

On the Acquisition of Final Voiced Stops*

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Children recognize many distinctions among the linguistic sounds they hear long before they are able to produce them (e. g., Dodd 1975, Mac-coby & Bee 1965, N. Smith 1973). They may recognize the difference between *dog* and *doll* yet pronounce both [dɒ]. One problem they have to solve is how to deal with this discrepancy. How should they produce the contrasts they perceive when they have not yet mastered the adult techniques for doing so? At first they simply don't try to produce certain contrasts. Their words typically lack final consonants ([dɒ] for *dog*), unstressed syllables ([wei] for *away*), and clusters ([tɪ] for *stick*), as well as many other segments present in the adult versions (see Ferguson & Farwell 1975, Kiparsky & Menn 1977, Macken 1979, Menn 1976, N. Smith 1973). Later, although they may try to produce more of the contrasts they perceive, they often lack the skills necessary to make these match the adult targets. Yet erroneous productions may reveal that they have analyzed certain contrasts even when they don't produce them. The problem children have to solve is how to align what they can produce with what they already perceive.

In this paper, we consider one particular problem and how children solve it: the perception and production of final voiced consonants. Children usually begin by omitting all final consonants, as in [dɔ] for *dog*, [bɪ] for *fish*, etc. Once they start attempting final consonants, they typically master nasals and voiceless stops first and voiced stops later. *Moon* becomes [mun], and *stick* [tik], while *dog* remains [dɔ]. Some children omit all final voiced stops; others replace them with voiceless stops at the same place of articulation, e. g., a final [t] in place of [d], with concomitant lengthening of the vowel, so *mat* [mæt] contrasts with *mad* [mæ:t] (Velten 1943, N. Smith 1973; see also Hooper 1977). These alternatives are summarized in (1):

(1)

Adult targets			Child forms					
			(i)			(ii)		
m	n	ŋ	m	n	ŋ	m	n	ŋ
p	t	k	p	t	k	p	t	k
b	d	g	-	-	-	p	t	k
Other			-	-	-	-	-	-

These strategies show that children have identified the nasals and voiceless stops as being in contrast with each other, and as contrasting with zero, or, perhaps, with voiced final stops. When children substitute /k/ for /g/ in *big*, for example, we have overt evidence that they have correctly identified the appropriate place of articulation. But evidence that they are aware of voicing at this stage is typically indirect: Children first produce voiceless stops appropriately in words like *stick* or *cat* but continue to omit voiced ones in words like *big* or *mad*; then they begin to produce voiceless ones in place of voiced ones as well, e. g., [bɪk], [mæt]. Voiceless substitutes for voiced stops, then, only emerge after appearing, appropriately, in target words with voiceless stops.

In this paper, we document, for two children, an intermediate stage that gives direct evidence that they have analyzed both voicing and place of articulation in final voiced stops. The path these children followed at first was typical. The first final consonants they produced appropriately were the (voiced) nasals [m], [n], and [ŋ] (in words like *boom*, *moon*, and *sing*), followed shortly by the voiceless stops [p], [t], and [k] (in words like *hop*, *bite*, and *stick*). At this point, final voiced stops, as in *bib*, *kid*, or *rug*, were simply omitted. But then, for some months, the three voiced stops in final position ([b], [d], and [g] in adult

targets) were systematically replaced by their homorganic nasals, often with a following voiceless stop at the same place of articulation, [mp] for [b], [nt] for [d], and [ŋk] for [g]. These contrast with target final nasals because of the voiceless release, a voiceless stop at the same point of articulation. We will call this approach, shown in the third row of (2), the "nasal strategy":

(2)

Adult targets			Child forms		
m	n	ŋ	m	n	ŋ
p	t	k	p	t	k
b	d	g	m(p)	n(t)	ŋ(k)

From these data, we will argue that these two children had analyzed final stops at this point in terms of (a) place of articulation, and (b) voicing. They relied on nasal consonants because they had already mastered the production of nasals in both initial and final position, at all three places of articulation - labial, alveolar, and velar. The evidence for such an analysis, we argue, is much more direct with such a nasal strategy than it is with either omissions alone or substitutions of the equivalent voiceless stop for a final voiced stop. Finally, we suggest that reliance on a nasal strategy is closely linked to the articulatory difficulty of producing final voiced stops.

The Data

Our data are drawn from the spontaneous speech of Damon and Eva, recorded in detailed longitudinal notes by the first and second authors respectively. These notes were kept on a daily basis and supplemented by some tape-recordings. Both D and E were acquiring English as their first language.

D's data¹ can be divided into three periods, the first characterized by mastery of final nasals and voiceless stops, the second by use of the nasal strategy, and the third by mastery of final voiced stops. During Period 1, D had mastered his first final consonants, the three nasals, [m], [n], and [ŋ], and went on to master the three voiceless stops, [p], [t], and [k]. Both classes of sounds were produced where they were called for in target words. In targets ending in [b], [d], or [g], however, D omitted the stops altogether. This is summarized in (3):

(3)

Adult targets			D's forms		
m	n	ŋ	m	n	ŋ
p	t	k	p	t	k
b	d	g	-	-	-

D already had a voiced/voiceless contrast in initial position by this time. This period covered about two months, roughly from age 1;6 to 1;8.

During Period 2, D applied the nasal strategy to all target words ending in [b], [d], and [g]. The outcome of this strategy is summarized in (4):

(4)

Adult targets			D's forms		
b	d	g	m(p)	n(t)	ŋ(k)

This period lasted from age 1;8,1 to 1;10,14, the last point at which D was observed using this strategy. During this period, D applied the nasal strategy to 33 word-types whose adult versions contained final voiced stops. The inventory of forms used, the child's age at each observation,² and the point of eventual adult-like production, are listed in Appendix 1. During this period, D was also unobtrusively tape-recorded several times when he was spontaneously producing words that should have ended in [b], [d], or [g] (e. g., in naming pictures in a Richard Scarry book). Target words on these tapes provided a more permanent record against which to check on-the-spot transcriptions. Instances of about 50% of the types observed were checked this way, and showed no discrepancies with the forms noted in the daily observations.

In Period 3, D replaced final nasals with the appropriate voiced stops in all the target words that should have contained [b], [d], or [g]. At this point, D also began to produce final liquids, [l] and [r], and final voiced and voiceless fricatives, [v], [z], and [s]. His inventory of final consonants just before his second birthday is summarized in (5):

(5)

Adult targets			D's forms		
m	n	ŋ	m	n	ŋ
p	t	k	p	t	k
b	d	g	b	d	g
	lr			lr	
v	zs		v	zs	

Our next set of data is drawn from the extensive daily notes made by the second author in her diary record of E.³ These notes were supplemented by annotated summaries of E's vocabulary made every two weeks,⁴ and by occasional tapes. About one sixth of the target words observed in E's speech were recorded. These forms were all in accord with the on-the-spot transcripts. E's data are also divided into three periods. The first, from about 1;3 to 1;6, covers the months when E began to make appropriate use of both final nasals and voiceless stops.⁵ The second covers the period when she applied the nasal strategy to all target words ending in [b], [d], and [g]. This lasted from 1;5,14 to at least 1;10,27, with examples of some forms noted up to age 2;0,5. During Period 2, E applied the nasal strategy to 37 word-types where the adult target contained a final voiced stop. All the pertinent words and the forms observed are listed in Appendix 2. The point of onset of E's third period, when the nasal strategy was replaced by production of the appropriate final voiced stops was not documented since phonetic notations in the diary were virtually discontinued after about 1;10,7.

The corpora of forms from the two children are very similar. They used a similar number of pertinent word-types, and much the same range of tokens. There was also considerable overlap in many of the words produced (compare Appendices 1 and 2).

Damon

Final nasals: By the end of Period 1, D typically produced final nasals wherever adult targets called for them, and in monosyllabic words produced the nasal at the appropriate place of articulation, e.g., [m] in *room*, *vroom*, *cream*, *comb*, and *swim*; [n] in *plane*, *down*, (*ma*)*chine*, *gone*, *raisin*, *spoon*, *mine*, and *all done*; and [ŋ] in *swimming*, *raining*, *crying*, *ring*, and *string*. (Velar [ŋ] became more frequent during this period with *-ing* on verbs.) In two words, though, both long established in his lexicon, D persisted in using consonant harmony, often producing final [m] instead of [n], as in *man*, which alternated between [mæm] and [mæn], and *cushion*, usually [bəbum] (see N. Smith 1973).

From Period 1 onwards, D also produced several words with target nasal + stop clusters in final position. Those in which the nasal was followed by a voiceless stop were labial *jump*; alveolar *ant*, *don't*, *aunt*, and *won't*; and velar *drink*, *bank*, *pink*, and *sink*. The labials fluctuated

throughout Period 2 between [-m] and [-mp]. The alveolars consistently appeared as [-n]. And all the velar clusters appeared appropriately as [-ŋk]. This distribution of voiceless stops following a nasal parallels the use of voiceless releases in D's application of the nasal strategy during Period 2 (see Appendix 1).⁶

Final voiceless stops: During Period 1 (from 1;6,24 to 1;8,7), D also began to use final voiceless stops. These were established gradually at all three places of articulation: [p] appeared in *up* (1;6,24), *sleep* (1;7,2), *top* (1;7,9), and *cup* (1;7,14); [t] was produced first as a glottal stop but during this month appeared as final [t] in *shut* (1;7,0), *carrot* (1;7,2), *float* (1;7,7), *blanket* (1;7,9), *nut* (1;7,14), *put* (1;7,14), *out* (1;7,16), *hit* (1;7,29), and *bite* (1;8,5). Several words continued to be produced with a final glottal stop in place of [t], e.g., *get* (1;7,7), *wet* (1;7,7), *boat* (1;7,9), *eat* (1;7,21), and *cart* (1;7,23), but from 1;8 or so, new monosyllabic words containing a final voiceless alveolar were typically produced with final [t]. Before final [k] emerged as [k], it too appeared as a glottal stop in some words. But final [k] was already established in many words at the start of this period and appeared, for example, in *bike* (1;7,0), *stuck* (1;7,0), *back* (1;7,2), *cork* (1;7,7), *book* (1;7,7), *duck* (1;7,8), *fork* (1;7,21), *broke* (1;7,23), *milk* (1;7,23), *truck* (1;7,28), *snake* (1;8,7), and *stick* (1;8,8).

Omission of final voiced stops: During the same period, D consistently omitted final voiced stops. To give just a few examples, *Herb* was pronounced [hɜ] (1;6,24), *food* [fu:] (1;7,0), *dog* [dɔ] (1;7,1), *bird* [bɜ] (1;7,2), *need* [ni] (1;7,7), *bed* [be] (1;7,8), *leg* [le] (1;7,16), *bib* [bi] (1;7,23), *outside* [awtsai] (1;7,29), *road* [row] (1;8,14), *knob* [nɔ] (1;8,14), and *read* [ri] (1;8,15). At no point during this period did D use either a glottal stop or a voiceless stop in final position in words requiring a voiced stop.

The Nasal Strategy: In D's speech, the nasal strategy appeared to be systematic by place of articulation. At first, he added the velar nasal [ŋ] (normally followed by [k]) only to target words in final [g]. Thus, the first 11 words he applied the nasal strategy to were *rug* [rʌŋk] (1;8,1), *pig* [piŋk] (1;8,1), *bug* [bʌŋk] (1;8,2), *bag* [bʌŋk] (1;8,2), *big* [biŋk] (1;8,4), *ladybug* [leidi bʌŋk] (1;8,5), *frog* (rʷɔŋk] (1;8,7), *dog* [dɔŋk] (1;8,11), *leg* [leŋk] (1;8,12), *flag* [rʷæŋk] (1;8,19), and *plug* [pʷɔŋk] (1;8,19). So in the space of two and a half weeks, he used [ŋ] in a number of established and new words in his vocabulary. Some words that had long been in his vocabulary alternated between their older forms and the new nasal forms.⁷ For instance, *dog* was usually produced as [dɔ], and was only observed twice as [dɔŋk] (1;8,11/1;8,22). Most

words, though, were used consistently with final [ŋ]. New words acquired during this nasal period entered immediately with [ŋk] in place of final [g], as in *flag* [r^wæŋk], *plug* [p^wɔŋk] (both 1;8,19), and *fig* [fɪŋk] (1;9,14).

Once he had amassed a number of words in [ŋ(k)], D began to add nasals to words that ended in labials and alveolars as well. His first were *Bob* [bɒm/bɒmp] (1;8,19), *bib* [bɪm] (1;8,21),⁸ and *scab* [k^oæm] (1;8,21), followed by *rhubarb* [ruba:m] (1;8,23), and *tub* [tʌm] (1;8,26) in the same week. *Knob* followed a week later, [nɒm] (1;9,0), and one well established word, *Herb*, alternated a couple of times in the following month between its usual form, [hɜ], and a nasal form [hɜm] (1;9,23/1;9,28).

The first alveolar [d] forms D replaced by nasals did not appear until three weeks after the onset of the nasal strategy. At first, they were assimilated to the labial class with final [m] rather than [n], e.g., *God* [gɒm], *lid* [jɪm], *sled* [sɛm/sjɛm] (all 1;8,22), *bed* [bɛm], *cupboard* [kægɒm] (both 1;8,23). In the next few days, *lid* shifted to [jɪn] (1;8,25), but the next few final alveolars were still produced with [m] rather than [n]: *Rod* [rɒm], *red* [rɛm] (both 1;8,29), *road* [rowm] (1;9,0), and *read* [rɪm] (1;9,5). A week later, D began to use [n] more consistently on words ending in a final voiced alveolar: *bird* was produced as [bɜn] (1;9,13), and, in the next week, *word* emerged as [wɜn] (1;9,14) and *wood* as [wɒn] (1;9,21). Overall, then, words ending in [d] were among the last to which D applied the nasal strategy.

Finally, D applied the nasal strategy on a very few occasions when he was attempting to produce other final voiced segments. He had begun to produce plural -s on nouns, and on one occasion produced the form *toes* as [town] (1;10,9), with the final voiced allomorph replaced by a nasal at the same point of articulation. *Swimming pool*, originally [wɪmɪŋpu], also appeared during this period with a final nasal, [wɪmɪŋpun] (1;9,23/1;10,7). A couple of months later, the nasal was replaced by the appropriate liquid, [wɪmɪŋpul] (2;0,9), and *roll* was produced as [rown] (1;11,4) but repaired immediately to [rowl]. Final /l/ and /r/ both began to appear from 1;9-1;10 onwards. The appropriate final liquids in *ball*, *door*, *floor*, *doll*, *wheel*, *sore*, *stool*, *hole*, *bowl*, *fall*, *fell*, *towel*, *tickle*, *bottle*, *more*, *water*, *car*, *cereal*, *racquetball*, *roll*, *full*, *table*, *sugar*, and *shower* all emerged between 1;9,15 and 1;11,18.

Replacing nasals with voiced stops: In Period 3, just over two months after the introduction of the nasal strategy, D produced his first final [g], in *dog* (1;10,14). This was followed a few days later, in rapid succession, by [g] in *bug* (1;10,16), *rug* (1;10,17), *big* (1;10,19),

with occasional lapses back to the nasal form,⁹ *ladybug* (1;10,19), *plug* (1;10,19), *bag* (1;10,21), *frog* (1;10,22), and *flag* (1;10,28). From this point on, any residual uses of a final nasal form were promptly repaired to the target voiced stop, [g]. Only one new word, *fig*, entered his vocabulary after this with final [ŋk] instead of [g].

The first [b] in final position appeared at much the same time, in *Herb* (1;10,13), followed six days later by *Bob* (1;10,19). (Both names were frequent in D's speech, and while *Herb* only occasionally appeared with a final nasal, *Bob* had been [bɒmp] for several weeks.) From this point on, D used only final [b] in these two names. In the next week or so, he also used a final [b] with *bib* (1;10,23), *crab* (1;10,25), and *scab* (1;10,28). That is, having got one final [b], the rest of his words with a final [b] quickly followed – just as they had for the velars – over the relatively short space of two weeks.

D's first final [d] appeared during the same period, in a newly acquired word, *cloud*[kawd] (1;10,21). Two days later, he produced *bed* as [bɛd] (1;10,23), and four days after that *bird* as [bɜd] (1;10,27). In the next month, his remaining uses of final [n] for [d] all shifted to [d]: *read* [rid] (1;11,5), *lid* [lid] (1;11,10), *red* repaired from [rɛn] to [rɛd] (1;11,11) with [rɛd] becoming the only form from then on, and *road* [rowd] (1;11,17). From this point on, all new words acquired were produced with the appropriate final [d]. Also, a few words with final [d] to which the nasal strategy had not been applied, e.g., *outside* [awtsai], *bread* [b^wɛ], from now on appeared with final [d]: [awtsaid], [b^wɛd].

Eva

Final nasals: In Period 1, before E's first uses of the nasal strategy, she too used final [m] in words like *come* (1;4,3), *gum* (1;4,15), and *home* (1;4,21); final [n] in *chin* (1;3,2), *moon* (1;3,26), *on* (1;4,3), *skin* (1;4,11), *again* (1;4,18), *done* (1;4,19), and *run* (1;4,28); and final [ŋ] in *ding* (the noise of a windbell) (1;4,9). In many words calling for [n] or [ŋ], though, E produced only [m], e.g., *moon* [muwm] (1;4,2), *man* [mæm] (1;4,4), *down* [dɔm] (1;4,6), *balloon* [byæm] (1;4,9), *swing* [byæm] (1;4,18), and *bang* [bæm] (1;4,27), as a result of consonant harmony (see N. Smith 1973). Over the next two months, however, she made increasing use of the appropriate final nasals.

From the end of Period 1 onwards, E also produced nasal + stop

clusters appropriately in final position: final [-ŋk] in *thank*, *drink*, and *bonk*; [-nt] in *plant*, *don't* and *pants*, and [-mp] in *jump*. As in D's case, the distribution of her voiceless stops after nasals in such final clusters paralleled her uses of a voiceless release in the nasal strategy.¹⁰

Final voiceless stops: During the same period, E began to use final voiceless stops at all three places of articulation. Final [p] now appeared consistently in words like *up* (1;4,18), *cup* (1;4,21), *soap* (1;4,23), *drip* (1;5,1), *wipe* (1;5,6), *tape* (1;5,11) *pop* (1;5,13), and *soup* (1;5,14). Final [t] appeared in such words as *hot* (1;4,13), *got* (1;4,18), *hat* (1;4,19), *coat* (1;4,20), *wet* (1;4,20), and *bite* (1;4,22). And final [k] appeared in *coke* (1;3,18), *clock* (1;3,25), *sock* (1;4,13), *yuck* (1;4,18), *back* (1;4,21), *block* (1;4,24), *book* (1;4,24), *milk* (1;4,27), *cake* (1;5,10), *rock* (1;5,11), *walk* (1;5,14), and *look* (1;5,16).

Omission of final voiced stops: During Period 1, E consistently omitted final voiced stops. For example, *bird* was produced as [bi] (1;3,2/1;4,15/1;4,19), *bread* as [byæ] (1;4,19), *slide* as [dæy] (1;5,1), *seed* as [di] (1;5,6). E did produce final stops on three words with target voiced stops: In one, *cold*, she produced a voiced alveolar stop, [gɔwd] (1;4,23), but it's not clear whether she continued to produce this word in this form. In the second, *bead*, she produced a voiceless final stop, [bi:t], on at least three occasions (1;4,23/1;5,8/1;5,9). In the third, *big*, she also produced a voiceless final stop, [bik] (1;5,14/1;5,15). These appear to have been E's only attempts in Period 1 at a final consonant in words calling for a voiced stop. All others were produced with no final stop at all.

The Nasal Strategy: At 1;5,14, E began using the nasal strategy and, unlike D, applied it from the start to all three places of articulation. She used it first in a word with a final [g], producing *egg* as [æŋk] (1;5,14). She continued to produce *egg* in this form for at least the next five months (to 1;10,27) and possibly longer. In the next two weeks, E produced [ŋ] in *hot-dog* [-dɑŋk] (1;5,16), *frog* [ɔŋ] (1;5,18), and *bag* [bæŋk] (1;5,20). She produced [n] in *seed* [dint] (1;5,15), *bed* [bæn] (1;5,30), and *good* [ɡun] (1;5,30). Both the velar and alveolar nasals were normally followed by a voiceless release, [k] and [t] respectively. E also used [m] in *bib* [bim] (1;5,29). During the next month, she added final nasals to another word with a final [g], *pig* [biŋk] (1;6,4), and to nine more with final [d], *food* [bun] (1;6,5(I)), *bead* [bin] (1;6,0-1;6,14), *mad* [mæ:n] (1;6,18(I)), *did* [din] (1;6,21), *(out)side* [dəyn] (1;6,29), *kids* [ɡins] (1;6,27), *Brad* [bæn] (1;6,28), *dead* [dænt] (1;7,0), and *slide* [dæyn] (1;6,15-1;7,0). E continued to apply the nasal strategy at least until 1;10,27.

E also briefly applied the nasal strategy to an intervocalic [g] as well. *Eggy* took the form [æŋki] (1;4,17). But other diminutives like *doggie*, *buggie*, *froggie*, and *birdie*, all appeared with a medial voiced stop. *Tiger* did appear once with an inserted medial nasal, followed by a voiced stop, [taɪŋgi] (1;7,2), immediately after an adult utterance of the word. And so did *wagon*: [bæŋki] (1;7,16), again in imitation.¹¹ E also produced some medial voiced or flapped targets with medial nasals instead, e.g., *I did* as [andɪn] (1;6,21), *naughty* as [nani] (1;7,4) then [nɒdi] (1;7,8) (also corrected from [nani] to [nɒdi] in imitation of an adult at 1;7,17), *noodle* as [nuni] (1;8,9), *hiding* as [aɪnɪn] (1;10,27), *put it in* as [pʌn in i:n] (1;10,28), and *putting* as [pʌnɪn] (2;0,15).¹²

E's reliance on the nasal strategy appeared to affect other parts of her phonology as well, notably words with medial nasals. *Tummy* appeared as [tɒmpi] (1;5,24(I)), then as [dɒmbi] (1;6,9/1;6,16/1;7,0); *fanny* was produced as [bændi] (1;6,6(I)/1;6,15), then [bænti] (1;7,8), *all cleany* as [aŋgɪndi] (1;6,14(I)), *Jennies* as [dændɪs] (1;6,16(I)/1;7,29), *funny* as [bændi] (1;6,18), *tiny* as [daɪndi] (1;6,27(I)/1;7,1), *dinner* as [dɪndi] (1;6,30(I)), *boney* as [bɒndi] (1;7,0(I)), *panny* as [pænti] (1;7,6), *comby* as [gɒmbi] (1;7,6(I)), *Kimmy* as [gɪmbi] (1;7,6(I)), *tennis* as [tændɪs] (1;7,6), *doughnut* (earlier [dɒwndi] (1;7,5(I)) as [dɒndɪt] (1;7,18(I)/1;7,25/1;8,3/1;8,17), *dummy* as [dɒmbi] (1;7,18), *spinach* as [bɪndi] (1;7,21(I)), and *brownie* as [bɒwndi] (1;8,0(I)). Interestingly, other words like *mommy* or *Nanny* (grandmother) were never produced with an inserted stop after the medial nasal.¹³

According to the summary notes, E was still applying the nasal strategy most of the time at 1;10,7. But there is a slight indication from a month earlier that she was trying to produce final stops, still not fully voiced but in clear contrast to her heavily aspirated final voiceless stops, with *bead* as [bi:t⁰] (1;8,27), *kids* as [gɪts] (1;8,28), and *eggs* as [yæks] (1;8,28). She also produced *big* as [bɪk] (1;9,5), and tried a target nasal+voiced stop combination two days after that, with *hands* as [ænts] (1;9,7) instead of her usual final nasal.

Discussion

These data show two things. First, the two children produced final voiced stops only after they mastered final nasals and voiceless stops. Second, they mastered final voiced stops only after applying the nasal strategy to them. Why should final voiced stops be difficult for children to produce? And why did these children rely on a nasal strategy?

In producing a final voiced stop, the speaker must maintain voicing during closure. To do this requires enough subglottal air pressure to keep up the voicing until the stop closure is released (Slis 1970, Smith & Westbury 1975). In a study of adults, final voiced stops were partly devoiced as often as 50% of the time. That is, voicing lasted only for the first two-thirds of the stop duration (B. Smith 1979). Children in the same study partially devoiced their final stops 98% of the time, maintaining voicing for only the first third of the stop duration, that is, for only half the interval, proportionately, that adults did. Since both the two- and four-year-olds studied were producing target voiced stops, Smith's findings suggest that the difficulty younger children experience stems from their inability to maintain voicing in final stops.

Children resolve this difficulty in different ways: They may wait until they can maintain some degree of voicing before adding in the appropriate voiced stops. Alternatively, they may try to produce voiced stops but fail. These failures have been interpreted in one of two ways. Some observers have suggested that children were simply substituting a voiceless stop for the voiced one. Others have postulated a phonological process of devoicing that is applied to all stops in final position.¹⁴ Yet another alternative is that children may contrast voiced with voiceless final stops by producing longer vowels before what should be voiced stops (Velten 1943, Hooper 1977).¹⁵

Our study documents yet another solution children apply when they cannot yet maintain sufficient subglottal pressure to produce and prolong voicing in final stops. Both Damon and Eva produced the nasals homorganic with the target voiced stops, often with a devoiced nasal release (as in *pig* said as [pɪŋk]). Both children already contrasted different points of articulation for final voiceless stops (e.g., *cup*, *out*, *book*) and could also produce two or more different nasals in final position (e.g., *swim*, *plane*, *ring*). Since nasals are produced with closure at the point of articulation with simultaneous voicing, the nasal strategy allowed the children to mark both place of articulation and voicing at the point where their adult targets required final voiced stops. Both Damon and Eva relied on this strategy for several months. The open velum allowed free passage of air from the lungs, so they could maintain the voicing needed for the contrast with final voiceless stops (as in *bag* versus *back*: [bæŋk], [bæk]). At the same time, the non-nasal, voiceless release marked such forms as being in contrast with target nasals in words like *boom*, *man*, or *ring*.

These two children are not unique in adopting a nasal strategy. A child called Lasan, described by Fey and Gandour (1982), produced

all his final voiced stops from 1;9 to 2;1 with a nasal release. That is, when he produced words ending in a voiced stop, he consistently followed the stop with a homorganic nasal. He produced *light bulb* as [ʃajt^hbabɪm], *bead* as [bidɪŋ], and *big* as [bɪŋ]. He treated new (nonsense) words introduced during this period like other words ending in voiced stops: each final voiced stop was consistently followed by a nasal. Fey and Gandour argued that Lasan's motivation here was to establish a contrast between final voiceless and voiced stops. We suggest further that Lasan adopted his strategy for the same reason that Damon and Eva adopted theirs. Both strategies allowed the children to voice their final stops.¹⁶ In applying their nasal strategies, all three children made use of resources already mastered. And they made use of them to mark surface contrasts before they could produce the target segments appropriately (see also Ingram 1975). That is, they used old means to solve a new problem.

The consistent maintenance of both voicing and place of articulation in D's and E's nasal strategy is strong evidence that they had analyzed the contrasts between voiced and voiceless stops at different points of articulation before they could produce them. This differentiation of voiced and voiceless stops is further backed by the children's contrasts between target final nasals and voiced stops: the latter were often followed by a non-nasal, voiceless release; the former never were. In comprehension, these children had clearly perceived and identified the dimensions of the contrasts in question. In production, they relied on their nasal strategy to make the necessary contrasts, as shown in (6):

(6)

Adult system			Child system		
m	n	ŋ	m	n	ŋ
p	t	k	p	t	k
b	d	g	m(b)	n(t)	ŋ(k)

If the analysis of the nasal strategy we have offered is correct, we have evidence that children unable to produce final voiced stops have nevertheless analyzed and represented them appropriately. The appropriateness of the representation is further supported by the rapid replacement, during Period 3, of D's nasal + stop combinations by the appropriate voiced stops: final [m(p)] went to [b], [n(t)] to [d], and [ŋ(k)] to [g] within two to three weeks. Children, then, perceive dimensions of contrasts they cannot yet produce. And they are ingenious at finding

strategies to realize such forms in production when they are still unable to produce them.

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Footnotes

- 1 Damon, son of the first author, is an only child growing up in northern California. His exposure to English at this point was from his father who spoke a standard mountain-west US English, and his mother who spoke British English (RP, slightly modified by eleven years in the US). During the months under study, D produced an increasing number of word combinations (with an upper range of six to eight words), and his first grammatical morphemes, *-ing*, plural *-s*, and occasional irregular and regular past tense forms.
- 2 Ages are given in years, months, and days.
- 3 Eva is the younger of the second author's two children. Her main exposure to English had been from her parents who both spoke a standard central US English, and a caretaker who spoke a midwest (Kansas) variety of US English. During the period under study, E at first produced mainly one word at a time, but within a couple of months produced an increasing number of two-word combinations and her first grammatical morphemes, plural *-s* and *-ing* (around 1;9). By 1;8 to 1;9, her utterances had increased in length, for an upper bound of about six words.
- 4 The summaries occasionally contained forms not noted separately in the daily records. Examples cited only in the summaries are listed in Appendix 2 with the appropriate double dates, e.g., 1;6,0-1;6,14.
- 5 Unlike D, E had no voiced/voiceless contrast in initial or medial position at this stage: All her stops appeared to be voiced. For E, then, the first site of such a contrast was final position.
- 6 D also produced several words with a target voiced stop following the nasal during this period: *hand*, *ground*, *land*, *rubberband*, *around*, and *find*, all

- with final [-n]. Final [-nd] only emerged at 1;11,11 with the acquisition of *sand*.
- 7 This was probably because well established words may become frozen in a form that reflects earlier phonological organization (see Ferguson & Farwell 1975, Macken 1979).
 - 8 Up to this point, *bib* had always been [bɪ], except for one occasion when D (1;7,24) fluctuated all day between three different forms: [bɪ], [bib], and [bɛβ]. The next day he was back at [bɪ], and appeared to rely on that form exclusively until he began to apply the nasal strategy.
 - 9 The fact that such lapses were always promptly repaired to a form with the target final voiced stop suggests that D was monitoring to make sure the final segments matched the target representations he had stored in memory (see further Clark 1982). Earlier, he had repaired a rare final voiceless stop to a nasal, e. g., [r^wɔk] to [r^wɔŋk] (1;8,8).
 - 10 E also used several words with target final [-nd] cluster during Periods 1 and 2: *hand* (1;4,4 on), *band* (1;4,5 on), *sand* (1;5,14/1;6,3), *stand* (1;6,3/1;7,20), *find* (1;7,5/1;7,6/1;7,12/1;8,4), and *kind* (1;8,3). All were consistently produced with final [n], except for one instance of *hand* as [ænt] (1;4,22), after which it reverted to [æŋ], and *band* which appeared as [bæm] (1;4,5/1;4,18), with consonant harmony. The consistent uses of final [-n] in these words parallels D's data for similar words.
 - 11 A comparable instance in D's corpus occurred at 1;11,28, when D had virtually abandoned the nasal strategy. Following an adult utterance containing the word *muddy*, D attempted it twice as [mʌni], and then a minute or two later, with no intervening adult utterance, produced [mʌndi]. All D's other intervocalic voiced stops were consistently produced as voiced stops throughout the nasal strategy period.
 - 12 Rather less explicably, E also occasionally inserted a nasal before a few target voiceless stops. E neutralized the voiced/voiceless contrast in medial position: all these stops were voiced for her. For example, she produced *broken* as both [bɔŋɡɪn] and [bɔɡɪn] (1;5,28), *open* as [ɔwmbɪn] and [ɔwbin] (1;7,2), *paper* as [bæmbɪ] (1;7,5), *I can't* as [aŋɡænt] (1;7,8), and *chicken* as [dɪŋɡɪ] (1;7,29).
 - 13 As Lass (1984) pointed out, it is common in everyday speech for a nonfinal nasal to be followed by a stop with the voicing value of the next segment, e. g., *something* pronounced as [sʌmpθɪŋ]. This kind of consonant epenthesis also occurs in language change, e. g., OE *þunor* > *thunder* (Lass, 1980).
 - 14 However, such a characterization seems misleading if the voiceless stop children produce under these circumstances is the outcome of articulatory difficulty. See also Macken and Barton (1980).
 - 15 This strategy should go hand in hand with the use of apparently voiceless stops for voiced targets. Whether it actually does is not well documented.
 - 16 For some solutions to difficulties in voicing initial stops, see Macken and Barton (1980), and Allen (1985).

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Appendix 1: Data from Damon (1;8,1–1;10,14)

Words are listed in order of production, with subsequent tokens and their forms noted according to the age at which they were observed. (All forms are listed with their original transcription from the diary record.) The emergence of adult-like production is marked with an asterisk (*) following the age (once stable, no subsequent instances are listed). Forms produced immediately after an adult production of the target word are marked by I (imitation). A capital R marks a spontaneous repair.

- rug [rʌŋk] 1;8,1(I)/1;8,8/1;9,14/[rʌg] 1;10,17*/
 pig [pɪŋk] 1;8,1/1;8,8/
 bug [bʌŋk] 1;8,2/[bʌg] 1;10,16*
 ladybug [leɪdɪbʌŋk] 1;8,5/[beɪbɪbʌŋk] 1;8,12/1;10,16/[beɪbɪbʌg] 1;10,19*/
 1;10,23*/
 bag [bʌŋk] 1;8,2(I)/[bæŋk] 1;8,9/1;8,27/1;9,1/1;9,29/[bæg] 1;10,21*/
 1;11,15*/
 big (earlier [bɪ]) [bɪŋk] 1;8,4/1;9,14/1;9,21/[bɪg] 1;10,19*/1;10,28*/
 [bɪŋk-R-bɪg] 1;10,22*/[bɪg] 1;10,28*/1;11,4*/
 [bɪŋk-R-bɪg] 1;11,11*/[bɪg] 1;11,16*/1;11,18*/
 big stick [bɪŋ tʰɪk] 1;8,16(I)/big ball [bɪŋk bɔl] 1;9,25/
 big car [bɪŋk kɑ] 1;9,29/big door [bɪg dɔ] 1;10,20*/
 frog (earlier [rʷɔ]) [rʷɔŋk] 1;8,7/[rʷɔk-R-rʷɔŋk] 1;8,8/ [rʷɔŋk/rʷɔŋ] 1;8,26/
 [rʷɔg] 1;10,19*/1;10,22*/
 dog (earlier and usually [dɔ]) [dɔŋk] 1;8,11/1;8,22/[dɔg] 1;10,14*/
 leg (earlier [lɛ]) [lɛŋk] 1;8,12/[lɛg] 1;11,17*/
 flag [rʷæŋk] 1;8,19/[rʷæŋ] 1;9,14/[rʷæg] 1;10,28*/
 plug [pʷɔŋk] 1;8,19/1;8,26(I)/1;9,2/1;9,16/[pʷɔg-R-pʷɔg] 1;10,19*/
 Bob (earlier [bɔ]) [bɔm/bɔmp] 1;8,19/[bɔb] 1;10,19*/1;10,21*/
 bib (earlier [bɪ], [bɪ/bɪb/beβ] 1;7,24) [bɪm] 1;8,21/1;8,22/1;9,21/1;10,16/[bɪb]
 1;10,23*/1;10,24*/
 scab [kʰæm] 1;8,21/1;8,25/[kʰæmp] 1;9,14/[kʰæm/kʰæb] 1;10,28*/[skæb]
 2;0,9*/
 God [gɔm] 1;8,22(I)/
 lid (earlier [jɪ]) [jɪm] 1;8,22/[jɪn] 1;8,25/1;9,14/[lɪd] 1;11,8*/
 crab [kʰæm] 1;8,22/1;8,25/[kʰæb] 1;9,5*/[kʰæmp-R-kʰæb] 1;9,5*/[kʰæb]
 1;10,25*/[kʰæm/kʰæb] 1;10,28*/
 sled [sʲɛm/sem] 1;8,22/
 bed (earlier [bɛ]) [bɛm] 1;8,23/[bed] 1;10,23*/1;11,10*/
 rhubarb [rubɑ:m] 1;8,23/1;9,28/
 cupboard [kæɡɔm] 1;8,26/
 tub [tʌm] 1;8,26/
 Rod [rɔm] 1;8,29/
 red (earlier [rɛ]) [rɛm/rɛn] 1;8,29/1;10,12/[rɛn/rɛd] 1;11,11*/[rɛd] 1;11,23*/
 road (earlier [rɔw]) [rɔwm] 1;9,0/[rowd] 1;11,17*/
 knob (earlier [nɔ]) [nɔm] 1;9,0/
 read (earlier [rɪ]; once [rɪd] (I)) [rɪm] 1;9,5/[rɪ] 1;10,9/[rɪd] 1;11,5*/

bird (earlier [bʌ] [bʌn] 1;9,13/[bʌd] 1;10,27*/
 fig [fɪŋk] 1;9,14(I)/
 word [wʌn] 1;9,14/1;9,28(I)/
 wood [wʊn] 1;9,21/
 ride (earlier [wai] [waid] 1;9,21*/
 Herb (earlier [hʌ] always major form) [hʌm] 1;9,23 (very emphatic)/1;9,25/
 1;9,28/[hʌb] 1;10,13*/1;10,14*/
 head (earlier [hɛ] [hɛn] 1;10,15/[hɛd] 1;11,6*/
 showerhead [ʃawəhed] 1;11,16*/
 cloud (new word) [kawd] 1;10,21*/
 outside (earlier [awtsai] [awtsaid] 1;11,4*/1;11,5*/
 bread (earlier [bʷɛ] [bʷɛd] 1;11,13*/
 shutted [ʃʌtid] 1;11,13*/
 sad [sæd] 1;11,16*/

Appendix 2: Data from Eva (1;5,14–1;10,7, with occasional forms to 2;0,5)

As in Appendix 1, the words produced are listed in order, by age, together with subsequent observations noted from daily records or from summaries made every two weeks, in their original transcriptions. Nasalized forms produced immediately after an adult utterance of the same word are marked by I (imitation). Although few nasalized forms are noted after 1;10,7, the summaries suggest they persisted in some words at least to age 2;0.

egg [æŋk] 1;5,14/1;6,0–1;6,14/1;6,15–1;7,0/1;7,0–1;7,14/1;7,15–1;8,0/[æŋ]
 1;8,28/1;10,7/
 eggs [æŋks] 1;6,12/1;6,13/[yæks-R-æŋ] 1;8,28/
 seed (earlier [di] 1;5,6) [dint] 1;5,15/[din] 1;6,9/1;6,15–1;7,0/1;7,0–1;7,14/
 1;7,15–1;8,0/
 dog (earlier [dæ/da] [daŋ] 1;8,1/1;8,4/
 hot-dog [-daŋk] 1;5,16/1;5,20/[-dæŋ] 1;6,28/
 hot-dogs [daŋs] 1;6,28/
 frog [ɔŋ] 1;5,18 (I)/[baŋ] 1;6,4(I)/[baŋk] 1;6,0–1;6,14/1;6,17/1;7,0–1;7,15/
 1;7,15–1;8,0/[raŋ] 2;0,5/
 frogs [baŋks] 1;6,11/1;6,13/1;7,0–1;7,14/
 bag (earlier [bæy] 1;5,23) [bæŋk] 1;5,20/[bæk-R-bæŋ] 1;6,4(I)/[bæŋk/bæŋ]
 1;6,15–1;7,0/[bæŋ] 1;7,11(I)/
 bean bag [binbæn] 1;6,15–1;7,0/[binbæŋk] 1;7,0–1;7,14/
 bib (earlier [baba] 1;4,27/[biba] 1;5,8) [bim] 1;5,29(I)/[bimp] 1;6,10/[bim]
 1;6,18/1;6,19/[bimp] 1;7,4/1;7,21/
 bibs [bimps] 1;6,19(I)/1;6,19/1;10,7/
 bed (earlier [bæ] [bæn] 1;5,30/1;6,4/
 good [gʊn] 1;5,30(I)/1;6,0–1;6,14/1;6,10/1;7,0–1;7,14/[gʊnt] 1;7,23(I)/[gʊn]
 1;10,7/

- bead (earlier [bi], [bit]) 1;4,23/1;5,8/1;5,9) [bin] 1;6,0-1;6,14/1;6,15-1;7,0/
 1;7,0-1;7,14/[bi:n] 1;8,27/[bit] 1;8,27/[bin] 1;10,7/
 beads [bins] 1;6,11/1;6,19/1;8,16/1;8,27/1;8,28/
 pig [biŋk] 1;6,4(I)/[bin] 1;8,25/
 food [bun] 1;6,5(I)/[ʃun] 1;10,7/
 slide (earlier [dæy] 1;5,1/1;6,0-1;6,15) [dayn] 1;6,15-1;7,0/[daynts] 1;7,0/
 [dæyn] 1;8,4/
 mad [mæ:n] 1;6,18(I)/
 did [din] 1;6,21(I)/[dint] 1;7,8(I)/[din] 1;10,22/[dint] 1;10,27/
 kids [gins] 1;6,27/1;7,0-1;7,15/1;7,15-1;8,0/[gits] 1;8,28/
 Brad [bæ:n] 1;6,28/1;7,29/1;8,27/
 outside [dayn] 1;6,29/1;7,17/[awtdayn] 1;8,27/[awtsayn] 1;10,27/
 dead [dænt] 1;7,0(I)/
 big ([bik] 1;5,14/1;5,15) [biŋk] 1;7,2(I)/[biŋ] 1;7,5/[biŋk] 1;7,9/[bin] 1;7,12/
 [bin/biŋk] 1;7,29(I)/[biŋ] 1;8,0/[biŋk] 1;8,17/[bik] 1;9,5/
 Big Bird [bin bun] 1;8,7/[bin bun] 1;8,17/[bin bun] 1;8,28/
 big horsie [biŋ owsi] 1;8,16/big bear [biŋ be] 1;8,17/
 washrag [abæ:n] 1;7,6(I)/
 leg [læŋ] 1;7,6(I)/
 legs [æŋks] 1;8,18(I)/1;8,19/1;10,17/
 bread (earlier [byæ] 1;4,19) [bæ:n] 1;7,6(I)/1;7,8/1;7,15-1;8,0/
 ride [wayn] 1;7,15/1;7,23/1;8,1/1;8,16/1;8,23/
 Bob [bæmp] 1;7,16/
 hide [ayn] 1;7,18(I)/1;8,19/
 read [min] 1;7,18/[win] 1;8,18/1;8,28/1;9,15/
 hard [ayn] 1;7,23(I)/1;7,24/
 need [nin] 1;8,1/[nint] 1;10,7/
 hold [own] 1;8,4/1;8,7/[ayn] 1;8,21(I)/
 bird (earlier [bi] 1;3,2/1;4,15/1;4,19) (Big) Bird [bun] 1;8,7/1;8,17/1;8,28/
 Hoag (name [hoig]) [oiŋk] 1;9,27(I)/
 head [æ:n] 1;10,6/
 bad [bæ:n] 1;10,7/
 crib [kimp] 1;10,7/
 hood [u:n] 1;10,7/
 red [rænt] 1;10,22(I)/
 Richard [witsun] 1;10,26/