Substantive Bias in Phonotactic Learning: Positional Extension of an Obstruent Voicing Contrast

Eleanor Glewwe
eleanorglewwe@ucla.edu
University of California, Los Angeles
CLS 53 | 26 May 2017

1. Background: Synchronic Learning Biases in Phonological Learning

- To what extent is the phonological typology shaped by synchronic learning biases?
- Synchronic (analytic) bias: Learners biased toward acquiring certain phonological systems over others
  - Complexity bias: bias against formally complex patterns
  - Substantive/naturalness bias: bias against phonetically unnatural patterns
- **Research question**: Does phonetic naturalness bias phonotactic learning?
- **Approach**: Test whether learners reproduce an attested and phonetically-motivated phonotactic implicational in an artificial grammar learning (AGL) experiment

1.1 Past Research on Synchronic Biases

- A number of studies have uncovered evidence for complexity bias: learners acquire featurally simpler phonological patterns better (Moreton 2008; Hayes et al. 2009; Skoruppa & Peperkamp 2011; Moreton 2012)
- Other studies have found evidence for substantive bias: learners prefer to acquire phonetically natural patterns and underlearn phonetically unnatural patterns (Wilson 2006; Becker, Ketrez & Nevins 2011; Becker, Nevins & Levine 2012; Finley 2012; Hayes & White 2013; White 2013)
  - But some studies that purport to find a naturalness bias could be reinterpreted as having found a complexity bias (Becker, Ketrez & Nevins 2011; Hayes & White 2013)
  - Others have a pattern of results that is not fully consistent with a naturalness bias account (Wilson 2006)
- Most of these studies have used an AGL paradigm
- Moreton & Pater's (2012a,b) review of work in this area concluded that there is fairly robust evidence for complexity bias but scant evidence for substantive bias

1.2 Synchronic Biases in Phonotactic Learning

- Investigations of substantive bias have focused mostly on alternations
- Few studies have tested naturalness bias in phonotactic learning:
  - Skoruppa & Peperkamp (2011): artificial dialects Harmonic French (natural) and Disharmonic French (unnatural) equally learnable → no evidence for substantive bias (but more complex Mixed French harder → complexity bias)

- Hayes & White (2013): English speakers underlearn unnatural phonotactic generalizations supported by the lexicon, as evidenced by a wug test → evidence for substantive bias
- Myers & Padgett (2014): natural phonotactic restriction against phrase-final voiced obstruents and unnatural phonotactic restriction against phrase-final voiceless obstruents equally learnable → no evidence for substantive bias

- My approach investigates not just phonotactic restrictions but a phonotactic implicational about the existence of contrasts in different positions
  - Implicitly asking learners to compare existence of contrasts across positions may cause a bias to emerge when simply testing learnability of a specific phonotactic constraint doesn't

1.3 The Phonotactic Implicational

- **If a language contrasts voicing in obstruents word-finally (e.g. /ap/ vs. /ab/), it will contrast voicing in obstruents word-initially (e.g. /pa/ vs. /ba/), but not necessarily vice versa**
- Phonetic motivation: cues to obstruent voicing more abundant word-initially than word-finally; in particular, VOT available word-initially but not word-finally (Steriade 1997)
  - Voiced and voiceless obstruents should be more perceptually similar (i.e. harder to distinguish) at the end of a word than at the beginning of a word
  - If voicing contrast exists word-finally, where it is harder to perceive, it should exist word-initially, where it is easier to perceive (T/D# → #T/D)
- Implicational supported by the typology (Steriade 1997)

2. Experiment: Method

- In a nutshell: Expose subjects to an obstruent voicing contrast in word-initial or word-final position and test whether they extend the contrast to the other position
- Four training conditions defined on two dimensions: *Trained Contrast Position* and *Trained Neutralization Value*

Table 1: The Four Training Conditions

	#T	#D	T#	D#
#D…{T, D}# (*#T)	✗	✓	✓	✓
#T…{T, D}# (*#D)	✓	✗	✓	✓
#{T, D}…D# (*T#)	✓	✓	✗	✓
#{T, D}…T# (*D#)	✓	✓	✓	✗

- Properties of items (training and test)
  - $C_1VC_2VC_3$ shape
  - C_1 or C_3 a stop drawn from [p t k b d g]
  - Other two Cs sonorants drawn from [m n l r j w] (no final [j]s or [w]s)

- Vs drawn from [i a u]
- Bilabial, alveolar, and velar stops equally represented
- Half of items belong to minimal pairs
- Half iambs, half trochees (stress not correlated with position featuring the voicing contrast or position containing an obstruent)

- Sample training items for **#{T, D}…T# (*D#)**:

Table 2: Sample Training Items in #{T, D}…T# (*D#) Condition

#T	#D	T#	D#
pímir **t**ilár **k**awám …	**b**ímir **d**irín **g**awám …	míwi**p** laní**t** nuwá**k** …	

- Experiment conducted online using Experigen (Becker & Levine 2013)
- Training Phase
  - Subjects told they would be listening to some words of a new language
  - 2 blocks of the same 36 training items
  - Each training item paired with an image
- Test Phase
  - Subjects heard additional words and had to say whether the word could be a word of the language they had been listening to or not (Yes/No)
  - 1 block of 48 test items: #T, #D, T#, and D# items (same for all conditions)
  - No images
- Three types of test item:
  - *Familiar Conforming*: voicing and position conform to trained pattern, and item heard in training
  - *Novel Conforming*: voicing and position conform to trained pattern, but item not heard in training
  - *Novel Nonconforming*: voicing and position combination not heard in training

Table 3: Sample Test Items for Each Training Condition

	Familiar Conforming	Novel Conforming	Novel Nonconforming
#D…{T, D}# (*#T)	nimá**p**	rínu**p**	**p**írum
#T…{T, D}# (*#D)	nimá**p**	rínu**p**	**b**írum
#{T, D}…D# (*T#)	**k**awám	**k**ámir	múli**k**
#{T, D}…T# (*D#)	**k**awám	**k**ámir	múli**g**

3. Experiment: Predictions

- Subjects' acceptance rates of Novel Nonconforming items (relative to Novel Conforming items) indicate whether they have extended the obstruent voicing contrast to a new position in a given condition

#1 Substantive bias hypothesis (position—Trained Contrast Position):

- Recall the phonotactic implicational: T/D# → #T/D, but not vice versa
- Behavior consistent with implicational would be asymmetrical extension: subjects exposed to contrast word-finally should extend it to word-initial position **more** than subjects exposed to contrast word-initially extend it to word-final position

#2 Substantive bias hypothesis (voicing—Trained Neutralization Value):

- Voiced obstruents more marked than voiceless obstruents → more extension from voiced to voiceless obstruents than from voiceless to voiced obstruents

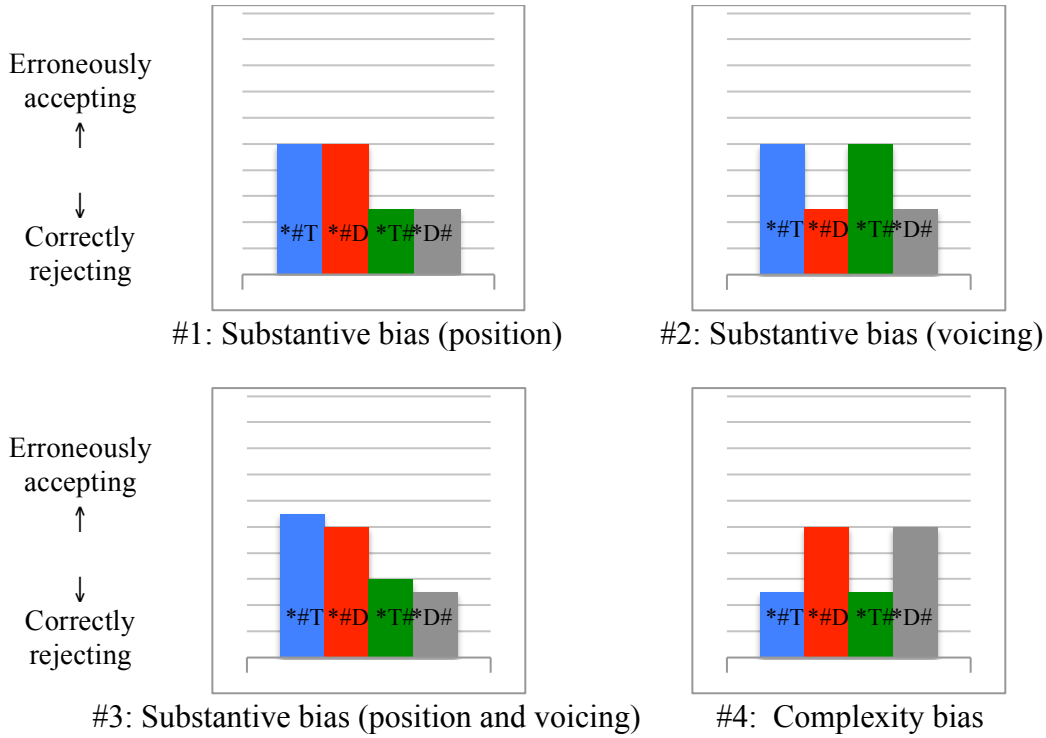
#3 Substantive bias hypothesis (position and voicing):

- More extension from word-final to word-initial position AND more extension from voiced to voiceless obstruents

#4 Complexity bias hypothesis:

- Due to presence of sonorant Cs in training items, constraint needed to exclude Novel Nonconforming items in neutralizing-to-T conditions could be more complex than constraint needed in neutralizing-to-D conditions
  - ➢ **#{T, D}…D# (*T#)**: kawá**m** ✓ míwi**b** ✓ míwi**p** ✗ → *[-voice]#
  - ➢ **#{T, D}…T# (*D#)**: kawá**m** ✓ míwi**b** ✗ míwi**p** ✓ → *[-son, +voice]#
- Predicts more "extension" from voiceless to voiced obstruents than from voiced to voiceless obstruents (opposite of voicing-related Hypothesis #2 above)

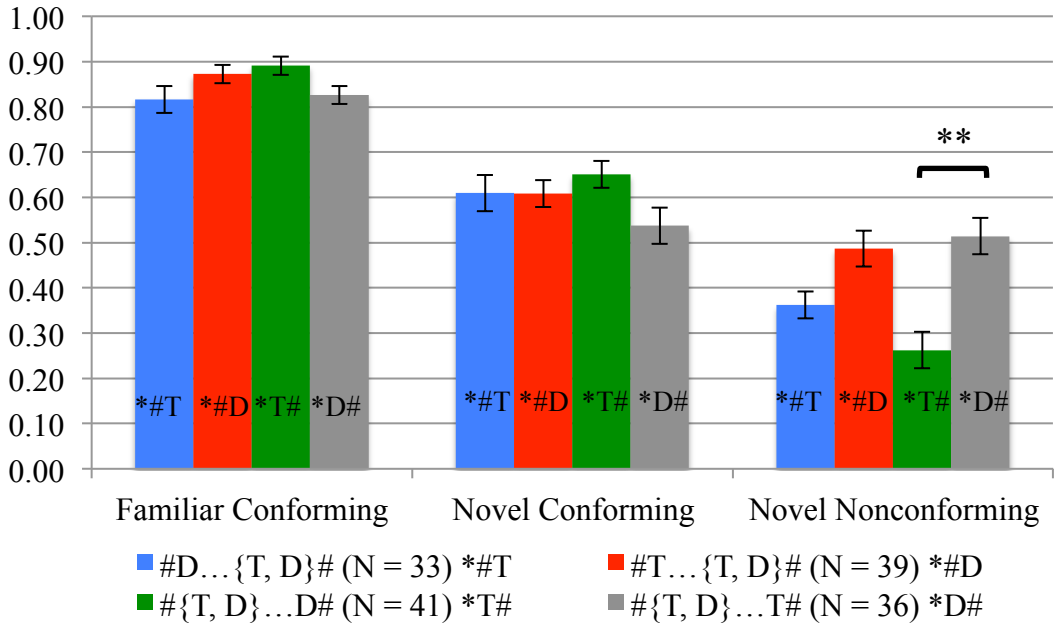
Fig. 1: Schematic Graphs: Predicted Relative Acceptance Rates of Novel Nonconforming Items by Condition According to Different Hypotheses



4. Experiment: Results

- Figure 2 shows the acceptance rates of the three types of test item across conditions:

Fig. 2: Acceptance Rate of Test Items by Condition



- Acceptance rates of Novel Conforming items:
  - Above chance in all conditions (generalization → learning of trained pattern)
  - Not significantly different across conditions
- Mixed-effects logistic regression fit to Novel Nonconforming items:
  - Dependent variable: response (accept or reject)
  - Fixed effect: Condition
  - Random intercepts for subject and item
- Conducted post-hoc pairwise comparisons of acceptances rates of Novel Nonconforming items (Tukey method)
- Reviewing predictions:
  - Substantive bias (position):

    #D…{T, D}# (*#T) > #{T, D}…D# (*T#)
    #T…{T, D}# (*#D) > #{T, D}…T# (*D#)

  - Complexity bias:

    #T…{T, D}# (*#D) > #D…{T, D}# (*#T)
    #{T, D}…T# (*D#) > #{T, D}…D# (*T#)

Table 4: Pairwise Differences in Acceptance Rate of Novel Nonconforming Items

	p
#D…{T, D}# (*#T) > #{T, D}…D# (*T#)	0.528
#T…{T, D}# (*#D) < #{T, D}…T# (*D#)	0.975
#T…{T, D}# (*#D) > #D…{T, D}# (*#T)	0.408
#{T, D}…T# (*D#) > #{T, D}…D# (*T#)	0.004 **
#T…{T, D}# (*#D) > #{T, D}…D# (*T#)	0.016 *
#{T, D}…T# (*D#) > #D…{T, D}# (*#T)	0.210

- Are the predictions borne out?
  - Substantive bias (position):

    #D…{T, D}# (*#T) > #{T, D}…D# (*T#) n.s.
    #T…{T, D}# (*#D) > #{T, D}…T# (*D#) no

  - Complexity bias:

    #T…{T, D}# (*#D) > #D…{T, D}# (*#T) n.s.
    #{T, D}…T# (*D#) > #{T, D}…D# (*T#) yes

- Phonotactic implicational not reproduced → no evidence for substantive bias: Subjects did not extend the contrast more from word-final position to word-initial position
- Partial support for complexity bias:
  - In word-final position, subjects learn *[-voice] better than *[-son, +voice]
  - In word-initial position, trend is there but difference not significant

5. Discussion

- The phonotactic implicational (T/D# → #T/D) was not reproduced in this experiment
  - No greater extension of contrast from word-final to word-initial position
  - Substantive bias hypothesis not supported
- Instead, subjects trained to "neutralize" to T seemed to extend to D more than subjects trained to "neutralize" to D extended to T
  - Opposite of behavior expected based on relative markedness of T vs. D
  - But given (voiced) sonorant Cs, can be explained by a complexity bias
  - #D…{T, D}# and #{T, D}…D# subjects can learn *#[-voice] and *[-voice]#
  - But #T…{T, D}# and #{T, D}…T# subjects must learn more complex *#[-son, +voice] and *[-son, +voice]#
  - Complexity bias account depends on English sonorants having active [+voice] feature
- Effect of complexity bias emerges significantly only for #{T, D}…D# vs. #{T, D}…T#
  - Why should difference in learnability between simple and complex constraint emerge only in word-final position and not in word-initial position?
- Results are in line with Moreton & Pater's (2012a,b) conclusion that there is compelling evidence for complexity bias but little for substantive bias

Acknowledgments

Many thanks to Kie Zuraw, Megha Sundara, Robert Daland, and Bruce Hayes for their guidance and advice. Thanks also to Adam Chong and audiences at the Southern California Meeting on Phonology 2017 and the UCLA Phonology Seminar.

References

Becker, M., Ketrez, N. & Nevins, A. (2011). The Surfeit of the Stimulus: Analytical Biases Filter Lexical Statistics in Turkish Laryngeal Alternations. *Language*, *87*(1), 84–125.

Becker, M. & Levine, J. (2013). Experigen – an online experiment platform. http://becker.phonologist.org/experigen.

Becker, M., Nevins, A., & Levine, J. (2012). Asymmetries in Generalizing Alternations To and From Initial Syllables. *Language*, *88*(2), 231–268.

Finley, S. (2012). Typological asymmetries in round vowel harmony: Support from artificial grammar learning. *Language and Cognitive Processes*, *27*(10), 1550–1562.

Hayes, B., Siptár, P., Zuraw, K., & Londe, Z. (2009). Natural and Unnatural Constraints in Hungarian Vowel Harmony. *Language*, *85*(4), 822–863.

Hayes, B. & White, J. (2013). Phonological Naturalness and Phonotactic Learning. *Linguistic Inquiry*, *44*(1), 45–75.

Moreton, E. (2008). Analytic bias and phonological typology. *Phonology*, *25*(1), 83–127.

Moreton, E. (2012). Inter- and intra-dimensional dependencies in implicit phonotactic learning. *Journal of Memory and Language*, *67*(1), 165–183.

Moreton, E. & Pater, J. (2012a). Structure and Substance in Artificial-phonology Learning, Part I: Structure. *Language and Linguistics Compass*, *6*(11), 686–701.

Moreton, E. & Pater, J. (2012b). Structure and Substance in Artificial-phonology Learning, Part II: Substance. *Language and Linguistics Compass*, *6*(11), 702–718.

Myers, S. & Padgett, J. (2014). Domain generalisation in artificial language learning. *Phonology*, *31*(3), 399–433.

Skoruppa, K. & Peperkamp, S. (2011). Adaptation to Novel Accents: Feature-Based Learning of Context-Sensitive Phonological Regularities. *Cognitive Science*, *35*, 348–366.

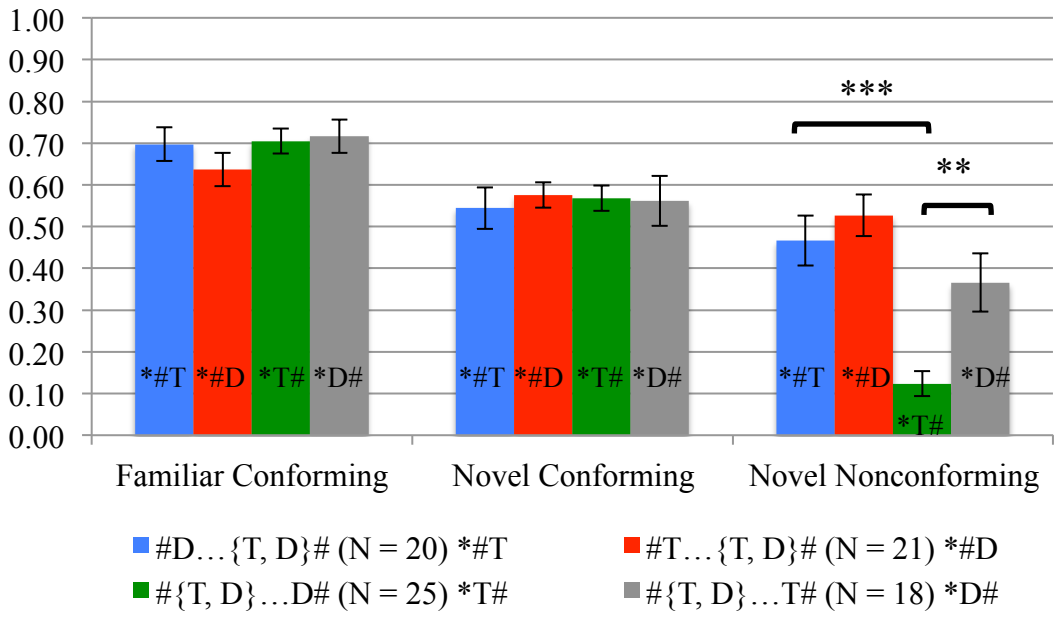
Steriade, D. (1997). Phonetics in phonology: The case of laryngeal neutralization. Ms. University of California, Los Angeles.

White, J. (2013). *Bias in phonological learning: Evidence from saltation*. Ph.D. dissertation. University of California, Los Angeles.

Wilson, C. (2006). Learning phonology with a substantive bias: An experimental and computational study of velar palatalization. *Cognitive Science*, *30*, 945–982.

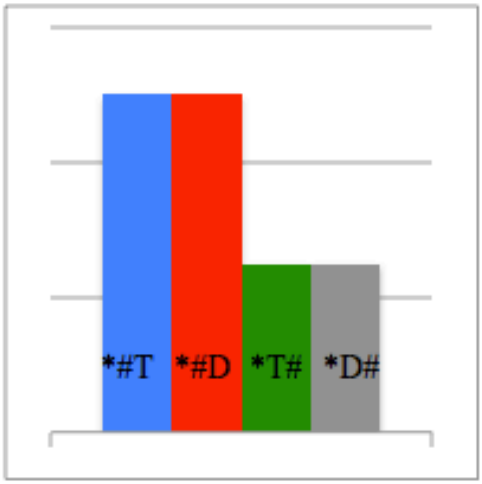
Appendix: An Earlier Version of the Experiment

Fig. 3: Acceptance Rate of Test Items by Condition

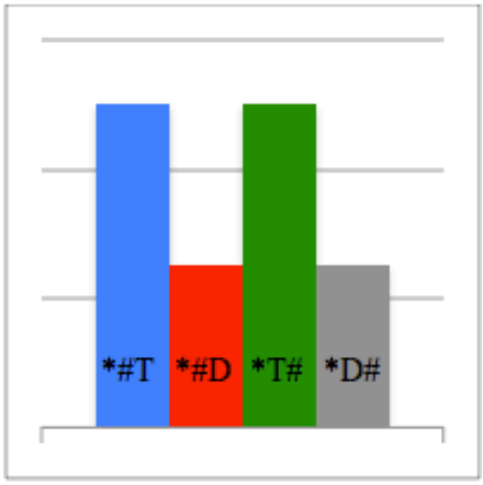


- Differences from final experiment:
  - Included fillers in which all 3 Cs were sonorants
  - Only 1 block of training: 72 items (half fillers)
  - Test block: 72 items (one third fillers)
- Acceptance rates of Novel Conforming items not above chance (except in **#T…{T, D}#**) → motivated increasing training
- Breaking down results further uncovered general dispreferences for word-final obstruents, especially T# → motivated eliminating all-sonorant fillers
- Pairwise comparisons: acceptance rate of Novel Nonconforming items in **#{T, D}…D#** significantly lower than acceptance rates in other three conditions
- No significant differences in acceptance rate among other three conditions
- Partial support for substantive bias: **#D…{T, D}# (*#T) > #{T, D}…D# (*T#)**
- Partial support for complexity bias: **#{T, D}…T# (*D#) > #{T, D}…D# (*T#)**

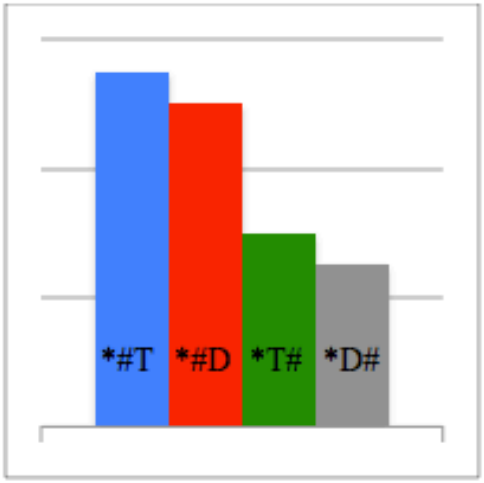
Dumpster



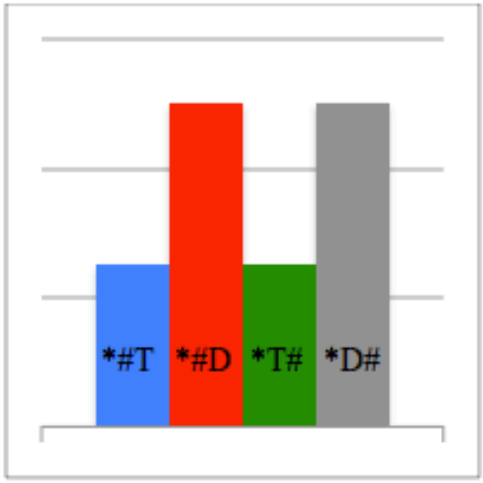
#1: Substantive bias (position)



#2: Substantive bias (voicing)



#3: Substantive bias (position and voicing)



#4: Complexity bias

Table 1: The Four Training Conditions

	#T	#D	T#	D#
#D-FinalContrast (*#T)	✗	✓	✓	✓
#T-FinalContrast (*#D)	✓	✗	✓	✓
InitialContrast-D# (*T#)	✓	✓	✗	✓
InitialContrast-T# (*D#)	✓	✓	✓	✗

Table 1: The Four Training Conditions

	#T	#D	T#	D#
#D…T/D# (*#T)	✗	✓	✓	✓

#T…T/D# (*#D)	✓	✗	✓	✓
#T/D…D# (*T#)	✓	✓	✗	✓
#T/D…T# (*D#)	✓	✓	✓	✗

Table 1: The Four Training Conditions

	#T	**#D**	**T#**	**D#**
#D…{T, D}# (*#T)	✗	✓	✓	✓
#T…{T, D}# (*#D)	✓	✗	✓	✓
#{T, D}…D# (*T#)	✓	✓	✗	✓
#{T, D}…T# (*D#)	✓	✓	✓	✗