

## **Materials for Annex**

### **Appendix to *Dynamic Self-Organization and Early Lexical Development in Children***

#### **Pronunciation errors in children's early speech**

Compared with adult lexical forms, children's early speech involves many omissions, substitutions, additions, and reduplication of certain sounds or syllables. These patterns of pronunciation errors often reflect children's lack of full mastery of articulatory programs at early stages of learning, and the error patterns also show great individual variations (Clark, 2003; Menn & Stoel-Gammon, 1993; Peccei, 1999). Although speech production errors have been extensively investigated in adult psycholinguistics (with or without a connectionist perspective, see Dell, 1986, 1990; Dell, Chang, & Griffin, 1999, for example), few previous connectionist models have examined children's pronunciation errors in early lexical development. One goal of the current study based on the DevLex-II model is to simulate these error patterns and to identify cognitive mechanisms underlying early stages of vocabulary development.

#### **Phonological errors in DevLex-II**

Table 1 presents a list of typical examples from our network's word productions at different training times. These errors parallel children's early word pronunciations, such as omission of consonants at the end of a word (e.g., output for 'bib' at epoch 50), deletion of a consonant from consonant clusters (e.g., output for 'smile' and 'glue' at epoch 60), and substitution of consonants with similar phonemes (e.g., producing /b/

instead of /d/ for ‘bird’). These errors were due to (a) incomplete meaning-to-phoneme links, and (b) incomplete sequence learning of phonemes. Because of the relatively simplified representations in our model, some characteristics of children’s word production are not captured. For example, the model does not encode information on syllabic stress, and thus cannot simulate the omission of unstressed syllables. Still, our model shows clearly how children’s early phonemic errors can arise from incomplete consolidation of word sequences, amplified by limitations in phonemic memory.

An examination of Table 1 also indicates other interesting patterns. For example, in two different simulation trials, responding to the word *sock*, the system gave two different patterns of production error, the deletion of consonant /k/, and the substitution of it with /t/ (see Table 1 for the two cases of *sock*). Given that the simulation trials had the same training parameters, this difference reflects individual variations that are similar to those found both within and across different developmental stages in children (Menn & Stoel-Gammon, 1993; Leonard et al., 1980; Bernhardt & Stemberger, 1994).

Finally, most of the examples in Table 1 also reflect a general developmental shift in phonological pattern formation. At the earliest stages of learning, the network’s productions were highly simplified and often very different from the target pronunciations. During the middle and late stages of learning, with the emergence of self-organized phonemic structure and the developing associative links, correct productions increased gradually. The production errors, though still present, were much closer to the target pronunciations and had typical error patterns as discussed

above. The coexistence of correct and incorrect word pronunciations corresponds to empirical patterns in children's phonological development from babbling to word production (Clark, 2003; Foster-Cohen, 1999; Menn & Stoel-Gammon, 1993; Vihman 1996; Bernhardt & Stemberger (1998). The transition from incorrect sequences, omissions, and substitutions to correct pronunciations indicates that DevLex-II is able to capture developmental patterns in phonological acquisition with simple self-organizing principles.

## References

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*Table 1. Sample production errors from 10 simulation trials\**

Words	Epochs (Training Time)					
	30	40	50	60	80	100
Foot (/fʊt/)	/ʊu:/	/fʊ/	/fʊ/	/fʊ/	/fʊt/	/fʊt/
Dog (/dɔ:g/)	-	/d/	/d/	/dɔ:/	/dgɔ:/	/dɔ:g/
Sock (/sɔ:k/)	/ʃd/	/su:/	/su:/	/sɔ:/	/sɔ:/	/sɔ:/
Bib (/bɪb/)	/ɑ:/	/br/	/br/	/br/	/brɪb/	/brɪb/
Apple (/æpəl/)	-	/æp/	/æp/	/æp/	/æpə/	/æpəl/
Cat (/cæt/)	/a/	/cæ/	/cæ/	/cæ/	/cæt/	/cæt/
Brush (/brʌʃ/)	/n/	/bən/	/bən/	/bəʃ/	/bəʃr/	/brəʃ/
Smile (/smaɪl/)	/pəɪi:/	/ɪma/	/ɪma/	/maɪl/	/maɪl/	/maɪl/
Glue (/glu:/)	/ɪ/	/g/	/g/	/gu:/	/gu:/	/gu:/
Sock (/sɔ:k/)	/a/	/sɔ:t/	/sɔ:t/	/sɔ:t/	/sɔ:t/	/sɔ:t/
Hide (/haɪd/)	/ɪb/	/ɪhb/	/hɑɪb/	/hɑɪb/	/hɑɪb/	/hɑɪb/
Bird (/bɜ:d/)	/ʊ(d;n)/†	/bb/	/bɜ:b/	/bɜ:b/	/bɜ:b/	/bɜ:b/
Bottle (/bɔ:təl/)	/tæ/	/btɑ:əæ/	/btɑ:əæ/	/btɑ:əæ/	/bɑ:təæ/	/bɑ:təæ/
Glasses (/glæsəz/)	/ts/	/æzi:n/	/gæzi:n/	/gæsəz/	/gæsəz/	/glæsəz/

\* IPA (International Phonetic Alphabets) fonts may be required to read the phonetic transcriptions in this table.

- No unique output of the word since the word is confused with other words on the semantic map at the current time.

† Both the phonemes /d/ and /n/ on the phonemic map were the best matching units in response to the semantic representation of 'bird'.