knowledge at 18 months*. Expressive and receptive OCDI vocabulary scores were positively related (Table 2) and correlated negatively (and in the case of expressive vocabulary, significantly) with the observed age at 4-word point (Table 2). That is, the earlier a child reached the 4-word point, the greater their reported expressive vocabulary at 18 months.

Reliabilities

The stable production of consonants in babble and of word forms was coded by three trained research assistants, including the first author. Four 3-minute video excerpts, randomly selected from recordings collected when the infant was 10 months old, were used to calculate transcription reliability. These segments were phonetically transcribed by all three coders and reliabilities calculated in terms of percentage agreement as to possible consonants (/p, b/, /t, d/, /k, g/, /m/, /n/, /ŋ/ ,/l/ /s/) between every two transcribers. Average agreement was 69% (range 65% - 72%), which rose to 80% (range 76% to 89%) when the infrequently used consonants /l/ (used by 3 infants) and /s/ (2 infants) were excluded. This is in line with similar studies involving the transcription of pre-linguistic babble (DePaolis et al., 2013; Majorano et al., 2014; McCune & Vihman, 2001). Since transcription was used here to establish the point at which each infant could produce two consonants and four words, the first author reviewed each infant's video recordings and checked that they had met criterion on the date calculated and not before or after.

Pointing was coded by a trained research assistant. A randomly selected sample (11/46 infants or 24%) was independently coded by the first author. Pearson's correlations indicated excellent agreement (r = .99, $p < 0.01$). Disagreements and borderline cases were discussed and resolved. Finally, the gesture produced at observed pointing onset for each infant was checked and confirmed by the first and final authors.

Results

We first explore the relation between pre-linguistic babble and pointing before considering how each of these behaviours relates to maternal education. Next, we report regression models that test how these three measures relate to first word production and expressive and receptive vocabulary at 18 months.

What is the Relation between Babbling, Pointing, Maternal Education and Infant Language?

There were large individual differences in age of onset of both babble and pointing. Babble onset tended to precede the onset of index finger pointing. The median age for the onset of babble was three months before that of pointing, at almost 10 months of age. All infants had begun to babble by 15 months and to point using their index finger by 18 months. Descriptive statistics for pre-linguistic infant measures and maternal education are presented in Table 1. The cumulative percentage of children beginning to babble and point, month by month, is presented in Figure 1.

[Please insert Table 1 & Figure 1 about here]

As can be seen in Table 2, infant pointing onset and babble onset were not significantly correlated, suggesting that they are not different measures of a single

'communicative readiness' construct. Consistent with previous findings in the literature, maternal education was unrelated to babble onset (Oller, Eilers, Basinger, Steffens, & Urbano, 1995). However, there were small to moderate correlations between maternal education and pointing onset and between maternal education and receptive and expressive language at 18 months.

[Please insert Table 2 about here]

What Best Predicts First Words?

Age at babble and pointing onset and maternal education were used to build regression models predicting the age at which infants were first observed to produce four words (4-word point). Model selection was performed by comparing all possible combinations of predictors including a null model (R Core Team, 2014). The best fitting model was one with babble onset alone as a predictor, which constituted a significant improvement on a null model (Table 3). The addition of pointing onset or education gave no improvement to any model, including the null model. It is worth noting that some children (n = 6) produced four words before they were observed to point, suggesting that pointing is not a necessary precursor of word production.

[Please insert Table 3 about here]

What Best Predicts Expressive and Receptive Vocabulary at 18 months?

Model comparison was again performed to identify the best account of expressive vocabulary and receptive vocabulary development at 18 months. For expressive vocabulary, the best fitting model included babble onset and maternal education as predictors (Table 4). The addition of babble onset to a model with maternal education alone also gave a significant

improvement ($F(1, 44) = 8.103$, $p = .007$), as did the addition of maternal education to a model with babble onset alone ($F(1, 44) = 4.252$, $p = .045$), indicating that these predictors explain separate variance. The addition of pointing onset gave no significant improvement to any model. Considered alone it gave no improvement on a null model. When added to a model with babble onset and maternal education, it gave a marginal improvement ($F(1, 42) = 3.491$, $p = .068$).

[Please insert Table 4 about here]

For receptive vocabulary, the best fitting model included pointing onset and maternal education as predictors (Table 5). When considered alone, maternal education gave a significant improvement over the null model ($F(1,44) = 4.268$, $p = .045$), but pointing did not ($F(1,44) = 2.712$, $p = .107$). The addition of pointing onset to a model with maternal education alone gave a significant improvement ($F(1, 43) = 6.5932$, $p = .014$), as did the addition of maternal education to a model with pointing onset alone ($F(1, 43) = 8.245$, $p = .001$), indicating that these predictors explain separate variance. The addition of babble onset gave no significant improvement to any model. Considered alone it gave no improvement on a null model ($F(1,43) = 2.812$, $p = .1007$) . When added to a model with pointing onset and maternal education, it gave a marginal improvement ($F(1,42) = 4.011$, $p = .051$).

[Please insert Table 5 about here]

Discussion

This study found that babbling (consonant production) develops independently of pointing and maternal education. When all three factors were considered simultaneously, only babble emerged as a significant predictor of the age at which infants began to produce words, explaining 22% of the variance. When later measures of vocabulary were considered,

babble and maternal education emerged as predictors of word production whereas pointing and maternal education predicted word comprehension.

These findings suggest that phonological readiness is more important for the transition to word production than previously recognised. Since infants are typically found to engage in canonical babble from around 6-8 months (Oller, 1980), and even learn some sound-referent associations at this age (Bergelson & Swingley, 2012), it has been claimed that they have, so to speak, jumped the articulatory and associative hurdles and that only social cognitive developments would be left to determine when infants began to produce words (Tomasello, 2001). Yet this does not appear to be the case. Practice with babbling continues to be a strong determinant of the onset of word production and one that appears to be unaffected by the social environment.

Why might babble onset predict later productive vocabulary? Of course, starting to practice vocalizations earlier will make word production easier. However, there is a considerable gap in between the time infants started to babble (approaching 10 months median onset for the measure used here) and the time they started to produce words (15 months median onset). Thus, even infants who were slower to start to babble had ample vocal resources by 12 months such that they could have produced a word if their phonological repertoire were the only constraint. It is likely that early babble was associated with early word production for additional reasons. One option is that by starting to vocalise early, infants shaped their own environments, eliciting responses from the caregiver that, a) encouraged more vocal practice, b) made it salient that vocalisation can be used to communicate, and, c), assisted infants in identifying the function of first words (Goldstein & Schwade, 2008; Vihman, 2014). Finally, it could also be that babble onset reflects some third

variable, not studied here, that is beneficial for language learning such as the inclination to engage with others socially.

In contrast to clear predictions in the literature, the ability to point did *not* emerge as an important determinant of the onset of word production. Of course, unlike speech sound production, pointing is not a necessary component of word production. However, the act of pointing is thought to represent the first means of intentionally directing others' attention to the external world. Whereas first instances of babbling appear devoid of communicative intent (and are considered a motor milestone, not a social one), first acts of pointing can readily be interpreted as imperative or declaratives acts. For this reason, the act of pointing has been argued to pave the way for language production (Butterworth, 2003; Tomasello, 2008). Children in this study did tend to produce pointing gestures before their first words (only 6/46 children failed to do so). But, other than this, we found no synchrony between the onset of index finger pointing and the onset of first word production. It is only when we examine word comprehension at 18 months that we find a link between pointing and vocabulary development. This is in line with findings of a recent meta-analysis that showed that the association between pointing and language development increases with age (Colonnesi et al., 2010). This suggests that, while the mastery of pointing may not be essential for initiating word production, its use facilitates subsequent lexical development.

One might query whether the findings would have differed if we had considered a broader set of communicative gestures, for example, open handed points and/or 'show' gestures (Cameron-Faulkner, Theakston, Lieven, & Tomasello, 2015) or indeed if we had used experimental paradigms to elicit pointing behaviour (Liszkowski & Tomasello, 2011) rather than observe it naturalistically. We measured index finger pointing specifically as this has been theoretically argued and empirically found to be the key predictor of lexical

development (Butterworth, 2003; Colonnesi et al., 2010). Whether or not using an experimental paradigm would have elicited more pointing behaviour at an earlier age is an interesting question. Some have observed that infants point more often in naturalistic settings, in the home rather than in the lab (Leroy, Mathiot, & Morgenstern, 2009), but it is possible that taking a 'distal display' to the home and asking parents to carry infants around to look at it might elicit more gestures. We also focussed on onset rather than frequency of pointing since we were concerned with infants' capacity to engage in these behaviours. Since the onset of pointing appears to be constrained by infant-internal factors, whereas the frequency with which they go on to use the gesture depends heavily on socialization (Matthews et al., 2012), future research might explore the predictive value of frequency measures compared to onset measures.

Pointing did emerge as a predictor of word comprehension at 18 months, along with measures of maternal education. This is likely because parents tend to respond to infant gestures with relevant words (Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007). If this is the case, a key question remains to be answered: why does early babbling apparently not have the same language-eliciting effect and thereby also predict comprehension? It might be argued that, while parents often respond to vocalisations, they won't necessarily do so by 'translating' these into conventional language since much babble has no obvious communicative target. Thus, parental responses that facilitate language development likely only occur in response to 'communicatively intentional babbling', where the infant's vocalisation is clearly intended to direct another's attention (Esteve-Gibert & Prieto, 2012; Goldstein, Schwade, Briesch, & Syal, 2010; McCune, Vihman, Roug-Hellichius, Delery, & Gogate, 1996). Devising a list of clear markers of intention is a well-recognised challenge (Bruner, 1973). Consequently, we opted to have both pointing and babble onset coded without reference to extra indicators such as gaze alternation (as is standard, e.g., Colonnesi

et al., 2010; Vihman, 2014) and without considering instances when these behaviours co-occur (Wu & Gros-Louis, 2014). In future studies, it would be fruitful to compare parental responses to infant gestural and vocal communication of different types to establish whether parents predictably respond to certain constellations of behaviour with language that would facilitate word learning (Olson & Masur, 2013).

This issue of identifying instances of intentional communication is also important for unpicking when infants come to have full intentional control over the production of words as symbols. It is quite possible that verbally precocious infants produce words without fully grasping their symbolic function because they are in a routine situation where production of a given phonological form is heavily primed. While referential intent was a criterion in the word coding scheme adopted here, it is of course very difficult to tell whether or not an infant used a word symbolically. Being able to tell when a child has truly made this transition to word use proper, and what interim steps individual children may make along the way, is of course of the greatest theoretical importance. To fully chart this out, we will need to triangulate the results from studies of language production with studies of comprehension (e.g., Bannard & Tomasello, 2012; Vouloumanos, Onishi, & Pogue, 2012) and neural markers of intentional communication (e.g. Gredebäck, Melinder, & Daum, 2010; Peeters, Chu, Holler, Hagoort, & Özyürek, 2015). The conclusion from the current study is that this process will require careful attention to phonological development.

To summarise, this study analysed frequent recordings of 46 infants between 9 and 18 months and found that the age at which infants began to babble explained 22% of the variance in the age at which they began to produce words. In contrast to predictions in the literature, pointing onset did not predict word onset. However, along with maternal education, pointing onset predicted the number of words the infants understood at 18 month

of age. This is in line with recent meta-analyses and suggests that socialization factors become increasingly important for lexical growth over the second year of life. When it comes to making the initial transition to conventional language, however, it is the onset of babble that paves the way for children's first words.

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Tables and Figures

Table 1: Descriptive Statistics for Pre-linguistic Infant Measures and Maternal Education (N= 46)

	Minimum	*Maximum*	*Median*	*SD*
Babble onset (age in days)	277	464	298	47.254
Pointing onset (age in days)	283	559	385	76.017
Four Word Point (age in days)	355	575	469.5	61.021
Maternal education	2	5	5	.809

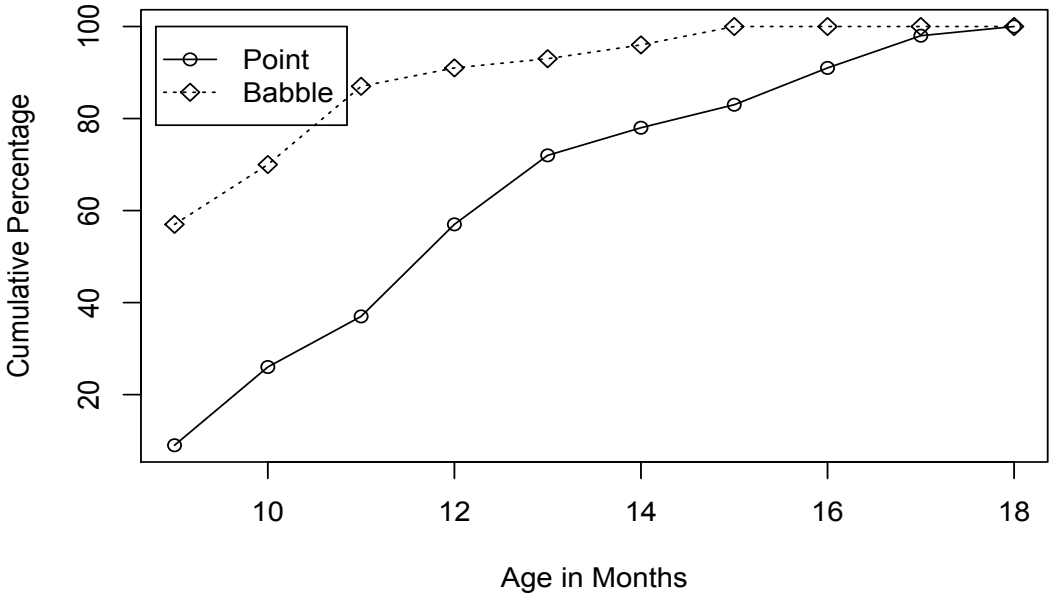

Figure 1: Cumulative Percentage of Infant Babble and Pointing Onset as a function of age in months (N=46)

Table 2: Correlation Coefficients (Pearson's r) among Pre-linguistic Infant Measures and Maternal Education (N=46)

	[1]	[2]	[3]	[4]	[5]	[6]
[1] Babble onset						
[2] Pointing onset	-.130					
[3] Maternal Education	-.079	.305*				
[4] 4-word-point	.470**	.091	-.038			
[5] Expressive vocabulary at 18m	-.402**	-.096	.306*	-.502**		
[6] Receptive Vocabulary at 18m	-.245	-.241	.297*	-.205	.521**	

** p<0.05; ** p<0.01.*

Table 3: Regression Model fitting Babble Onset to Infant Age at 4-word point

	B	*T*	*P*
Babble onset	.607	3.530	.001

R^2 = *.221, F(1,44)=12.464, p =.001*

Table 4: Regression Model fitting Babble Onset and Maternal Education to Expressive Vocabulary at 18 months

	B	*T*	*P*
Babble onset	-.411	-2.847	.007
Maternal Education	17.363	2.062	.045

R^2 = *.237, F(2,43)=6.685, p =.003*

Table 5: Regression Model fitting Pointing Onset and Maternal Education to Receptive Vocabulary at 18 months.

	B	*T*	*P*
Pointing onset	-.341	-2.568	.013
Maternal Education	35.855	2.871	.006

R^2 = *.210, F(2,43)=5.702, p=006*