What we hear depends on where we hear it: Perceptual Adaptation in Bengali-English Bilingual Speech

Abstract

Listeners adapt to atypical or unfamiliar speech by temporarily adjusting (recalibrating) their phonetic category boundaries. Previous research indicates that lexical information can guide perceptual recalibration in one's native language (L1). However, evidence for adaptation in L2 has been mixed, with great variation across different language pairs and sound contrasts. This project will investigate recalibration of a non-native vowel contrast in bilingual speakers of Bengali and English, through lexically guided learning in L2 (English). We plan to examine whether adaptation in L2 takes place in this language group, and if so, whether learning transfers to a related sound category in L1. A lexical decision task and a categorization task will be used to measure boundary shifts in L1 and L2 respectively. A goodness rating task will be used to detect any reorganization in the internal structure of sound categories. Finally, we will assess whether performance on adaptation tasks correlates with some metric of mixed-language experience in daily life, which could allow us to predict individual differences in adaptive behaviour. To achieve the research objectives, an online speech perception experiment will be created using the jsPsych software, and collected data will be subjected to statistical analyses. The results will add to existing empirical data, and expand upon current research questions in perceptual adaptation and bilingualism.

Keywords: Perceptual Adaptation, Speech Accommodation, Vowels, Bilingualism, Lexical cues, L2

Background and Rationale

A remarkable feature of spoken language is that people easily understand each other in spite of enormous phonetic variability in speech (due to physiology, dialects, accents, idiosyncrasies). Perceptual Adaptation (also learning, retuning, or recalibration) is a mechanism which uses the inherent flexibility of our perceptual system to tackle this problem. Upon encountering an unusual pronunciation, listeners can disambiguate it using information present outside the speech signal. This "learning" temporarily alters mental representations of sound categories, and is used to process subsequent speech from the same speaker, enhancing communication. Current research indicates that this ability depends on daily language experience, and varies substantially across language communities and individuals. Therefore, studies on varied populations and languages are required to fully understand it. In bi/multilingual individuals, cross-language effects of perceptual learning can provide insights into how multiple languages are stored and processed in the mind, which has implications for theories of Bilingualism.

Existing work on perceptual adaptation has largely focused on language communities in the West. However, the rich linguistic diversity in India provides ideal conditions under which adaptation is expected to occur. Therefore, this work will add to empirical data by studying perceptual adaptation in a new population—Bengali speakers in India. Widespread multilingualism allows us to

investigate cross-language transfer—following from recent findings, we ask how adaptation in a second language (English) affects the perception of one's native language. The socio-linguistic complexity of English in India leads to considerable individual differences in language experience. Since much of the recent research in perceptual adaptation focuses on individual response patterns, we examine whether greater experience with mixed-language input benefits individuals in adapting to unfamiliar speech. These findings will add to a larger body of research on speech adaptation, which has theoretical implications for understanding language processing in bilingual speakers, and broader practical utility for second language teaching and developing efficient speech-recognition software.

PROJECT DETAILS:

1 Scope

This study examines speech processing in bilingual speakers, using (i) Experimental data from performance on a set of language perception tasks, and (ii) Self-reported data from a language background questionnaire. The study will be conducted online, and no identifying information will be collected. We focus on native speakers of Bengali in India who use English as one of their second languages, and define "bilingualism" as the self-reported regular use of at least two languages. The population sample consists of literate speakers with internet access. The experimental paradigms used in this study are well-established in the literature on speech perception. To elicit the required language experience data, we adapt an existing survey tool to better reflect the multilingual setting of our population of interest. The data will be subjected to between-subject statistical analyses. Potential limitations: i) varying degrees of experience with languages other than English and Bengali, ii) differences in equipment and audio quality among participants, iii) ensuring understanding of instructions and attention to task in a remote study.

2 Literature Review

Perceptual adaptation is the ability of the perceptual system to reorganize in response to encountered stimulus. A seminal study by Norris, McQueen, and Cutler (2003) first demonstrated that upon encountering an atypical pronunciation, listeners can use top-down lexical knowledge to disambiguate it. When participants heard a physically identical sound that was associated with either /f/ or /s/ depending its lexical context, they showed learning in the direction of the associated fricative. Following this, numerous studies have used similar paradigms to probe medium-term perceptual learning in various languages and contexts, using lexical knowledge (Norris et al., 2003; Bruggeman & Cutler, 2020; Chan, Johnson, & Babel, 2020), visual cues (Bertelson, Vroomen, & De Gelder, 2003), orthography (Mitterer & McQueen, 2009) etc.

Reinisch, Weber, and Mitterer (2013) first demonstrated that perceptual learning can occur in L2, despite the postulated difficulties in listening to an L2 compared to L1 (reflected in poorer performance in other tasks like listening in noise (Lecumberri, Cooke, & Cutler, 2010) and coping with dialectal variation (Mitterer & McQueen, 2009)). Confirming this, subsequent studies also attested that L2 immersion, dominance, and phonological similarity with L1 are not prerequisites for learning (Cutler, Burchfield, & Antoniou, 2018, 2019; Drozdova, Hout, & Scharenborg, 2014;

Schuhmann, 2016). However, some adaptation studies have also revealed asymmetries in the extent of learning in L1 and L2 (Cutler et al., 2018; Hanulíková & Ekström, 2017; Schuhmann, 2016). Two explanations have been proposed: (i) Difficulty in processing an L2 compared to L1— Llompart and Reinisch (2019) discovered that non-native L2 contrasts are coarsely differentiated in the phonological system. This suggests that lexically-guided retuning for non-native contrasts in L2 would be more difficult. (ii) Factors related to the sound systems of the two languages, rather than their L1 vs L2 status (e.g., Cutler et al., 2018).
Most studies using the above paradigm have focused on consonant contrasts. Studies on vowel contrasts, though relatively fewer, have generally confirmed retuning (Franken et al., 2017; Chládková, Podlipskỳ, & Chionidou, 2017). A 2017 experiment by Chládková et al. discovered that participants could retune vowel categories (here in L1) using both word and non-word training stimuli. They concluded that in vowels, retuning could be guided by distribution in the input— lexical context is not a prerequisite. This suggests that if perceptual learning in L2 is indeed restricted due to poorer lexical representations, then vowel category retuning might be less susceptible to its effects than consonant contrasts.

The extent of perceptual retuning reflects a measure of flexibility in the sound system of the language. Research on bilingual populations whose L1 use is limited to a very specific set of interlocutors (Dutch émigrés in Australia; Bruggeman & Cutler, 2020, heritage language speakers; Cutler et al., 2019) have shown that the capacity for adaptation may be lost if not "practiced" regularly. These studies conclude that the ability to adapt to non-canonical pronunciations depends on the amount of variability encountered, rather than the overall extent of language use. This was further evidenced in a study by Chan et al. (2020), which found that L2-dominant Cantonese speakers in Vancouver successfully retuned category boundaries in their L1, and task performance was not related to participants' language dominance scores.

Prior research has shown that perceptual retuning is not restricted to the exact set of training materials. Learning can generalize across words (McQueen, Cutler, & Norris, 2006), phonologically related sounds (Kraljic & Samuel, 2006), and speakers (Eisner & McQueen, 2005). A 2013 study by Reinisch first demonstrated that perceptual learning can generalize across languages—training Dutch-English bilinguals to retune the /f/–/s/ contrast in L2 (English) caused a comparable shift in the perception of the /f/–/s/ contrast in L1 (Dutch). Here, the contrast and the respective sound categories were phonetically similar across the two languages. A subsequent study (Drozdova et al., 2014) found that retuning in L1 can affect a phonetically distinct (non-native) category in L2. Drozdova, Van Hout, and Scharenborg (2016) further discovered that modification of a non-native L2 category could be achieved solely through L2 input, without any involvement of L1. As far as we are aware, there is no research yet on whether training in a non-native L2 contrast can affect a native sound category, but data from speech production suggest that L1 patterns do change as a result of L2 learning (Chang, 2012).

3 Present study (extended rationale and novelty)

Retuning in L2 Previous research has demonstrated that perceptual learning depends on the nature of language experience, and varies across language communities. We build on this work by studying perceptual adaptation in a new population—Bengali-English bilingual speakers in India. India has a vast linguistic diversity, and widespread multilingualism. English is taught as an L2 in schools, and used as a lingua franca in most urban, cosmopolitan settings. Although generally

agreeing that Indian English (IE) is a distinct language variety with a specific target phonology, most existing literature has noted extensive regional variation due to L1-influence from different native languages (Sirsa & Redford, 2013; Gargesh, 2008; Thundy, 1976). Thus, listeners encounter a great variety in English pronunciation. At the same time, there is strong social incentive to understand it (both due to its link-language function, and high prestige value). Therefore, it seems reasonable to expect that perceptual learning, as a mechanism that allows for adaptation to individual variability, would be employed in such a setting. In light of previous findings on adaptation in L2 (cf 2), we ask whether Bengali speakers show lexically guided perceptual adaptation in English vowel contrasts. This will be studied using a categorization task.

Cross-language transfer Next, extending the existing line of questioning about the nature of cross-language influence in perceptual learning (cf 2), we ask whether perceptual learning in a non-native L2 contrast can affect a related L1 category. General Indian English (GIE) (Masica, 1972) distinguishes between the low vowel /a/ (car) and the mid-central vowel /ʌ/ (cut), primarily in the vowel height (F1) dimension. Bengali, which lacks a mid-central vowel, does not. Thus, /ʌ/–/a/ is a non-native L2 contrast for our population of interest, and is used in this study. In Bengali, a shift of the /a/ category boundary in the F1 dimension would not endanger contrast with any other vowel. Therefore, such a movement is not expected to be disallowed by language-specific constraints. On the other hand, since the shift would not be phonologically relevant, it is not expected to enhance intelligibility (by disambiguating the speaker's utterances). Therefore, a related question here is whether perceptual learning would transfer across languages even when it is not potentially "useful". Since /ʌ/–/a/ minimal-pair words are not available in Bengali, a lexical decision task will be used to measure shifts in category boundary.

Internal category structure Prior research suggests that perceptual learning leads to not just boundary shifts, but also an internal reorganization of the phonetic category (Xie, Theodore, & Myers, 2017). Since the shift along an /ʌ/–/a/ continuum does not cue a contrast in Bengali, we have no a priori reason to believe that the cross-language transfer of learning (if any) should affect the category boundary in this case. Therefore, we will use a goodness rating test to assess any changes in the internal category structure of the vowels.

Individual differences Finally, given that language experience regulates adaptation, and the majority of existing studies have noted between-subject variation in responses, we ask whether the response patterns of individuals can be explained by some aspect of their daily language use. To this end, we will adapt the Bilingual Language Profile survey tool (Birdsong, Gertken, & Amengual, 2012) to assess whether the extent of adaptation and transfer correlate with the extent of mixed-language input a listener encounters in daily language use.

The research questions in this study can thus be summarized as follows:

(i) Do bilingual speakers retune their perceptual category boundaries for a non-native vowel contrast in L2?

(ii) If so, does this shift affect the structure of a related L1 sound category?

(iii) Does the extent of flexibility in L2 (i), and the transfer between L2 and L1 (ii), within an individual correlate with some metric of multilingual language use in daily life?

Objectives:

(i) Test whether participants' perceptual cateory boundaries of /ʌ/ and /a/ in English shift towards the lexically guided stimuli

(ii) Check for a parallel shift in the category boundary or organization of /a/ in Bengali

(iii) Create a survey tool that quantifies mixed-language use in a multilingual setting, and test if individual scores statistically correlate with performance in adaptation tasks

4 Methodology

4.1 Participants

Bilingual speakers of Bengali and English living in India. Minimum 25 participants in each test condition (total 75). Participants will be recruited online, and remain anonymous.

4.2 Stimuli

All materials will be recorded by a single bilingual speaker of Bengali and English.

Exposure stimuli: A short (approximately 6 minutes; Babel, Senior, & Bishop, 2019) story in English, containing comparable instances of /ʌ/ and /a/ (critical words). Following Chládková et al. (2017), vowels in the critical words will be manipulated using the source-filter resynthesis in Praat (Boersma & Weenink, 2016), to give three versions of the story-

(i) Version A– all instances of /a/ are replaced with a vowel ambiguous between /a/ and /ʌ/; /ʌ/ vowels are unmanipulated

(ii) Version B– converse of (i)

(iii) Control– the original unmanipulated recording

Test stimuli:

(i) English—5 minimal pairs differing in the critical vowel, ex: fur-far

(ii) Bengali—5 monosyllabic words containing /a/ (corresponding non-words by replacing /a/ with /ʌ/ will be recorded for creating the ambiguous items)

Following Chládková et al. (2017), 12-step vowel continua will be created from each word pair, giving 60 critical items in each language. 5 filler-word pairs, which do not contain the target vowels, will also be included (60 filler items).

4.3 Procedure

The experiment will be designed using the jsPsych software, as an online study which can be completed in a single sitting, on a computer/smartphone. Each participant will be randomly assigned to one of three exposure groups- A, B, or Control. A session will consist of these phases:

I. Exposure: The participant will listen to one version of the story (A, B, or Control), i.e. will be exposed either to manipulated /a/ vowels, or manipulated /ʌ/, or unmanipulated vowels

II. Test: The participant will complete four perception tasks– categorization, lexical decision, goodness rating (English and Bengali)– in randomized order. Each test block will be preceded by written instructions in the corresponding language.

III. Language experience questionnaire

Task descriptions:

- Categorization task: To test for shift in category boundary in English. Participants will see two words on the screen (ex: FUR and FAR), and be asked to indicate which one corresponds to the item they hear.
- Lexical decision task: To test for shift in category boundary in Bengali. Participants will hear an item, and be asked to indicate whether it is a real Bengali word.
- Goodness rating task: To test for a change in the category structure of /a/ in Bengali, /a/ and /ʌ/ in English. Participants will hear a word, and be asked to rate how "good" the pronunciation of the specified vowel is, using a 7-point Likert scale.

5 Analysis

(i) Categorization data: Following Chládková et al. (2017), a binomial logistic regression with F1 as the independent variable will be used to determine the vowel category boundary for each participant. A difference between the experimental and control groups (shift in the direction of the exposure-phase stimulus) will indicate that perceptual learning has taken place.

(ii) Lexical decision task: The percentage of "word" responses at each step of the vowel continuum will be calculated. A significantly higher acceptance rate of ambiguous tokens as real words in group A, and lower acceptance rate in group B, compared to the Control group will indicate that perceptual learning has taken place.

(iii) Goodness rating task: Following Xie et al. (2017), individual ratings for each vowel will be converted into z-scores, and a linear mixed effects model in R (R Core Team, 2016) will be used to determine an effect of exposure group on goodness ratings. A significant effect of exposure will indicate that the structure of the sound category has changed due to perceptual learning.

(iv) Individual responses: A correlational analysis between the chosen metric of mixed-language experience and performance scores obtained from (i) and (ii) will be carried out. A significant correlation will suggest that the proposed metric can predict the extent of perceptual learning and transfer in an individual.

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