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RES-062-23-0092
Dynamic interactions between perception and production: **An integrated experimental and observational study**
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Award holders should also submit **seven additional <u>copies</u>** of this Form, and eight copies of the research report and any nominated outputs to be evaluated along with the Report.

A copy of the complete Report, comprising this form and the research report, should be formatted as a single document and sent as an email attachment to **reportsofficer@esrc.ac.uk**. Please enter the **<u>Award Reference Number</u>** as the email subject.

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This Report is an accurate statement of the objectives, conduct, results and outputs (to date) of the research project funded by the ESRC.

1. Award Holder(s) Signature

NB. This must include anyone named as a co-applicant in the research proposal.

TITLE	INITIALS	SURNAME	SIGNATURE

2. Administrative Authority Signature

	DATE:

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A machine-readable copy of any dataset arising from the research must be offered for deposit with the Economic and Social Data Service (ESDS) at the UK Data Archive within three months of the end of the award. All enquiries should be addressed to the Acquisitions Team, ESDS, University of Essex, Wivenhoe Park, Colchester CO4 3SQ or by email to acquisitions@esds.ac.uk

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PROJECT DETAILS

ESRC END OF AWARD REPORT: PROJECT DETAILS

AWARD NUMBER:	RES-062-23-0092		
AWARD TITLE: (the box will accommodate up to 4 lines of text)	Dynamic interactions between perception and production: An integrated experimental and observational study		
AWARD START DATE	**March 1, 2007**	**TOTAL AMOUNT EXPENDED:**	**£ 683,448.42**
AWARD END DATE	**May 31, 2009**		
In the case of awards which have transferred please include: the full expenditure at each institution and relevant transfer dates.			

AWARD HOLDER(S):

NB. This must include anyone named as a co-applicant, as originally listed in the research proposal.

TITLE	INITIALS	SURNAME	DATE OF BIRTH	No HOURS PER WEEK/ % TIME ON PROJECT
Professor	M. M.	Vihman	23/12/39	5 hrs
Dr.	T.	Keren-Portnoy	9/3/66	18.5 hrs

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V/C/210, 2nd Floor, Block C, Vanbrugh College University of York Heslington, York YO10 5DD	**FAX NUMBER** 01904 432673

ACTIVITIES AND ACHIEVEMENTS QUESTIONNAIRE

1. Non-Technical Summary

How do children develop the basic knowledge and skills needed to begin to learn to talk? We know little about the ongoing relationship between emergent abilities to perceive speech and produce speech-like vocalisations (babble), and we also lack clear evidence regarding the relationship of those abilities to the onset of word learning and use. This study explored this relationship in a longitudinal design, following 60 children in the development of word recognition and segmentation, consistent consonant production, and word production. The model is based upon Dynamic Systems theory (Thelen & Smith, 1994), which assumes that when relatively simple skills combine, more complex behavioural patterns can emerge. In this case, basic vocal and perceptual skills eventually lead to the onset of an early lexicon.

We evaluate production skills based on weekly recordings from age 9 months to the point where the child makes reliable and consistent use of two consonants or Vocal Motor Schemes (VMS). Perception capacity is assessed on the basis of two headturn tasks, a word-form recognition test at 10 months and a word segmentation test at 11 months. In both these tasks words likely to be familiar to the infants from the home (henceforth Familiar words) are contrasted with words which are unlikely to be familiar to the infants (Rare words). In the word-form recognition task the words are presented in a list, and in the segmentation task the words are embedded in sentences. Advances in word production are assessed based on monthly home recordings up to age 18 months. Age at onset of first word use is defined as the age at which 4 different spontaneous words are identifiable in a 30-minute naturalistic observational session in the home.

An extreme preference for either Familiar over Rare words or sentences (or vice versa) was taken to indicate that the infant distinguished between the two types of words, and therefore indicated successful performance on either head turn task.

To summarize our findings:

1. Lexicon size at age 9 months (based on parental report) correlated significantly with performance on the two experimental tasks, with a larger lexicon correlating with *low* 10-month word recognition scores and with *high* 11-month segmentation scores. The fact that the relationship is with low scores in the one case and with high scores in the other gives further credence to our interpretation of both types of preference as 'success' (or a mark of relative infant advance).
2. The infants who had two VMS already by the time they participated in the word recognition task were significantly more variable and more extreme in their preferences than the infants who did not yet produce consonants consistently at the time of the experiment. This indicates that the infants who were more advanced in production were also more advanced in word recognition. A correlation between the degree of preference (in either direction) and the age at attaining two VMS is marginally significant and expresses the same relationship between degree of production advance and word recognition.
3. Both age of attaining two VMS and performance on the word recognition task are important for segmentation success: The only group among whom the majority of infants succeeded at the segmentation task was the group of infants who had both (a) attained two VMS by the time of the word recognition experiment and (b) succeeded at word recognition.
4. The only variable which was related to the age at which the children started to produce words was the age at attaining two VMS, which proved a strong predictor of age at first word use. Neither of the two experimental tasks showed any relationship with the age of production of the first words, but as we are still in the process of collecting all the data

regarding word production, we may yet find a relationship between early word form recognition and segmentation and later word production.

These results suggest that babbling provides infants with an important early mechanism for finding connections between their own vocal production and the speech produced by others. By recognizing that what they hear is similar to what they produce, infants can better recognise sound patterns in the input based on their similarity to their own productions. Thus, babbling helps babies recognize and maintain in memory sound sequences which contain sounds that are familiar from their own babble, thereby helping them remember frequent word forms which appear in the input. This newly gained familiarity with some frequent word forms together with the enhanced salience of parts of the input speech supports segmentation of familiar words from running speech. We have also found that babbling scaffolds first word use. To date we have not found evidence for a relationship between recognition and segmentation of familiar word forms and the beginnings of word production, but we are continuing to investigate this issue.

2. Dissemination

A. Please outline any specific plans you have for further publication and/or other means of dissemination of the outcomes and results of the research.

1) A paper detailing the longitudinal findings relating to advances in perception, production and word learning and to the relationships between them will be submitted to *Journal of Experimental Psychology*.
2) A paper focusing on language learning from the perspective of Dynamic Systems theory, looking at variability in Head-Turn measurements within child as an index of approaching advance and relating such variability to advances in both production and perception, will be submitted to *Developmental Science* or *Developmental Psychology*.
3) We have discussed with the editor the possibility of publishing an SRCD monograph on the dynamic interactions between production and perception; this remains a longer term goal.

B. Please provide names and contact details of any non-academic research users with whom the research has been discussed and/or to whom results have been disseminated.

3. Nominated Outputs (see Guidelines 1.4)

Please give full details of the two nominated outputs which should be assessed along with this report. Please provide **one** printed copy of publicly available web-based resources, **eight** copies of any nominated outputs **must** be submitted with the End of Award Report.

4. Staffing

Please detail appointments and departures below for ALL staff recruited for this award. Where possible, please note each person's name, age, grade; and for departing staff, destination type on leaving.
(Destination types: Academic post, Commercial, Public Sector, Personal, Other).

NB. This section must not include anyone who is an award holder.

Title	Initials	Surname	Date Of Birth	Grade	Appointment Date	Departure Date	Destination Type & Post
Mrs.	N. M. A.	Williams (formerly Armstrong)	19/4/81	6	01/03/2007	13/03/2009	Research assistant in NHS
Miss	A.	Bidgood		4	01/07/2007	31/05/2009	Continuing
Miss	P.	Claxton		4	01/11/2008	03/03/2009	Personal
Mrs.	R.	Dodgson		5	01/07/2007	30/04/2009	Continuing
Miss	M.	McGillion		4	01/08/2007	31/05/2009	Continuing
Miss	H.	Sears		4	01/07/2008	31/05/2009	Continuing

5. Virements

Since 1st April 1996 investigators may vire between grant headings without reference to Council, except where major capital items are being provided for. Please detail below any changed use of resources and the benefits or problems this brought.

Due to the fact that some requests for travel expenses were listed on two grants running concurrently, we've moved £4000 out of the Travel header into Staff.
In addition, the budget for Lab Services (£ 23026) was not used. The proposal was written while the investigators were in the University of Wales Bangor, where it was required that lab services were budgeted for. The actual study was run at the University of York, where, due to differences in the budgeting for technical support, this sum could not be used.

6. Major difficulties

Please detail below any major difficulties, scientific or administrative/logistical, encountered during your research and comment on any consequent impact on the project. Further details should be included in the main report, including any advice you might have for resolving such problems in future projects.

There were no specific difficulties. We meant to follow the children until they reached 16 months of age, but in the course of the study it became clear that they were not yet producing many words by age 16 months, so we decided to follow them for two more months.
Regarding the Head-Turn procedure, we had meant to use previous data collected in our lab as a baseline data for identifying ‘success’ and ‘failure’ in the word-form recognition and segmentation tasks. However, since we had made some changes to the stimuli, we decided to run new baseline groups with the new stimuli. We therefore ran 2 additional groups (one a month younger and one a month older than our main participants) for each of the Head-Turn tasks, making for four additional groups of participants, who participated in the Head-Turn tasks only and were not followed longitudinally.

7. Other issues and unexpected outcomes

Please describe any outcomes of your research, beneficial or otherwise that were not expected at the outset or other issues which were important to the research, where these are not addressed above. Further details should be included in the main report.

One unexpected outcome was the finding that success at the Head-Turn tasks was expressed as a preference for either type of stimulus (Familiar or Rare). Head-Turn results are usually interpreted as showing one type of preference or the other within the group, but not both. The common practice is sufficient when the aim is to get group results, but as we were interested in finding the individuals within a group who could be seen as ‘successful’, we needed to look more carefully at the entire distribution of scores. We believe that it is justified to adopt this novel way of looking at success in Head Turn tasks.

8. Contributions to ESRC Programmes

If your project was part of an ESRC Research Programme, please describe your contributions to the Programme’s overall objectives, and note any impacts on your project resulting from your involvement.

N/A

9. Nominated Rapporteur

Please suggest the name of one person who would be suitable to act as an independent rapporteur for your project. Please state full address and telephone number.

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Dynamic interactions between perception and production

Background

Advances in speech perception and receptive word knowledge in the first year are widely assumed to play a critical role in facilitating language learning in the second year. Recently a few studies have even reported predictive relationships between early speech perception tests and later language learning outcomes (e.g., Tsao et al., 2004; Newman et al., 2006). Given this emerging relationship it would seem well worthwhile to study how early production skills may affect early perception as well as later language learning, but few researchers have addressed this question. This project explored the interaction of production and perception and their relative contributions to word learning by gathering both observational and experimental data from a large sample of children at the onset of language learning.

Among the potential predictors of later language skill is the degree of success in untrained word form recognition. Hallé and Boysson-Bardies (1994) used a simple Head-Turn procedure (HT) to show that 11-month-old French infants, without benefit of training, respond with longer looks to a list of words likely to be familiar from the home than to phonotactically matched rare words; the study has been replicated with English infants, using both HT (Vihman, Nakai, DePaolis & Hallé, 2004) and Event Related Potentials (Thierry, Vihman & Roberts, 2003; Vihman et al., 2007), as well as with Dutch children (Swingley, 2005). It is plausible that sensitivity to phonological patterns in the input, a necessary basis for word form recognition, should constitute an important foundation for word learning and the construction of phonological knowledge.

A second focal perceptual skill is segmentation, which has had the benefit of a good deal of experimental research (e.g., Jusczyk & Aslin, 1995; Jusczyk, Hohne & Bauman, 1999; Jusczyk, Houston, & Newsome, 1999; Mattys & Jusczyk, 2001; Johnson, Jusczyk, Cutler & Norris, 2003; Houston, Santelmann & Jusczyk, 2004). Success at segmentation experiments in the first year has been found to be an important predictor of later advances, as measured by size of lexicon at age two years and both semantic and syntactic knowledge between ages 4 and 6 years (Newman et al., 2006). But what is the basis for individual infants' ability to segment running speech? This ability has been shown to be present to some degree as early as 6 months of age (Bortfeld et al., 2005), but some segmentation tasks, requiring a wide range of skills – such as the ability to detect phonotactic and allophonic regularities, distinguish different stress patterns, or use coarticulation cues – have been seen only at later ages, ranging up to 12 months. Most segmentation studies with infants have focused on word training in the laboratory, followed by testing with short narrative passages. The findings thus provide evidence for what children of a given age are capable of learning, but do not provide information as to the extent to which children actually rely on such skills in everyday life.

Ongoing work on segmentation in our laboratory has revealed that 11-month-olds do not, as a group, segment familiar words out of short narrative passages in the absence of specific training or priming (DePaolis, Keren-Portnoy & Vihman, in revision). At 12 months a larger number of infants succeed at the untrained segmentation task, but with wide individual variation. The difference between segmentation ability following training in the laboratory and untrained segmentation of familiar words at 12 months is of considerable interest, given the long-term value of segmentation skills demonstrated by Newman et al. (2006). Training in the laboratory permits a more rigorously controlled study but has less ecological validity than untrained segmentation. The observed timing of the ability to 'find' untrained familiar words in running speech is consonant with the logical assumption that this skill is dependent on untrained word form recognition, reliably seen by 11 months in most children learning Dutch, English or French in a monolingual setting.

Turning to the development of production abilities in this period, vocal practice, or babbling, has been shown to be a strong predictor of age of onset of first word use. McCune & Vihman (2001) reported that a measure of stable consonant production ('Vocal motor schemes', or VMS) predicted age of 'referential' or context-flexible word use (i.e., generalized word production in appropriate contexts) in 20 children acquiring American English, followed from 9 to 16 months. These findings have been replicated with 12 UK children seen from 11 to 24 months. Age at two VMS is highly significantly correlated to age at 'context-bound' or 'primed' first word use as well as to later referential word use (Keren-Portnoy, Vihman & DePaolis, 2005).

Although perception and production might mature independently without mutual influence (Jusczyk, 1997, ch. 7), there is good reason to believe that vocal production plays a critical role in advances in speech perception, based on both theoretical considerations (Vihman, 1991, 1993, 1996; Davis & MacNeilage, 2000) and recent empirical findings. Once 'canonical' or adultlike syllables (Oller, 2000) are in repertoire – typically, between about 6 and 8 months – an 'articulatory filter' can begin to function to highlight selected patterns of input speech that are a rough match to the child's own well practiced vocal patterns, rendering those patterns particularly salient to the child. This can account for the fact that infant attention to segmental patterning is found only by about 9 months, although advances in knowledge of ambient language prosodic patterning are seen some months earlier (Vihman & DePaolis, 2000; Vihman, 2002). An effect of infants' own vocal patterns on their attention to speech has now been demonstrated empirically, using as stimuli both isolated lists of nonwords (Vihman & Nakai, 2003) and narrative passages (DePaolis, Vihman & Keren-Portnoy, in revision). In the study conducted by DePaolis et al. looking time was measured in response to passages containing nonwords based on individual infants' VMS. This study found a group effect of the infants' interest in the nonwords based upon the production patterns of each individual infant.

This effect based of infants' individual production patterns suggests that only intensive observation of infant production can provide an adequate basis for testing hypotheses about the dynamic developmental interaction of perception and production. Given such a basis, the high individual variability consistently found in small-group production studies can be expected to interact with infants' ability to attend to and remember patterns heard in the fast-changing speech stream. In fact, individual differences are regularly observed in infant speech perception studies, although those differences are not usually emphasized. The present study exploited the natural differences in children's development in a large-scale study of production and perception from late in the first year through 18 months, when most children have made a start on word learning.

Figure 1 illustrates the interrelated system of emergent skills that we see as critical to first word learning. The items highlighted by balloons in the figure are the immediate focus of this study. Figure 1 is consistent with a dynamic systems view (Thelen & Smith, 1994) of language development in which relatively simple skills (like patterned babble) combine to create rapid advances in development. So, for example, consistent vocal practice with one or more supraglottal consonants ('babble'), the recognition of isolated word forms, and the ability to segment familiar words from speech should combine in infants in idiosyncratic ways to lead to first word use.

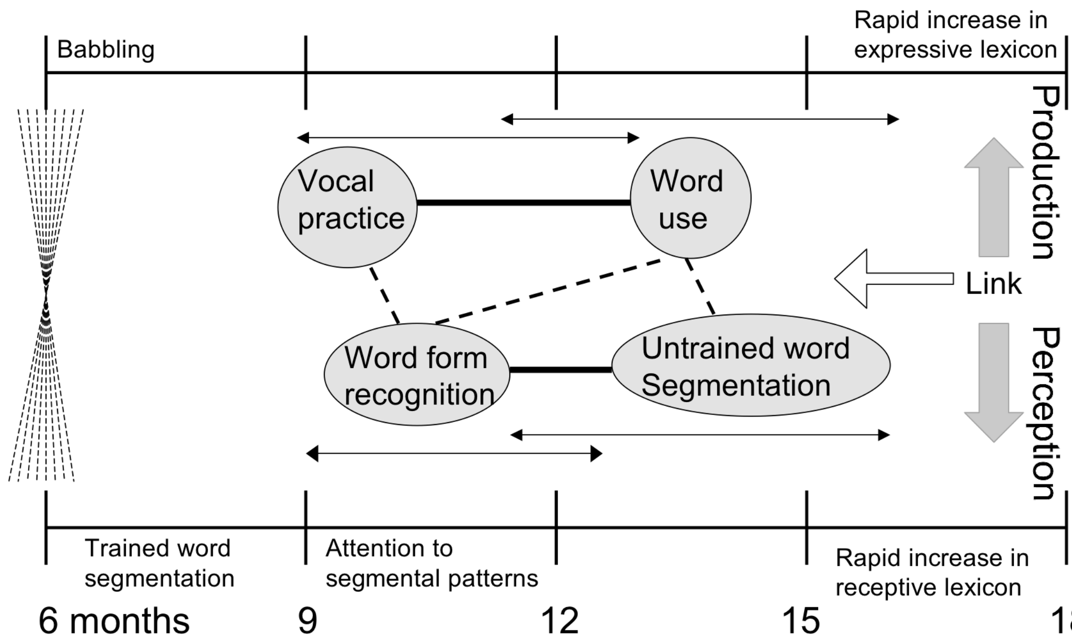

Figure 1. Independent timelines for production and perception. *Double solid arrows* indicate variability along the timeline. *Dotted lines* indicate facilitative rather than obligatory. *Solid lines* indicate a fixed sequence. The *cluster of dotted lines* at the far left indicates that the typical range of variability in production and perception is intimately linked, such that neither should greatly outpace the other.

The onset of *word use* is a generally accepted milestone that critically depends on both perceptual and production capacities (Lindblom, 1992; Davis & MacNeilage, 2000). Word recognition would seem to be a logical prerequisite for word use, while vocal practice has been shown to be an essential basis for word production (McCune & Vihman, 2001; Keren-Portnoy et al., 2005). But what is the relationship between the ability to segment words in the laboratory and later word use? Newman et al. (2006) have shown that the best word learners at 24 months, based on parental report, were successful segmenters in the first year (with training). However, there is also evidence that isolated words are a significant source of children's early words (Ninio, 1993; Brent & Siskind, 2001). The relative timing of the ability to deploy segmentation skills in relation to early word production is thus unknown.

The current study investigated interactions between milestones in perception and production that have been found to be predictive of later language learning; we sought to relate those indicators to age at onset of first word use and early vocabulary size. Our perceptual milestones were *early word form recognition* and *segmentation ability* and the production milestone was *vocal practice*. At the earliest stage, we expected measurable advances in vocal practice to affect familiarity with word forms. We also expected those skills to combine to affect the ability to segment words out of running speech. An alternative hypothesis, that advances in production are unrelated to advances in perception, would predict that only receptive knowledge drives segmentation capacity, with no role for vocal practice. *Word use* was expected to be facilitated by advances in vocal practice as well as in perceptual skills. Given the mixed evidence regarding the importance of segmentation ability for word learning, we also tested the role of segmentation ability as a predictor of first word production.

Objectives

Our overall objective was to develop a model of the interaction of emergent production and perception skills over the period of transition into language. More specifically, our objectives were:

1. *To establish the extent to which vocal production experience (or vocal practice) is relevant to the ability to recognize isolated words and to segment highly familiar words out of running speech, in the absence of specific training or situational priming.*
2. *To establish the relative contribution of receptive word recognition and production practice to word learning.*
3. *To establish the relationship, if any, of children's success in untrained segmentation to first word use.*

We detail below the findings that address each of these objectives.

Methods

Production skills were assessed with weekly audio and video recordings from 9 months until the infant attained two VMS, then monthly to 18 months. We planned to record each infant to 16 months, since the number of words that infants were producing by this age in previous studies (e.g., Vihman & McCune, 1994) was sufficient to establish the factors that contribute to first word use. Early in the study it became clear that the 16-month-old toddlers were producing very few words, so we followed the entire sample for two more months. The recordings were transcribed phonetically and words were identified following our usual procedures (Vihman & McCune, 1994).

Perception skills were assessed using two Head-Turn tasks. The first was a word-form recognition task (WR) administered at 10 months. The stimuli were lists of words produced in isolation, half of which consisted of 12 words likely to be familiar to the infants (Familiar words, based on MacArthur Communicative Developmental Inventory [CDI] data from a previous group of 99 infants being raised in English in North Wales, aged 9-11 months.[1]). The other half were 12 (Rare) words unlikely to be familiar to infants (based on frequency counts of no more than 6 in 1,014,232 in Francis & Kučera, 1982). The Rare words were comparable to the Familiar words in terms of their segments (consonant and vowels) and phonotactics (See Appendix for stimuli). The second task (SEG) involved segmenting a comparable set of Familiar and Rare words from short passages. In this experiment infants were presented with a passage, consisting of six sentences, each containing two Familiar or two Rare words. Each passage contained only

[1] The words used for the Familiar lists were the words reported with the highest frequency (range 12 – 71), provided that they began with a stop consonant and were neither interjections (*uh-oh) n*or babytalk words (*num nums*) nor Welsh.

one type of 'target' words, either Familiar or Rare.. We constructed two lists for each type of stimuli, with half the infants being presented with list A and half with list B, for both Familiar and Rare words. Infants who heard A lists in the WR task received B lists for SEG and vice versa.

The SEG task was administered at 11 months of age, rather than 12 as planned, since results from a similar study (DePaolis, Keren-Portnoy & Vihman, in revision) found that 12-month-old infants succeeded at the task; our goal was to test at an age where there would be high group variability in success and failure.

Procedure of Head-Turn tasks. The stimuli for WR and SEG were recorded using a female speaker with a Northern English dialect. We used a different speaker for the stimuli in each task to avoid any carryover due to familiarity with the speaker. All items were recorded in a sound-treated room (IAC Model 400) using a Sennheiser ME 66 microphone (with K6 power module) connected to a Tascam DA-P1 digital recorder sampling at 44.1 K Hz. The stimuli were transferred digitally onto a PC hard drive for eventual output. Acoustic analysis across the stimuli in each task revealed no difference in amplitude, F0, or duration ($p > 0.05$).

The HT procedure used was similar to that described in Kemler-Nelson et al. (1995). Seated on the caregiver's lap in a quiet darkened sound treated room, the infants faced the central panel of a three-sided test booth where a camera and red light were mounted. A blue light and speaker were mounted on each side panel. A PC and video monitor were located in the adjoining room where the experimenter controlled stimulus presentation and recorded infant looking times by pressing the left and right mouse buttons. The computer initiated and terminated trials in response to signals from the experimenter. In each trial, the infant's gaze was centered by the blinking red light. The experimenter then initiated the computer run trial involving a blinking blue light on the left or right of the infant. When the infant was judged to orient to the blue light, a trial was presented from that speaker. If the infant looked away from the speaker for more than two seconds, the trial was terminated and another begun. Multi-talker babble created from the same speaker of the stimuli used in the experiment was delivered to the headphones worn by the experimenter and caregiver to mask the actual test stimuli. The caregiver also wore foam-insert hearing protection. All stimuli were presented at an average level of 65 dB (Tenma 72-6635 sound level meter).

Each experimental session consisted of a familiarization and test phase. In the familiarization phase the infant was presented with two lists (WR) or passages (SEG) of each of the two test conditions, familiar and rare, counterbalanced for order. The familiarization trials consisted of a randomized presentation of the twelve words (WR) or the six sentences (SEG) of each test passage. This condition was intended to expose the infant to the test procedures since our previous experiments using the HT paradigm have indicated that the initial trials lead to overly long looking times that do not seem to be indexed to the type of stimuli presented.

The test phase of the experiment consisted of 12 trials, six each of the two test conditions. The test trials were pseudo-randomized such that each pair of words (WR) or each sentence (SEG) appeared first in one trial. This ensured that each infant heard each of the 12 familiar and rare words at least once. The order of presentation in the test phase was such that the first four trials were counterbalanced across test conditions. The counterbalancing at the beginning was designed to control for an anticipated decrease in looking times, independent of the stimuli, over the course of the test trials (see Vihman et al., 2004, for an analysis of looking time by trial). The final eight trials were pseudo-randomized such that no more than two identical test trials occurred together. In both phases, the side of presentation was pseudo-randomized such that no more than three successive presentations from one side were allowed.

Production advance measures.
Vocal Motor Schemes (VMS): This is a measure of consistency and productivity of (supraglottal) consonant use. We used two different criteria for identifying a child's VMS: (1) A minimum of ten uses of a given consonant in each of at least three out of four consecutive half-hour sessions (McCune & Vihman (2001) and (2) a total of 50 or more uses of a given consonant in one to three successive recording sessions (DePaolis, 2006). We date the emergence of a VMS to the first of these criterial sessions. Age of attainment of the second VMS is dated to the emergence of the child's second VMS.

First word use was identified following the procedures outlined in Vihman & McCune (1994). No minimum number of uses is required.

Results
Analyses. It is customary to analyze Head Turn (HT) results in terms of group performance, characterizing the entire group as having 'passed' the task (or not), based on a significant difference between the looking times (LT) to A and B stimuli. Longer looking is characterized as expressing either a familiarity or a novelty preference. We tested the infants at an age at which we did not expect the group as a whole to succeed, and we set out to distinguish between those infants who did or did not show significantly greater interest in one type of stimuli. We had anticipated that, at the level of the individual child, success on the task would be expressed by longer LTs to the Familiar over the Rare stimuli, but our results cannot easily be interpreted in this way. On an individual level, any extreme difference in LTs between the two types of stimuli indicates that the two types have been distinguished, so that such a difference must be taken to signify success, whether favoring Familiar or Rare stimuli. To control for differences in individual infants' length of looking we base our analyses not on differences in mean LTs but rather on the proportion of time an infant looked towards Familiar stimuli out of total LT to both Familiar and Rare:

P[reference] ratio = LT (Fam.) / [LT (Fam.) + LT (Rare)].

As can be seen from looking at the P-ratio distributions in the two tasks (Figs. 2 and 3), extreme P-ratios appear on both the very high and the very low ends of the scale. If we treat both ends of the P-ratio as 'success' and the middle as 'failure', then the scale is not ordinal. We therefore transformed this scale into two different variables:

(I) *Distance scores* measure the distance of the P-ratio from the point of no preference (0.5). Using this measure, P-ratios of both 0.8 and 0.2 become 0.3;

(II) *Binary HT scores* treat P-ratios in either the lowest or the highest quartiles as success and those in the two middle quartiles as failure.

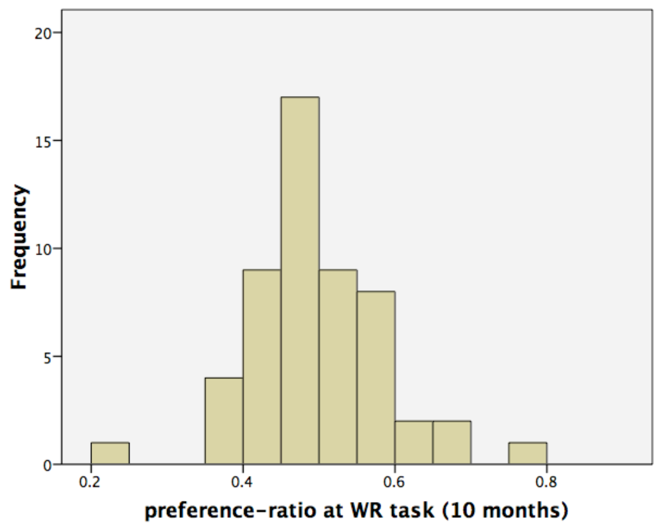

Figure 2. P-ratio for WR task (10 months)

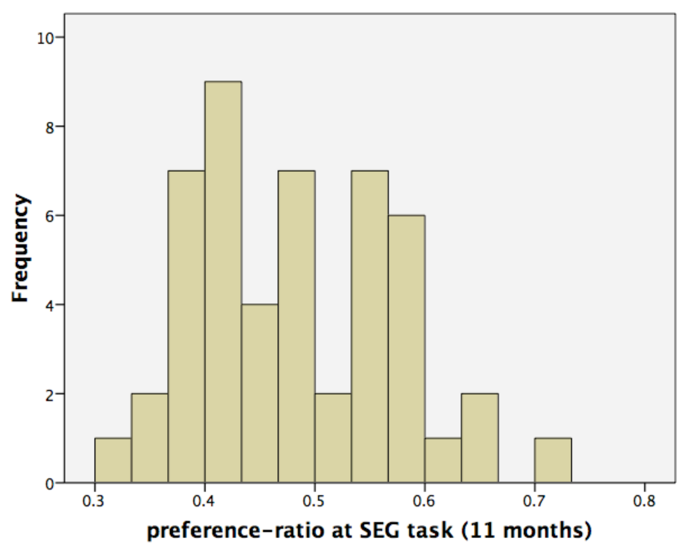

Figure 3. P-ratio for SEG task (11 months)

Though not part of our original plan, we investigated the relationship between (receptive) lexicon size as measured by parental reports on the CDI and performance on the HT tasks. We reasoned that performance on WR should correlate with infant word knowledge, i.e., with lexicon size. This also applies to performance on the segmentation task, although in this task familiarity with words may not be a sufficient condition for success, which additionally depends on the ability to segment those words from fluent speech.

Findings

1. *Lexicon size* (9-mo. CDI) and *performance on WR*: The Distance score on the 10 month WR correlates significantly with lexicon size at age 9 months (r = .377, p= .04, two tailed). Interestingly, this relationship seems to be driven by the infants with the very

low P-ratios who have relatively *large* lexicons (lexicon size correlates *negatively* with the P-ratio on the WR task: r = -.42, p = .02, two tailed). The same lexicon size measure correlates *positively* with the P-ratio measure on the SEG HT at 11 months (r=.425, p=. 03, two tailed), but does not significantly correlate with the distance score on the SEG task. The fact that lexicon size correlates with performance on the HT tasks, but that the infants with the more advanced lexicon have very low preference-ratios in one task and very high ones in the other, gives further credence to our interpretation of both ends of the P-ratio scale as signifying success.

2. *Production advance (VMS) and word recognition*. Two findings are of interest:

a. *Variability.* Figure 4 plots the age at 2 VMS (in days) against P-ratios on WR. The vertical line shows the average age at which the infants were tested on WR, around 10 months. The points to the left of the vertical line are the P-ratios of the infants who had attained two VMS by the day of their HT and those to the right of the line are those of the infants who had not yet attained two VMS by the test date. As can be seen, the P-ratios of the infants whose production is more advanced at time of test are much more widely dispersed than those of are their less advanced counterparts. The difference in variance between the group of infants who had not attained two VMS vs. that of those who had is significant (Levene's Test for Equality of Variances: F = 5.059, p = .029, df = 51). The greater dispersion in the group with the more advanced production stems from their having more extreme P-ratios than the infants who have not yet attained two VMS.

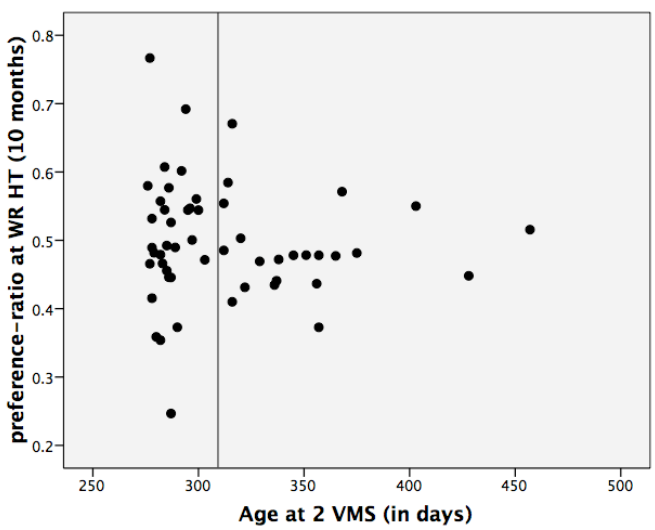

Figure 4. Variability in P-ratios on WR, reflecting differences between infants who had vs. had not attained two VMS by the test date.

b. *Correlation of production and perception.* Here again we took both high and low P-ratios to reflect success at the HT task. The correlation between the Distance HT score and Age at 2 VMS just misses significance (r=-.22, p=.058, one tailed). The correlation is negative, as infants who succeed in the task (with high Distance scores) tend to have attained 2 VMS at a younger age.

3. *WR, Age at 2 VMS and SEG (11 months):* We ran a two way ANOVA, with two independent variables: the Binary WR score and a Binary VMS score – dividing the infants into those who had attained 2 VMS and those who had not at time of WR (10 months). This measure divides the group into early and late attainers of 2 VMS. The dependent variable was the Binary SEG score. The ANOVA is significant, with a main effect for the Binary VMS measure ($F = 5.044$, $p = .03$) and, more importantly, the interaction between the Binary WR score and the Binary VMS score is significant ($F = 4.393$, $p = .04$). The only cell in which a clear majority of infants succeeded in the SEG task is that which contains the group of infants with both 2 VMS at the time of WR *and* success (extreme high or low scores) on WR (Fig. 5).

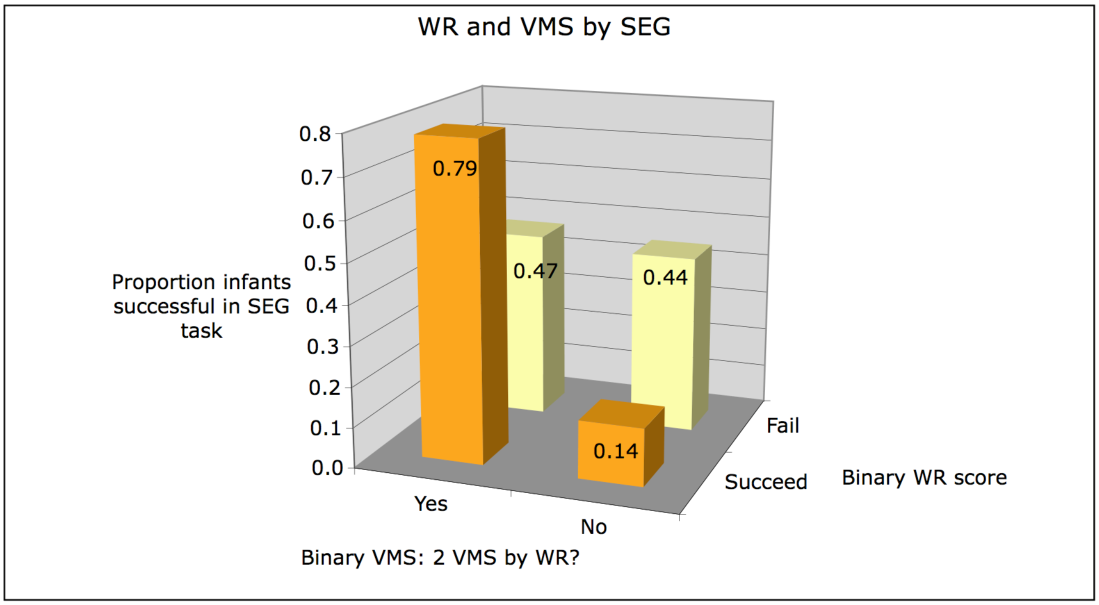

Figure 5. WR and VMS interaction with SEG.

4. *WR, Age at 2 VMS and SEG as predictors of Age at first words:* Only Age at 2 VMS is a strong predictor of Age at first words (regression analysis, n= 49, R^2=.205, β=.453, t=3.701, p=.001). As we have not yet established the final cumulative lexicon counts for all the children, we must wait to determine the relationship between word learning and earlier receptive progress.

Discussion

Finding 1: We expected performance on WR to correlate with lexicon size at 9 months since those infants with a larger lexicon are more likely to recognize words. The fact that this relationship holds for both high and low P-ratios highlights a potentially important unexpected finding in this study. Novelty and familiarity effects not only change over the course of an individual infant's test (Vihman et al., 2004) but are also highly variable, based upon the experience that the infant brings into the experiment.

Finding 2: The significant difference in variability in WR as indexed by production (age at 2 VMS) shows a strong relationship between production and performance on the perception task. Interestingly, the infants who had achieved two VMS by the time of WR showed both novelty and familiarity preferences. If these results are analyzed as a group effect using only average looking times, there is no difference between the two groups of infants, even though the underlying patterns clearly show an interaction between production and perception. The correlation between the WR distance score and Age at 2 VMS nearly reaches significance, suggesting that infants who are early stable consonant producers are those who tend to succeed in the WR task. This again underscores the relationship between production advance and word recognition.

Finding 3: The relationships between WR, SEG and VMS are provocative and will require more analysis. As presented, the results support our original theoretical argument (illustrated in Figure 1) that language development proceeds in a way best described as a dynamic system in which simple skills combine to catalyze change to more complex ones. It is striking that the infants who succeeded on the WR task and had begun to use at least two consonants consistently (VMS) were significantly more successful at the SEG task (Fig. 4). Neither of these skills is a prerequisite for success at SEG, as is evident from the fact that infants who do not vocalize can comprehend language, but the results strongly suggest a support role for vocal practice on both word recognition and segmentation.

Finding 4: Although we have found the expected relationship between VMS and first words, we as yet been unable to find a relationship between WR and SEG and first words. It is clear from the results presented here that the relationships between VMS, WR, SEG, and First Words are complex. In addition, once we have the final cumulative lexicon counts we will use path analysis (AMOS in SPSS) to further explore these variables and determine how much of each correlation is due to direct and indirect effects, and to common and correlated causes.

Activities

DePaolis, R. A.& Keren-Portnoy, T., & Vihman, M. M. (2007). Dynamic Interactions between perception and production. Biennial Meeting of the Society for Research in Child Development (SRCD), Boston. April.

Keren-Portnoy, T., DePaolis, R. A., & Vihman, M. M. (2007). Production practice and lexical learning: A Dynamic Systems account. SRCD, Boston. April.

Vihman, M. M. (2007). Variability in the Emergence of phonological systematicity. SRCD, Boston. April.

Vihman, M. M. & DePaolis, R. A. (2007). The origins of phonological knowledge: A dynamic systems approach. Linguistics Institute of America, 3-week summer course.

DePaolis, R. A., Keren-Portnoy, T., & Vihman, M. M. (2008). The relationship between babble, word recognition, word segmentation, and first words in individual infants. 11th meeting of the International Congress for the Study of Child Language, Edinburgh, July.

Keren-Portnoy, T., DePaolis, R. A., Vihman, M. M., (2008). Speech production and perception: Their interactions and effects on language learning. Psychology Department, Ben Gurion University of the Negev, Israel, December.

DePaolis, R. A. & Keren-Portnoy, T. (2009). The interaction of production and perception skills in infancy and their effects on word learning. 17th Manchester Phonology Meeting, Manchester. May.

DePaolis, R. A., Seal, B., Koegler, H., Hudson, A., & Pustinovich, S. (2009). Evidence for manual support in the acquisition of first words. Multimodality of communication in children: gestures, emotions, language and cognition, Toulouse. July.

Seal, B, DePaolis, R. A., Koegler, H., Hudson, A., & Pustinovich, S. (2009). Early manual and vocal activity in infants. (2009). To be presented at the American Speech-Language-Hearing Association, New Orleans. November.

Keren-Portnoy, T., DePaolis, R. A. & Vihman, M. M. (2009). The interaction of speech production and perception in infancy. To be presented at the American Speech-Language-Hearing Association, New Orleans. November.

DePaolis, R.A., Keren-Portnoy, T., & Vihman, M.M. (submitted, 2010). The influence of babble, word recognition, and segmentation on first word use. International Conference on Infant Studies, Baltimore. April.

DePaolis, R. A., Seal, B., Koegler, H., Hudson, A., & Pustinovich, S. (submitted, 2010). The co-occurrence of manual and vocal activity in pre-linguistic infants. International Conference on Infant Studies, Baltimore. April.

Future Research Priorities

A new line of research being pursued using the large data set from this project concerns the role of manual activity in providing support for first words? The videos collected in this project are being coded for manual activity at both James Madison and Gallaudet Universities, as a collaboration between R. DePaolis and Brenda Seal (Gallaudet University), whose research interests include sign language and cochlear implants (see presentations above).

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Appendix A Word Stimuli for the WR experiment

List A		List B	
Familiar	Rare	Familiar	Rare
baby	pauper	birdie	beadle
biscuit	tendon	bottle	blotter
breakfast	brindle	clever	dapper
careful	geezer	dolly	gully
cuddle	dabble	gentle	tendril
mummy	deacon	granddad	plunder
dinner	Berber	daddy	gecko
dirty	turbo	nappy	netter
dummy	tinny	naughty	doughty
grandma	crofter	teddy	tatty
telly	daman	tickle	kindle
tired	mired	toothbrush	tangram

Appendix B Sentences for the SEG experiment. The target familiar and rare words are in bold.

List A Sentences: Familiar

The **biscuit** was the **breakfast to**day.
Her **mummy** is quite **careful** now.
Some **dummies** are not **dirty** at all.
His **grandma** can be **tired** too.
Your **dinner** had a **telly** then.
A **baby** will have **cuddled** again.

List A Sentences: Rare

The **pauper** was the **geezer** today.
Her **tendon** is quite **mired** now.
Some **deacons** are not **tinny** at all.
His **Berber** can be **brindle** too.
Your **crofter** had a **turbo** then.
A **daman** will have **dabbled** again.

List B Sentences: Familiar

The **dolly** was the **daddy** today.
Her **toothbrush** is quite **gentle** now.
Some **teddies** are not **naughty** at all.
His **granddad** can be **clever** too.
Your **bottle** had a **nappy** then.
A **birdie** will have **tickled** again.

List B Sentences: Rare

The **blotter** was the **beady** today.
Her **gecko** is quite **doughty** now.
Some **tangrams** are not **dapper** at all.
His **tendril** can be **tatty** too.
Your **plunder** had a **gully** then.
A **netter** will have **kindled** again.