Acquisition of Nasal Place Assimilation by 4.5-month-old Infants

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Infants 4.5 months of age are hypothesized to be in the "initial state" for acquisition, which in Optimality Theory means their grammars rank all markedness constraints above any faithfulness constraints. We investigated their sensitivity to nasal place assimilation as a means of comparing two versions of OT: the standard version of Alan Prince and Paul Smolensky, and the "Targeted OT" of Colin Wilson.

Nasal place assimilation is a cross-linguistically common process in which nasal stops take on the place of articulation of a following obstruent consonant: *i**mp**ossible, i**nt**angible, i**ŋk**congruous.*

Adult English speakers do not have nasal place assimilation in most morphological contexts, while speakers of many other languages do—e.g., Japanese, Latin, Polish, Zoque, Luganda, Swahili. Since adult languages with nasal place assimilation have a proper subset of the consonant clusters found in adult languages without nasal place assimilation, the language learner must start with the hypothesis that the input language has nasal place assimilation (lacks different-place NC clusters), so that positive data (the existence of different-place NC clusters in the input language) can cause him or her to reject that hypothesis. Starting with the opposite assumption would make nasal place assimilation unlearnable, since no positive evidence would ever contradict the hypothesis that there is no nasal place assimilation—a typical subset problem.

The analysis of nasal place assimilation in standard phonological Optimality Theory (Prince & Smolensky, 1993; McCarthy & Prince, 1995) is that a markedness constraint against different-place NC clusters, AGREE (PLACE), dominates a faithfulness constraint against altering place of articulation, IDENT (PLACE). The initial assumption of nasal place assimilation is expressed as an initial state in which AGREE (PLACE) dominates IDENT (PLACE).

A competing analysis is offered by the theory of "targeted" constraints (Wilson, 2000): Nasal Place Assimilation happens in order to satisfy a markedness constraint that *only compares candidates that are sufficiently close with respect to a particular perceptual-similarity relation.*

The crucial difference between these two accounts, for our purposes, is this: In the initial state, with all markedness constraints ranked above all faithfulness constraints, Regular OT says that *any* change to the concatenation /am+di/ that gets rid of the different-place cluster is a good repair (improves harmony), while the targeted-constraint theory says that only Nasal Place Assimilation is.

To test these two competing accounts, we made use of the Headturn Preference Procedure (Kemler Nelson et al., 1995) under the auxiliary hypothesis that there would be a familiarity preference: When given a choice, infants prefer to listen to speech that is more like the language they are acquiring. We interpret this as meaning that they prefer speech that matches their internal model of that language, i.e, the grammar they have acquired so far. This assumption allows us to probe the state of a child's grammar by giving them a choice between two different kinds of stimuli, "A" (which has a particular property) and "B" (which lacks it). A preference for "B" can be interpreted as evidence that the property is ungrammatical for that child.

We used a paradigm developed by Jusczyk, Smolensky, and Alloco (2002). Stimuli simulated inter-word Nasal Place Assimilation:

(1) Stimulus schema

X ... Y ... X'Y'

am ... da ... anda (for example)

That is, the X and Y are to be interpreted as faithfully realized individual words, and the X'Y' as their concatenation; in this example, with nasal place assimilation. Stimuli like these could be presented in the same experimental session with stimuli like *am ... da ... amda*, with no nasal place assimilation, and infants' listening preferences for the two kinds of stimulus could be compared.

Jusczyk et al. (2002) found that infants—whether in the inital state at 4.5 months, or after considerable learning at 10 months—preferred the assimilated clusters over faithful realizations, at least when the only faithfulness violation is the change of place in the nasal. That is,

(2) Findings of Juszyk et al. (2002) for 4.5 month-olds

	/X/	/Y/	[X'Y']	Jusczyk et al. 2001		
1.	am N_2	bi C_2	ambi N_2C_2	+		Doesn't need assimilation.
2.	an N_1	bi C_2	anbi N_1C_2	–	–	Needs assimilation, but is not assimilated.
3.	an N_1	bi C_2	ambi N_2C_2		+	Needs assimilation; nasal assimilates to obstruent
4.	an N_1	bi C_2	andi N_1C_1			Needs assimilation; obstruent assimilates to nasal.

Note: "+" stimuli were preferred over "–" stimuli.

Experiment 1. What if instead the violation were repaired by changing place the place of the obstruent? Standard OT predicts that this will improve harmony compared to the fully faithful candidate; the theory of targeted constraints predicts it will do the opposite. Using the same experimental paradigm and subject population as Jusczyk et al. (2002), we presented 4.5 month-olds with a choice between stimuli of the form *an...bi...anbi* (no assimilation) and *an...bi...andi* (assimilation of the obstruent to the nasal). 49 English-learning infants participated. 17 were excluded—11 fussed out, 4 did not look to sides, 1 was interrupted by noise from construction work, and 1 heard French at home—leaving *N*=32 valid listeners 18 female, 14 male, ranging in age from 122 days to 156 days, with a mean age of 139 days.. Mean listening time for the no-assimilation stimuli was 13.6s, while that for the obstruent-assimilated stimuli was 14.0s. The mean difference for each subject was 0.37s in favor of the unassimilated stimuli, which was not

significantly different from 0 by a 2-sided *t* test (s.d. = 4.26s, $p > 0.40$). Surprisingly, it appeared that the infants in this experiment did not distinguish between the unassimilated stimuli (normal in many languages, including English) and the obstruent-assimilated ones (which never occur in any language). This result did not support either the standard OT hypothesis or the targeted-constraint hypothesis.

(3) Accumulated findings

	/X/	/Y/	[X'Y']	Jusczyk et al. 2001		Exp 1
1.	am	bi	ambi	+		
	N_2	C_2	N_2C_2			
2.	an	bi	anbi	–	–	=
	N_1	C_2	N_1C_2			
3.	an	bi	ambi		+	
	N_1	C_2	N_2C_2			
4.	an	bi	andi			=
	N_1	C_2	N_1C_1			

Note: "+" stimuli were preferred over "–" stimuli.

These results could have come about through antagonism between AGREE (PLACE) and IDENT (PLACE). Since each of the stimulus types in this experiment (Types 2 and 4 in the tables above) violated one constraint or the other, it could be that listener preferences were affected equally by both. If so, this would then raise the question of why the listeners of Jusczyk et al. (2001) preferred Type 3 stimuli (violating IDENT (PLACE) but satisfying AGREE (PLACE)) over Type 2 stimuli (which did the reverse). An obvious hypothesis was that they could hear the place difference in the obstruent syllable onsets of this experiment, but not in the nasal syllable codas of Jusczyk et al. (2001).

Experiment 2 was conducted to test this. Listeners were presented with a choice between assimilated and unassimilated stimuli which both satisfied AGREE (PLACE): *an...bi...ambi*, Type 3, versus *am..bi...ambi*, Type 1. Stimuli were recorded by the same speaker as in Experiment 1. 33 listeners participated. 9 were excluded: 5 fussed out, 2 would not look, 1 was lost to experimenter error, and 1 produced extreme outlying data. This left *N*=24 for analysis, 9 female, 15 male, ranging in age from 128 to 177 days, with a mean age of 142 days. Mean listening time for the Type 3 stimuli was 16.7s; that for the Type 1 stimuli was 14.6s. The average of each subject's difference was 2.1s in favor of the Type 3 stimuli, significantly different from 0 by a 2-sided *t* test (s.d. = 4.56s, $p < 0.05$). This confirmed that 4.5-month-olds are indeed able to detect a violation of IDENT (PLACE) caused by a change in coda nasal place, as hypothesized by Jusczyk et al. (2002). However, it raised the troubling question of why listeners should *favor* stimuli which violate a constraint over those which violate no constraint, when both are consistent with their grammar.

(4) Accumulated findings

	/X/	/Y/	[X'Y']	Jusczyk et al. 2001		Exp 1	Exp 2
1.	am N_2	bi C_2	ambi N_2C_2	+			+
2.	an N_1	bi C_2	anbi N_1C_2	–	–	=	
3.	an N_1	bi C_2	ambi N_2C_2		+		–
4.	an N_1	bi C_2	andi N_1C_1			=	

Note: "+" stimuli were preferred over "–" stimuli.

A possible explanation for the findings of Experiments 1 and 2 was that we had the wrong linking hypothesis: Rather than preferring stimuli consistent with their current grammar over stimuli inconsistent with it, infants prefer stimuli which are consistent with their current grammar over stimuli which are consistent with an alternative grammar. The lack of preference for Type 4 over Type 2 stimuli in Experiment 1 would then result from the impossibilty of *any* grammar in which Type 4 outputs would be optimal (no adult language has that pattern). The preference for Type 3 over Type 1 stimuli in Experiment 2 would come about because the Type 3 stimuli are consistent with the grammar AGREE (PLACE)»IDENT (PLACE) and inconsistent with the opposite ranking, while the Type 1 stimuli are consistent with both.

Experiment 3 was designed to falsify this. Listeners were presented with a choice between stimuli which undergo nasal place assimilation (Type 3, *an...bi...ambi*) and stimuli which undergo obstruent place assimilation (Type 4, the impossible *an...bi...andi*). If listeners did in fact prefer grammatical over ungrammatical stimuli, they should listen longer to the Type 3s. Materials were recorded by the same speaker as in Experiments 1 and 2, and the same procedure was followed as in those experiments. 33 infants participated. 7 fussed out, 1 was dropped due to experimenter error, and 1 was dropped due to parental interference, leaving N=24 valid participants, 18 female, 6 male, ranging in age from 117 days to 153 days, with a mean age of 139 days. Mean listening time for the Type 3 stimuli was 15.4s; that for the Type 4 stimuli was 14.9s. The mean of each subject's difference was 0.52s in favor of the Type 3 stimuli, not significantly different from 0 by a 2-sided t test (s.d. = 3.73s, $p > 0.30$).

(5) Accumulated findings

	/X/	/Y/	[X'Y']	Jusczyk et al. 2002		Exp 1	Exp 2	Exp 3
1.	am N_2	bi C_2	ambi N_2C_2	+			+	
2.	an N_1	bi C_2	anbi N_1C_2	–	–	=		

3.	an N_1	bi C_2	ambi N_2C_2		+		–	=
4.	an N_1	bi C_2	andi N_1C_1			=		=

Note: "+" stimuli were preferred over "–" stimuli.

The results, such as they are, are consistent with the hypothesis that this listener population only shows preference between stimuli that are consistent with the current grammar, and stimuli that are consistent with some alternative grammar. When offered a choice between stimuli which are inconsistent with any grammar (Type 4) and stimuli that are consistent with either the current grammar (Type 2) or an alternative grammar (Type 3), infants show no preference; when offered a choice between stimuli which are consistent with the current grammar, and those consistent with an alternative, they prefer the former.

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