

PERCEPTION, PRODUCTION, AND THE IMPLEMENTATION OF PHONOLOGICAL
OPACITY IN THE BANGLA VOWEL CHAIN SHIFT

Traci Christine Nagle

Submitted to the faculty of the University Graduate School
in partial fulfillment of the requirements
for the degree
Doctor of Philosophy
in the Department of Linguistics,
Indiana University
August 2020

ProQuest Number:28090209

All rights reserved

INFORMATION TO ALL USERS

The quality of this reproduction is dependent on the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if material had to be removed, a note will indicate the deletion.



ProQuest 28090209

Published by ProQuest LLC (2020). Copyright of the Dissertation is held by the Author.

All Rights Reserved.

This work is protected against unauthorized copying under Title 17, United States Code
Microform Edition © ProQuest LLC.

ProQuest LLC
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 - 1346

Accepted by the Graduate Faculty, Indiana University, in partial fulfillment of the
requirements for the degree of Doctor of Philosophy

Doctoral Committee

Kelly H. Berkson, Ph.D., chairperson

Stuart Davis, Ph.D.

Kenneth de Jong, Ph.D.

Michael P. Adams, Ph.D.

July 9, 2020

Copyright © 2020

Traci Christine Nagle

for Ma,
and for her granddaughter, Tara

Acknowledgments

This project has accrued a globe-spanning arc of indebtedness. Foremost among those who have helped me complete this work are the members of my committee. Without Kelly Berkson this dissertation would never have been finished. I showed up out of nowhere to ask that she supervise my work, and it was the best decision I made in my entire graduate career.

Encouragement, understanding, prodding, innovation, and advice—she offered it all, and always at just the right moments. Ken de Jong taught me phonetics, coached me in statistics, and seemed always to have faith in me even when I had little in myself. Stuart Davis has given me unfailingly wise counsel for many years and through many stages of my work. Michael Adams and I arrived at IU in the same year; he inspired me to study the linguistics and lexicography of English for my masters, a secondary line of research that continues to bring me joy (and publications). I thank each of them for their patience and support.

The research described herein began as a term paper in Advanced Phonology, taught by Dan Dinnsen and Ashley Farris-Trimble. I am grateful to both for inspiring me to pursue phonology and for pointing out this pattern in Bangla before I even knew what a chain shift was. After Dan retired, Michael Becker landed in Indiana, and in his brief time here he brought the buried programmer in me back to life and helped me craft the experimental dissertation that I had in mind.

Unsurprisingly, given that I began this project under Dan Dinnsen, my initial intention was to study how children acquired the vowel chain shift in Bangla verbs. I spent 5 months in India collecting recordings of sometimes-hilarious child speech with the invaluable help of Poulomi Paul and Soumi Banerjee. Thanks to them not only do I have many hours of child data for future

work, but I now recognize the advantages of the subway in Kolkata and can find College Street and Howra without a map. I promise I'll get to those child recordings soon.

At Indiana University, I benefited from the assistance of undergraduate researchers in the Phonetics and Phonology Lab, particularly Caroline Ehlhardt, Katie Blake, Chelsea Bonhotal, Abby Elston, Jacob Henry, Kristina Mihajlovic, and Max Nelson.

No project this long or this complex would have been possible without a village worth of friends and colleagues in the U.S., Canada, and Kolkata who helped in innumerable ways: the late Gautam Adhikari, Abhijit and Ilora Basu, Anumita Basu, Shohini Bhattachali, Nayana Bose, Becca Cambridge, Anamitraa Chakraborty, Swapan Chakravorty, Shibashis Chatterjee, Mina Dan, Anupam Das, Paramita Das, Suranjan Das, Stephanie Dickinson, Nandini Gupta, Walt Hakala, Abdul Hakim, Alisa Hendrix, Taj Islam, Ujjwal Jana, Ananda Lal, Shamsuddin Mahmud, Shivnath Mazumder, Shikha Mukerjee, Dipika Mukherjee, Sreemati Mukherjee, Rahul Mukherji, Joe Pater, Rinku Roy Chowdhury, Atanu Saha, Amitava Sarkar, Saurov Syed, and Rashad Ullah. I am also grateful to all the participants in my experiments, some of whom I know or got to meet, and others who remain anonymous even to me.

Various iterations of this work were presented as papers and posters at AMP (5th, New York University), LabPhon (15th, Cornell University), FASAL (6th, Massachusetts–Amherst), MidPhon (20th, Indiana–Bloomington; 19th, Wisconsin–Madison; and 13th, Ohio State), ASA (Pittsburgh), and at several departmental conferences and colloquia. I benefited there from audience questions and comments, and from stimulating conversation with like-minded scholars.

The travel required for data collection and conference presentations and graduate study in general, are costly but were made easier by funding from various entities, including the IU Linguistics Department, the IU Center for the Study of Global Change, the IU India Studies

Program, the IU Graduate and Professional Student Organization, the Kappa Alpha Theta Foundation, and the IU Credit Union.

The support and encouragement of my family—Anirban, Ananya, Arko, Mom, and Lou—sustained me all these years. I only wish my *shashuri* Nandini were still with us to see that I finally finished this. It was because of her son, Sumit, that I first started to study Bangla and thanks to him that I was able to get through to this finish line. Lastly, helping Tara grow into the intelligent, kind, and accomplished person she is took a lot of time away from this dissertation, but it was worth every minute.

PREVIEW

Traci Christine Nagle

PERCEPTION, PRODUCTION, AND THE IMPLEMENTATION OF PHONOLOGICAL
OPACITY IN THE BANGLA VOWEL CHAIN SHIFT

This dissertation explores the productivity of a phonologically opaque synchronic chain shift in Bangla, a language spoken in India and Bangladesh by 265 million people. Bangla exhibits a vowel-harmony chain shift in which certain verb-stem vowels alternate [(i ~ e), (e ~ æ), (u ~ o), and (o ~ ɔ)] based on the identity of a vowel in the neighboring suffix. This pattern is called a chain shift because harmonization with affix vowels causes stem vowels to move only one step along an ordered scale of vowel heights. Previous work has suggested that opaque patterns are difficult to learn and may not be extended to nonce words (e.g., Zhang 2016). Using production and perception experiments conducted with native speakers of Bangla, this dissertation investigates the nature of this alternation pattern in the grammar of native Bangla speakers. The central question is whether speakers can extend this chain-shift pattern to nonce words.

Though the chain shift pattern is exceptionless in real verbs, the results indicate that Bangla speakers do not freely extend this pattern to nonce words. Instead, they apply the chain shift only about half of the time. Analyses conducted to probe possible acoustic explanations for these results (e.g., incomplete neutralization, vowel-to-vowel coarticulation) suggest that the patterns observed cannot be explained by phonetics alone. Rather, they seem to point to underlearning (Becker, Ketrez, & Nevins 2011) of the chain shift pattern.

As Bangla remains under-examined in modern theoretical linguistic and phonological literature, this dissertation contributes to the general literature on Bangla. Its findings also carry implications for formal models of phonology and language learning, and for the

conceptualization and modeling of synchronic chain shifts. The results indicate that chain shifts, and possibly opaque patterns more generally, may operate very differently in cognitive systems than some theoretical models have assumed.

PREVIEW

Contents

List of Figures	xiii
List of Tables	xv
Chapter 1: Introduction	1
1.1 Overview	1
1.2 The vowel chain shift in Bangla verbs.....	3
1.3 Why does opacity matter?.....	7
1.4 Opaque phonology, productivity, and natural language	8
1.5 Contributions and overview of this dissertation	10
Chapter 2: Background: Relevant Aspects of Bangla Grammar and Literature Review .	12
2.1 Introduction.....	12
2.1.1 Organization of this chapter.....	13
2.2 Theoretical underpinnings and prior research.....	14
2.2.1 Opacity and chain shifts.....	16
2.2.1.1 Derivational and constraint-based approaches to chain shifts	18
2.2.1.2 The problem of acquisition	24
2.2.2 Nonce-word tests as windows into the productivity of morphophonological alternations.....	27
2.3 Prior linguistic study of Bangla	30
2.4 The grammar of Bangla	36
2.4.1 Sociolinguistics	36
2.4.1.1 Diglossia.....	36
2.4.1.2 Multilingualism.....	38
2.4.2 Syntax	39
2.4.3 Morphology.....	40
2.4.3.1 Nouns, pronouns, and postpositions	40
2.4.3.2 Verbs	41
2.4.4 Phonology	42
2.4.4.1 Consonant inventory	42
2.4.4.2 Vowel inventory & distribution	43
2.4.4.3 Stress patterns	46
2.4.4.4 Vowel alternations in verbs.....	47
2.4.4.5 Vowel alternations in non-verbs	48
2.4.5 Orthography	48
2.4.6 The Bangla verb.....	50
2.4.6.1 Composite verbs.....	51
2.4.6.2 Vowel alternations in verbs.....	52
2.5 Conclusion	54
Chapter 3: The Acoustics of Bangla Vowels	55
3.1 Introduction.....	55
3.2 Methods.....	56
3.2.1 Participants.....	56
3.2.2 Construction and presentation of reading list	56
3.2.3 Recordings and measurements.....	58
3.3 Bangla vowel acoustics.....	60

3.4	Conclusion	64
Chapter 4:	Generalizability of the Bangla Vowel Harmony Pattern in Verbs, Part 1	66
4.1	Introduction.....	66
4.1.1	Map of chapter	67
4.2	Experiment 1	67
4.2.1	Methods: Auditory selection task	69
4.2.1.1	Stimuli and response construction and recording	70
4.2.1.2	Frame sentences and direct objects	76
4.2.1.3	Experimental platform and presentation	77
4.2.1.4	Participants.....	79
4.2.1.5	Coding of responses	80
4.2.2	Results: Auditory selection task.....	80
4.3	Discussion	94
4.3.1	Real words	94
4.3.2	Conditions.....	95
4.3.3	Consonant frequency	96
4.3.4	Vowels	96
4.3.5	Limitations	97
Chapter 5:	Generalizability of the Bangla Vowel Harmony Pattern in Verbs, Part 2	99
5.1	Introduction.....	99
5.1.1	Map of chapter	100
5.2	Experiment 2, part 1 (perceptual categorization task)	101
5.2.1	Methods, perceptual categorization task.....	102
5.2.2	Results, perceptual categorization task	106
5.2.3	Interim assessment.....	111
5.3	Experiment 2, part 2 (nonce word task with verbal response).....	112
5.3.1	Methods: Spoken production task.....	112
5.3.1.1	Stimuli.....	112
5.3.1.2	Frame sentences and direct objects	113
5.3.1.3	Experimental platform and presentation	113
5.3.1.4	Participants and demographics.....	119
5.3.1.5	Coding of responses	120
5.3.1.6	Inter- and intra-rater reliability	121
5.3.2	Results: spoken production task.....	126
5.3.2.1	Influence of experimental condition on vowel harmony implementation.....	127
5.3.2.2	Influence of stimulus frequency on vowel harmony implementation.....	128
5.3.2.3	Influence of stem vowel on vowel harmony implementation.....	130
5.3.2.4	Influence of consonant frequency on vowel harmony implementation.....	135
5.3.2.5	Influence of stimulus item on vowel harmony implementation	136
5.3.3	Discussion	141
5.4	Conclusion	143
Chapter 6:	V2V Coarticulation & Covert Contrast.....	145
6.1	Introduction.....	145

6.1.1	Vowel-to-vowel coarticulation	145
6.1.2	Incomplete neutralization.....	147
6.1.3	Chapter map	148
6.2	Comparison method and data collection.....	148
6.2.1	Utterances analyzed	151
6.2.2	Acoustic measurements	152
6.3	Vowel comparisons.....	154
6.3.1	Acoustic comparisons	158
6.4	Results.....	161
6.4.1	V2V coarticulation in real nonverbs.....	164
6.4.2	Incomplete neutralization.....	164
6.5	Conclusion	166
Chapter 7:	Discussion	167
7.1	Lack of support for coarticulation.....	167
7.2	Questions about prior analytical assumptions.....	169
Chapter 8:	Conclusion.....	176
8.1	Contributions of this study.....	177
8.2	Limitations of this study and avenues for future research	178
Appendix A	Sample <i>sadhu bhasha</i> and <i>cholit bhasha</i> verb paradigms	180
Appendix B	Reading list items.....	182
Appendix C	Vowel formants from Reading List task for all tokens, by participant...	189
Appendix D	Participant demographics, Experiment 1	202
Appendix E	Nonce and real verb stimuli, Experiments 1 and 2	203
Appendix F	Stimuli with response options, Experiment 1	205
Appendix G	Frame sentences, Experiments 1 and 2	207
Appendix H	Frame sentences used with demonstration and training stimuli, Experiments 1 and 2.....	210
Appendix I	Recruitment email for auditory-response experiment.....	211
Appendix J	Participant demographics, phonetic sketch and Experiment 2	212
Appendix K	Words compared across type for vowel-to-vowel comparisons	214
Curriculum Vitae		

List of Figures

Figure 1: Vowel phonemes of Bangla in traditional vowel-space schematization, with relevant feature values	3
Figure 2: The vowel chain shift in Bangla verbs	5
Figure 3: Vowel alternations in present indicative Bangla verbs	5
Figure 4: Height and feature specifications for Bangla vowels	18
Figure 5: Linear and circular chain shifts	30
Figure 6: Vowel phonemes of Bangla (reprise of Figure 1)	44
Figure 7: On-screen instructions for reading-list task.....	58
Figure 8: Sample screen presentation of word ([botriʃ] ‘thirty-two’) in reading-list task	58
Figure 9: Demarcated vowel in reading list token	59
Figure 10: Mean vowel formants for each token, current study, female speakers	62
Figure 11: Mean vowel formants from three prior studies, female speakers.....	62
Figure 12: Mean vowel formants for each token, current study, male speakers	63
Figure 13: Mean vowel formants from three prior studies, male speakers.....	63
Figure 14: Presentation of experimental items, Experiment 1.....	78
Figure 15: Implementation of harmony by condition across all stimulus types.....	81
Figure 16: Implementation of harmony by condition, nonce stimuli	81
Figure 17: Implementation of harmony by participant frequent real verbs	82
Figure 18: Implementation of harmony by participant, less frequent real verbs	83
Figure 19: Implementation of harmony by participant, nonce verbs.....	84
Figure 20: Implementation of harmony by stimulus type.....	85
Figure 21: Implementation of harmony by stimulus item, real frequent verbs	86
Figure 22: Implementation of harmony by consonant pair frequency, nonce verbs	87
Figure 23: Implementation of harmony by stimulus stem vowel, nonce verbs in raising condition	89
Figure 24: Vowel responses by stimulus vowel, nonce verbs in raising condition	90
Figure 25: Implementation of harmony by stem vowel in verb stimulus, nonce verbs in lowering condition	92
Figure 26: Vowel responses by stimulus vowel, nonce verbs in lowering condition.....	93
Figure 27: Instruction pages and selected stimulus presentation page, perceptual categorization task	104
Figure 28: Response sheet (page 1), perceptual categorization task	105
Figure 29: Results by participant, perceptual categorization task	106
Figure 30: Results by intended vowel in the stimulus, perceptual categorization task	108
Figure 31: Vowels reported in perceptual categorization task, by stimulus vowel	109
Figure 32: Mean vowel formants (female), participants in current study (reprise of Figure 10)	110
Figure 33: Mean vowel formants (male), participants in current study (reprise of Figure 12) ..	110
Figure 34: Instruction screen, Experiment 2.....	113
Figure 35: Presentation of experimental item, raising condition, Experiment 2	115
Figure 36: Prompt for response, raising condition, Experiment 2.....	116
Figure 37: Acceptability rating task, Experiment 2	117
Figure 38: Segmenting of response sentence and verb within response sentence.....	121
Figure 39: Implementation of vowel pattern by experimental condition	127
Figure 40: Implementation of vowel pattern by token type and token frequency	129

Figure 41: Implementation of harmony by stem vowel, condition, and token frequency	130
Figure 42: Vowel responses by stem vowel, condition, and token frequency.....	133
Figure 43: Implementation of vowel pattern by stimulus, frequency, and condition, real verbs	137
Figure 44: Implementation of vowel pattern by stimulus and condition, nonce verbs.....	138
Figure 45: Results by stimulus and target vowel, perceptual categorization task	139
Figure 46: Demarcated vowel in reading list token	153
Figure 47: Vowel formant maps, average across female participants	155
Figure 48: Vowel formant maps, average across male participants	156
Figure 49: First vowel height across harmonization contexts, females	162
Figure 50: First vowel height across harmonization contexts, males	163
Figure 51: Vowel alternations in present indicative Bangla verbs (reprise of Figure 3).....	174

PREVIEW

List of Tables

Table 1: Vowel alternations in the present indicative of Bangla verbs	4
Table 2: Derivational application of vowel-harmony rules, (incorrect) feeding interaction	19
Table 3: Derivational application of vowel-harmony rules, (correct) counterfeeding interaction	20
Table 4: Correct OT analysis of high-mid vowel raising in Bangla	22
Table 5: Incorrect OT analysis of low-mid vowel raising in Bangla.....	22
Table 6: OT analysis: Local constraint conjunction (adapted from Mahanta (2007))	24
Table 7: Comparison of selected <i>sadhu bhasha</i> and <i>cholit bhasha</i> verb forms.....	37
Table 8: Formality in Bangla personal pronouns, nominative case.....	41
Table 9: Consonant phonemes of Bangla	43
Table 10: Distribution of [æ] and [e] in Bangla.....	45
Table 11: Distribution of [ɔ] and [o] in Bangla	45
Table 12: Phoneme/grapheme correspondence in Bangla	49
Table 13: A sample of Bangla monosyllabic and disyllabic verb stems	51
Table 14: Vowel alternations in present indicative Bangla verbs (reprise of Table 1).....	52
Table 15: Mean formant values by vowel and by speaker sex, current study	61
Table 16: Bangla consonants ranked in descending order of frequency in Mallik corpus (graphemes and IPA)	71
Table 17: Nonce verbs (purported nominal/citation form) used in Experiments 1 and 2, by place of articulation and frequency of consonants	73
Table 18: Real verbs (citation form) used in experiments 1 and 2, by place of articulation, frequency of consonants, and lexical frequency	74
Table 19: Vowels in response sets, Experiment 1	75
Table 20: Sample stimulus/response sets, Experiment 1	75
Table 21: Stimuli, perceptual categorization task.....	103
Table 22: Percentage match of perceptual categorization with intended stimulus vowel, by vowel and by participant.....	107
Table 23: Potential effects of perceptual confusion between [o] and [u] on nonce word experiment results	135
Table 24: Rates of implementation of vowel pattern and rates of correct categorization for selected stimulus items	140
Table 25: Categories of comparison of V ₁ in Bangla words	149
Table 26: Sample comparison across lexical categories and phonetic forms	160
Table 27: Predictions of F1 measurements for categories of words in Table 25.....	161
Table 28: General predictions of relative magnitudes of F1 measurements by token category .	161
Table 29: Comparison of pattern implementation rates by condition, all token types	170
Table 30: Comparison of pattern implementation rates by token type.....	171
Table 31: Comparison of pattern implementation rates by consonant pair frequency, nonce tokens	172
Table 32: Comparison of pattern implementation rates by stimulus vowel, nonce tokens	173

Chapter 1

Introduction

This subject has hitherto been utterly disregarded in Europe; and it is scarcely believed that Bengal ever possessed a native and peculiar dialect of its own, distinct from that idiom which, under the name of *Moor's*, has been supposed to prevail over all India.

(Halhed, 1969 [1778], p. ii)

1.1 Overview

This dissertation explores the productivity of a vowel harmony pattern in Bangla that has been analyzed in prior research as a synchronic chain shift (e.g., Mahanta, 2007, 2012). Chain shifts are conceptualized in phonological theory as instances of opaque alternations, called that because the linguistic principles that govern the alternations are not fully transparent in surface realizations. McCarthy (2007, p. 2) has called phonological opacity “one of the central themes of generative phonology.” From a theoretical standpoint, opaque interactions can be challenging to model in adult grammars (see, e.g., discussion in McCarthy, 2002, § 3.3.3.1), child learning trajectories (see, e.g., introductory discussion in Kager, Pater, & Zonneveld, 2004, pp. 5-6), or both. From an experimental standpoint, some opaque interactions that have persisted in spoken languages for generations seem to resist generalization to novel lexical items (e.g., Hsieh, 1970; Sanders, 2003; Zhang, 2019).

This lack of productivity is puzzling, for if a pattern has been passed from generation to generation, it must be learnable and extendable to not-previously-encountered words as children acquire an adult vocabulary. Indeed, formal computational modeling has shown opaque patterns to be learnable by machine subjects (e.g., Nazarov & Pater, 2017; Pater, 2014), and artificial-grammars that mimic opaque patterns in real language have proved learnable by human subjects (e.g., Ettlinger, 2008). And yet multiple experiments with speakers of languages such as Polish

(Sanders, 2003), Taiwanese (Zhang et al., 2006), and Hebrew (Sumner, 2003) have cast doubt on the productivity of opaque phonological patterns and, in the case of Sumner's work on Hebrew, on phonologists' ideas about how speakers represent these phenomena in their grammars.

This dissertation investigates the productivity of another opaque phonological pattern, using perception and production experiments and other measures to gain an understanding of how this process works in the grammars of speakers. The central question it poses is whether speakers can extend this chain-shift pattern to nonce words. The pattern in the language explored here (Bangla) differs from the opaque patterns in other languages just mentioned in several potentially critical ways. In both the Polish opacity(s) studied by Sanders and the Hebrew opacity studied by Sumner, the patterns occurred in only certain words within the lexical category under study. In the Taiwanese circular tone shift studied by Zhang et al., parts of the pattern defied notions of naturalness and markedness because a circular chain-shift analysis involves the changing of a less-marked form into a more-marked form. In each of those cases, it could be argued that these factors worked against the extension of the opaque pattern to nonce words. Unlike these previously studied cases, the opaque pattern in Bangla is phonetically grounded and is exceptionless—no variation affects the frequency of the alternation. Thus, if variation in the relevant portion of the grammar and an increase in markedness do result in a reduced pressure for implementation of a phonological pattern, then Bangla may be a more ideal language for the investigation of opaque alternations.

Nevertheless, the results of the study presented here, like those of the prior studies mentioned above, indicate that Bangla speakers do not freely extend this pattern to nonce words. Instead, they apply the chain shift only about half of the time. Analyses conducted to probe possible acoustic explanations for the pattern (e.g., incomplete neutralization, vowel-to-vowel

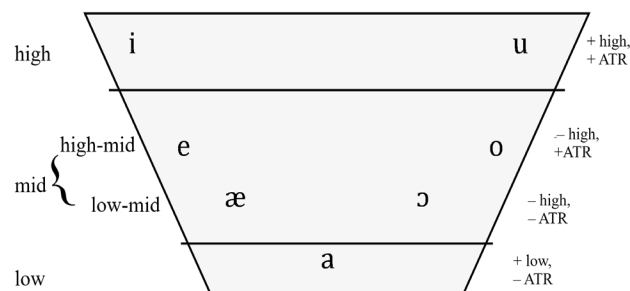
coarticulation) suggest that the patterns observed cannot be explained by phonetics alone. As will be discussed in later chapters, that fact that speakers do implement the pattern in nonce words at rates greater than chance, but not at rates that mirror their productions for real words, suggest underlearning (Becker, Ketrez, & Nevins 2011) of the chain shift pattern. More investigation addressing some potential shortcomings of the experiments presented here may further illuminate the influences on implementation rates.

The rest of this chapter will present a description of the opaque interaction in Bangla and then will address the relevance of opacity to linguists' understanding of natural languages.

1.2 The vowel chain shift in Bangla verbs

Bangla (also known as Bengali) contains seven oral monophthongs, as shown in Figure 1. Six of these participate in an alternation phenomenon generally described as a chain shift. This chain shift occurs in monosyllabic verb stems, as can be seen in the present-tense inflections of the sample of Bangla verbs shown in Table 1. There we see the following alternations: æ ~ e in the verb stem /dæk^h-/ 'see'; e ~ i in the verb stem /fek^h-/ 'learn'; ɔ ~ o in the verb stem /kɔr-/ 'do'; and o ~ u in the verb stem /ot^h-/ 'rise'. The higher alternating stem vowel in each pair occurs when a high vowel is present in the neighboring affix, and the lower alternating stem vowel

Figure 1: Vowel phonemes of Bangla in traditional vowel-space schematization, with relevant feature values



Sources: Chatterji (1986 [1928]), Ghosh (1997), Thompson (2010).

Table 1: Vowel alternations in the present indicative of Bangla verbs

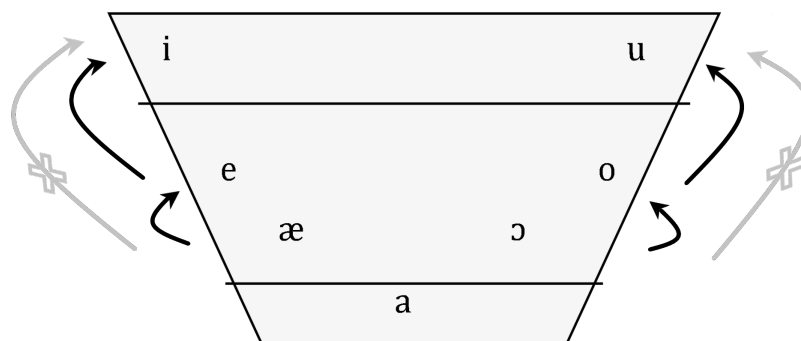
Affix		/dæk ^h -/ 'see'	/ʃek ^h -/ 'learn'	/kər-/ 'do'	/oʈ ^h -/ 'rise'	/rak ^h -/ ' '
1p.	/-i /	[dæk ^h i]	[ʃik ^h i]	[kəri]	[uʈ ^h i]	[rak ^h i]
2p. (fam.)	/-iʃ /	[dæk ^h iʃ]	[ʃik ^h iʃ]	[kəriʃ]	[uʈ ^h iʃ]	[rak ^h iʃ]
2p. (casual)	/-o /	[dæk ^h o]	[ʃek ^h o]	[kəro]	[oʈ ^h o]	[rak ^h o]
3p. (casual)	/-e /	[dæk ^h e]	[ʃek ^h e]	[kəre]	[oʈ ^h e]	[rak ^h e]

occurs when the vowel in the affix is a mid vowel (or a low vowel, though none are shown in the mini-paradigm here). Monosyllabic verbs with an [a] in their stem do not exhibit alternations in the present indicative, as shown for the stem /rak^h-/ in the rightmost column of the table. (In the present tense shown in Table 1, the only affix present in the surface representation is the person marker; the Bangla verb system includes other affixes for tense and aspect that intervene between the stem and the person marker, as is shown in the full verb paradigm in Appendix A. The distinction between *sadhu bhasha* and *cholit bhasha* shown in that appendix will be explained in Chapter 2.)

A number of scholars who have analyzed these alternations (e.g., Dasgupta, 1982; Dey, 1979; Lahiri, 2000b; Nagle, 2008; Paul, 1986; Sarkar, 2004; Singh, 1980) have described the pattern as one of regressive vowel height harmony or assimilation, triggered by the presence or absence of a [+high] or [+ATR] feature value in the vowel in the inflectional affix closest to the stem.¹ This assimilation is not complete, however. It takes the form of a chain shift, in which feature values change only one step along an ordered scale toward the harmonization trigger, as shown in Figure 2, where the black arrows show that æ → e → i and ɔ → o → u. Importantly,

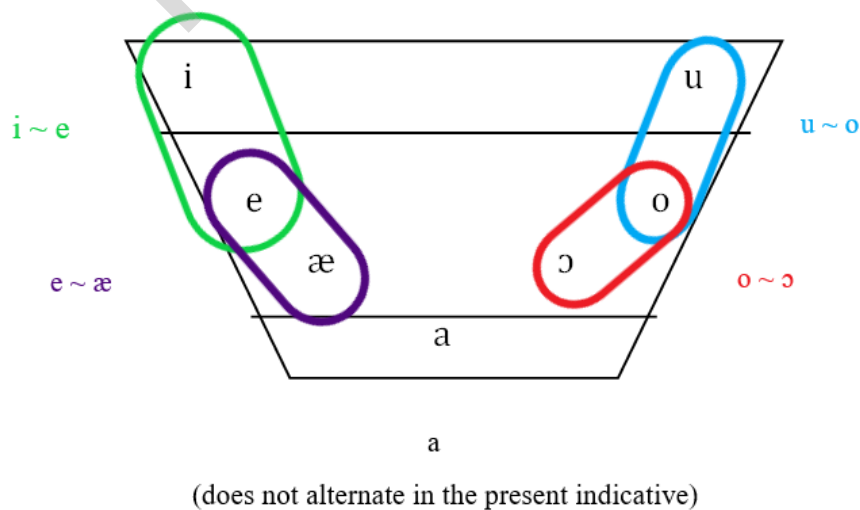
¹ The data presented in Table 1 is shown as a raising pattern (with a lower vowel in the underlying stem form) for the sake of simplicity of exposition. Whether the assimilation is one of raising caused by a [+high] affix vowel or lowering caused by a [-high] affix vowel is a matter of interpretation and does not materially affect the analysis presented here. The experimental results in Chapter 4 and Chapter 5 suggest the possibility that neither is correct.

Figure 2: The vowel chain shift in Bangla verbs



though, there is not a complete neutralization of height contrast between the focus (stem) vowel and the trigger (affix) vowel—that is, $*\text{æ} \rightarrow \text{i}$ and $*\text{ɔ} \rightarrow \text{u}$, as shown by the gray arrows in Figure 2 (see, e.g., Lahiri, 2000a; Mahanta, 2007; Nagle, 2008; Schmidt, 1996 describes a markedly similar pattern in the Bantu language Basaa). This alternation pattern is further illustrated in Figure 3, which groups each set of alternations and also shows clearly that the high-mid vowels [e] and [o] are each part of two alternations: each is the higher alternant when paired

Figure 3: Vowel alternations in present indicative Bangla verbs



with a low-mid vowel, and each is also the lower alternant when paired with a high vowel. These dual roles are important to note and will be discussed further in later chapters.

Chain-shift patterns are phonologically opaque, in the sense that speakers must form a generalization about the phonology that is not always true in the utterances of speakers (i.e., not “surface-true”). For instance, the generalization necessary to produce the first-person forms for the Bangla verb meaning ‘rise’ (in the rightmost column of Table 1—that [u] is preferred to [o] in the stem when preceding the high vowel [i] in the affix—does not hold true in the case of the first-person, familiar second-person, or formal forms of the verb meaning ‘do’ (also shown in Table 1), where [o] rather than [u] appears to be the preferred stem vowel in the high-affix context. The generalization “[u] is preferable to [o] before a high-vowel affix” that accounts for the stem vowel patterning in the verb ‘rise’ is not true, apparently, in the case of the verb ‘do’. A similar inconsistency arises when generalizing about the surface forms of the front stem vowels /æ/, /e/, and /i/. In a verb like that meaning ‘learn’, it appears that [i] is preferable to [e] before the high affix vowel [i]. And yet in a verb like the one meaning ‘see’, such a generalization is untrue, for there [e] is the vowel that appears in the syllable before that same high affix. In the case at hand, therefore, we can say that the generalizations are “not surface-true.” We will see in Chapter 2 that this surface-inconsistent vowel pattern is replicated in all monosyllabic verbs in Bangla, meaning that speakers of Bangla are exposed to a large amount of information that, on the surface, does not appear to be consistent. In the terminology used to describe opacity, this is a case of an “underapplication” of the generalization that [u] or [i] are preferable to [o] or [e], respectively, before a high vowel in the neighboring affix. In derivational terms, this pattern is described as “counterfeeding.”

1.3 Why does opacity matter?

Synchronic chain shifts are found in diverse languages (a partial compendium is provided in Moreton & Smolensky, 2002), and they are just one type of phonological opacity as it has been documented and analyzed in many languages and in several analytical frameworks (for a sampling, see, e.g. Anttila, 2006; Baković, 2007; Kiparsky, 2000; McCarthy, 2007; Moreton, 2004). McCarthy (2007, p. 2) has called phonological opacity “one of the central themes of generative phonology.” It initially presented a challenge to derivational frameworks with systems of simultaneous rules (e.g., Chomsky & Halle, 1968)—a challenge that was met with the development of models that included ordered rules (e.g., Kiparsky, 1968). But as many scholars in the field of phonology moved away from rule-based analyses and toward surface-oriented constraint-based models such as Optimality Theory (OT; Prince & Smolensky, 1993/2004) grounded in terms of typologically attested patterns (= markedness) and principled departures from it (= faithfulness), the challenges presented by opacity resurfaced. Certain phenomena, including chain shifts, pose difficulties for constraint-based models, since these patterns seem to arise from something other than just the interactions of markedness and faithfulness constraints (see, e.g., McCarthy, 2007, § 1.1; Mielke, Armstrong, & Hume, 2003, § 2). Numerous interpretations of and adjustments to constraint-based models have been proposed to account for the surface facts of chain shifts and other opaque patterns. Some re-introduce elements of sequenced derivation; others assign weights or probabilities to constraints and their ranking. These adjustments supplement the constraint interactions and thereby accommodate language patterns, such as opaque alternations, that seem to defy the basic idea of strictly ranked, permutable markedness and faithfulness constraints. Some of these ideas will be discussed in section 2.2.1.

Language patterns such as phonological opacity offer both a challenge and an opportunity to linguists, psycholinguists, and cognitive scientists attempting to understand and model the nature of “language” in the human mind. These patterns implicate some of the most fundamental questions being asked about human language today, such as which elements of language are stored in memory and in what form they are stored, how stored elements of language are accessed during the processes of language perception and production, and the means by which language-specific patterns are learned and applied both to items retrieved from storage and to newly encountered lexical items.

1.4 Opaque phonology, productivity, and natural language

Experimental investigations of phenomena in natural languages are crucial to the process of revising and refining linguistic theories, and they also offer fresh insights into the nature of much-described and much-analyzed linguistic phenomena. For instance, in their “islands of reliability” study of the alternations involving diphthongization in Spanish, Albright, Andrade, and Hayes (2001) challenged the assumptions of numerous prior proposed analyses that Spanish speakers must distinguish between alternating and non-alternating verbs in their stored lexical representations. By studying the behavior of Spanish speakers encountering nonce verbs, these authors showed that speakers have intuitive knowledge of phonotactic conditioning of the alternation pattern that makes such storage details unnecessary. Although the alternations examined by Albright et al. in Spanish do not exhibit opacity, their study and others like it demonstrate the importance of testing theoretical assumptions against speakers’ knowledge and implementation of patterns in their language, because our theory does not always imagine what actual speakers will do.