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Perceptual Categorization of Hñäñho-Specific Vowel Contrasts by Hñäñho Heritage Speakers in Mexico

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Abstract: For a large proportion of Mexican Indigenous speakers, it is common for the use of their native languages to shift across generations towards Spanish, the majority language in Mexico. This specific population can be defined as heritage speakers (HS) of their indigenous language, since many of them are Spanish-dominant bilinguals with a strong connection to their minority native language and culture, both of which they might only maintain in their family home where they were raised. The present study investigates the perceptual sensitivity of HS of Santiago Mexquititlán Otomi (Hñäñho) towards sounds of their native language to examine if these HS can accurately categorize Hñäñho vowels or whether their categorization is influenced by their dominant Spanish vowel system. Twelve Hñäñho HS (HHS) and twelve Mexican Spanish monolinguals (MSM) listened to the Hñäñho-specific vowel contrasts /a – ɔ/ and /ɔ – o/ and categorized them among the vowels of their respective mother tongue. Our results indicate that HHS correctly categorize vowels /a/ and /o/, which exist in both Hñäñho and Spanish, but do not accurately categorize the Hñäñho-specific vowel /ɔ/. Moreover, HHS and MSM showed similar patterns in terms of the proportion of /ɔ/ categorized as either /a/ and /o/. These results have implications for the maintenance of language-specific vowel contrasts and the vowel system of a minority language, such as Hñäñho, in the context of language shift towards Spanish in Mexico.

Keywords: vowel perception; heritage language; minority language; language dominance; language shift; language loss; endangered language; Otomi; Spanish; Indigenous bilingualism

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1. Introduction

In recent years, the study of speech perception in *heritage speakers* (HS) has received increasing attention, possibly due to the fact that phonology seems to be one of the most maintained domains of heritage languages (HL) in HS (Kupisch 2020; Polinsky and Scontras 2020). Some previous studies suggest that HS can maintain perceptual sensitivity to the sounds of their HL (i.e., their mother tongue), even decades after the last constant exposure to the HL occurred (Antoniou et al. 2012; Chang 2016; Lee-Ellis 2012; Lukyanchenko and Gor 2011; Oh et al. 2010; Oh et al. 2003; Tees and Werker 1984). On the contrary, there are also studies that show little to no effect of HL on the perceptual abilities of HS when compared to naïve monolingual listeners (Pallier et al. 2003; Ventureyra et al. 2004). Importantly, the speech perception of HL has not been extensively studied in marginalized HS, such as Mexican Indigenous HS, who differ from prototypical HS in several aspects (Mulík et al. 2021c). Because HS of Mexican indigenous languages are expected to have a larger vowel repertoire than monolingual Mexican Spanish speakers due to early exposure to the HL, experimental perceptual studies with such speakers would not only allow us to confirm our descriptive notions of the language, but also provide evidence that these HS may have the ability to distinguish the sounds of their non-dominant HL, despite being in

extensive contact with Spanish. The present work intends to shed light on these phenomena by investigating perceptual categorization of Hñäñho-specific vowel contrasts by Hñäñho heritage speakers (HHS) and Mexican Spanish monolinguals (MSM).

1.1. Bilingual Speech Perception

Speech perception is an ability that develops early in life, with the perceptual attunement to the sounds of the native language occurring in babies between 6 and 12 months of age (Kuhl 2004). According to the *Native Language Magnet* (NLM) model (Kuhl et al. 2008; Kuhl 1991), newborns differentiate all human speech sounds thanks to general auditory processing mechanisms, but perceptual categories pertinent to their native language are formed according to the distributional properties of the linguistic input during their first year of life. The activation of prototypical representations of native speech segments that act like perceptual magnets increases the perceived similarity between the members of the category, which produces a facilitation in the perception of native sounds and a difficulty in perceiving the sounds of non-native languages (Kuhl et al. 2008).

Bilingual speech perception involves the perception of first language (L1) and second language (L2) sounds. The most popular theoretical models that account for bilingual speech perception are the *Perceptual Assimilation Model of Second Language Speech Learning* (PAM-L2) (Best 1994; 1995; Best and Tyler 2007), the *revised Speech Learning Model* (SLM-r) (Flege 1995; Flege and Bohn 2020), and the *Second Language Linguistic Perception Model* (L2LP) (Escudero 2005; van Leussen and Escudero 2015). These models coincide in that the early exposure to the native language modifies the perceptual system in such a way that the formation of new L2 phonemic categories is influenced by the L1, even despite a relatively early and intensive exposure to the L2 (Best and Tyler 2007; Flege and Bohn 2020; Sebastián-Gallés and Soto-Faraco 1999). Additionally, bilingual speech perception of L1 sounds, particularly relevant for the situation of HS and HL, is also addressed by these models. According to the SLM-r, L1 and L2 perceptual categories can interact with each other and change as a function of input received in both languages (Flege and Bohn 2020). The PAM-L2 also acknowledges that perceptual adjustments related to learning an L2 could result in systematic changes in L1 perception (Best and Tyler 2007). Further, according to the L2LP, L1 perception will be affected by the L2 only if the bilingual does not receive enough L1 input; in other words, to reach an optimal perception in both languages, the bilingual must receive rich input in both the L1 and L2 (Elvin and Escudero 2019).

Taken together, current bilingual speech perception models take into account the dynamic nature of bilingualism and admit changes in L1 perception that was established early in life but seems to depend on the input received in both L1 and L2 during the bilingual's lifetime. HHS who participated in the present study received linguistic input almost exclusively in L1 Hñäñho in their early childhood, followed by Spanish as an L2. In line with the theoretical models reviewed above, perceptual abilities of HHS in L1 Hñäñho should be maintained, given that they continued receiving sustained input in their HL.

1.2. Mexican Indigenous Bilingualism and Hñäñho Heritage Speakers

As a result of the country's colonial past and Castilianizing language policies, the present-day linguistic landscape of Mexico is complex. On the one hand, most people in the country speak the majority language, Spanish, which is also used as the language of instruction in most schools and in mass media, while English is prioritized as the prestigious second language. On the other hand, the Mexican Indigenous population is immensely linguistically diverse, yet underrepresented in number. According to Mexico's National Institute for Indigenous Languages (*Instituto Nacional de Lenguas Indígenas, INALI*), there are 364 different regional language varieties belonging to 68 indigenous language groups and 11 language families (INALI 2008). However, this linguistic diversity is maintained only by the 6.2% of the country's population who at present still speak an indigenous language (INEGI 2021).

One of these languages is Otomi (Otomian < Oto-Pamean < Oto-Manguean), spoken in central Mexico (Lastra 2006). In particular, the regional variety of Otomi that is of concern in the present work is Santiago Mexquititlán Otomi (called *Hñäñho* by its speakers, the *Ñäñhos*), classified as belonging to the Querétaro Otomi variety (Simons and Fennig 2018) or the Low Northwestern Otomi variety (INALI 2008). Like other Otomi varieties, Hñäñho is considered *vulnerable* by UNESCO in terms of language endangerment (Moseley 2010). Although it is common for Ñäñhos to migrate to large urban areas for work, native Hñäñho speakers are typically born and raised in the rural community of Santiago Mexquititlán (Hekking 1995). The first Ñäñhos settled in this area during the Mexican colonial era, but extensive language contact with Spanish occurred only in the last century, when Santiago Mexquititlán was connected to other cities by roads and primary schooling in Spanish gained popularity (Hekking 1995). This contributed to a language shift from Hñäñho towards Spanish, and, in consequence, the vast majority (almost 93%) of Otomi speakers nowadays are Otomi–Spanish bilinguals (INEGI 2011).

In the urban environment, where about one third of all Mexican Indigenous people live, they often face discrimination, poverty, and prejudice that make speaking an indigenous language undesirable, whereas speaking Spanish is considered a valuable commodity (Velasco Ortiz 2007; Pérez Ruiz 2007; Cruz Pérez 2011; Bermeo 2011). Therefore, it is not uncommon for Mexican indigenous language speakers to be HS, since many of them are Spanish-dominant bilinguals with a strong connection to their minority native language and culture, both of which they might only maintain in their household. This is in line with a widely accepted definition of HS (Valdés 2001, 2005; Rothman 2009; Montrul 2013, 2016; Kupisch and Rothman 2018; Polinsky 2018).

Even though the term *HS* has not been traditionally used in Mexico to refer to Indigenous language speakers, Ñäñhos who reside in urban centers in Mexico have been reported to closely coincide with the definitions of HS (Mulík et al. 2021c). For instance, Hñäñho is the minority language used in urban Ñäñho homes, whereas Spanish is the majority language mostly learned either early or later in life as an L2 (Martínez Casas 2000; Guerrero Galván 2009; Mulík et al. 2021a). Notably, the different degrees of Hñäñho–Spanish bilingualism observed among urban Ñäñhos usually comprise limited knowledge of Hñäñho and a progressive gain of language competence in Spanish, which eventually results in a shift in language dominance (Martínez Casas 2000; Guerrero Galván 2009; Canuto Castillo 2015; Vázquez Estrada and Rico García 2016; Mulík et al. 2021a). The relevance of the Ñäñho culture and a strong family connection to the Hñäñho language has been reported to be experienced even by those Ñäñhos who have little to no competence in the minority language (Martínez Casas 2000; Guerrero Galván 2009; Canuto Castillo 2015; Vázquez Estrada and Rico García 2016; Mulík et al. 2021a).

The typical heritage features of urban Ñäñhos seem to be inseparably linked to a set of sociocultural characteristics that are not commonly included in HS definitions elsewhere (Mulík et al. 2021c). For Mexican Indigenous HS, these may include living in a situation of constant social, cultural, and linguistic conflict (Martínez Casas 2000; Canuto Castillo 2015) that stems from the ongoing processes of miscegenation (*mestizaje* in Spanish), discrimination (Martínez Casas 2000; Guerrero Galván 2009; Canuto Castillo 2015; Vázquez Estrada and Rico García 2016), and Castilianization (Guerrero Galván 2009; Canuto Castillo 2015; Vázquez Estrada and Rico García 2016; Mulík et al. 2021a). These, in turn, arise from the unfavorable positioning of the Indigenous people in both the historical and the present-day sociopolitical context of Mexico (López-Beltrán and García-Deister 2013; Plá 2014; Chamoreau 2014).

1.3. The Hñäñho Vowel System

The vowel system of Hñäñho, which consists of nine oral and one nasal vowel phonemes, has been phonologically and acoustically described in relation to the Mexican Spanish vowel system (Hekking et al. 2010, 2014; Mulík et al. 2019, 2021b). Figure 1 shows the ten Hñäñho vowels together with the five Spanish vowels, plotted in terms

of F1 (an acoustic correlate of vowel height) and F2 (an acoustic correlate of vowel frontness/backness) in Hz, as produced by three female, native Hñäñho speakers born between 1956 and 1968 who were also highly proficient in Spanish (Mulík et al. 2021b). Importantly for the present study, none of the Hñäñho vowels produced by these native Hñäñho speakers, who were born in Santiago Mexquititlán but were living in the city of Querétaro, showed any signs of vowel merging that would result in vowel contrast neutralization (Mulík et al. 2021b). This includes the distinct acoustic realization of the Hñäñho vowel /ɔ/, which is thus phonetically different (in terms of its F1 and F2) from all adjacent Hñäñho vowels (including the vowels /a/ and /o/) (Mulík et al. 2021b).

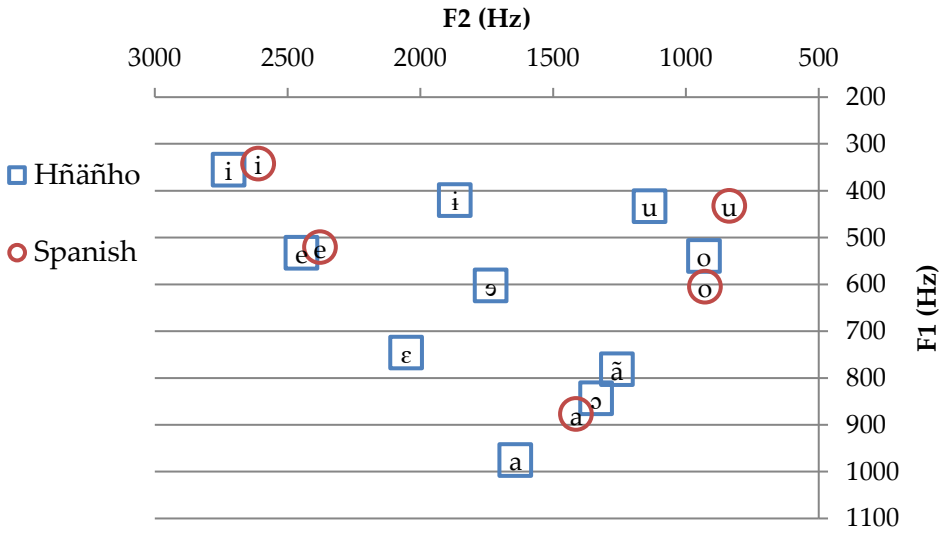


Figure 1. The vowel system of Hñäñho (vowel tags in blue squares) and Mexican Spanish (vowel tags in red circles) as produced by three female, native Hñäñho speakers highly proficient in Spanish. Vowel tags represent the mean of all produced vowel tokens (also see Mulík et al. 2021b).

According to Hekking et al. (2010, 2014), Hñäñho vowels /a e i o u/ are pronounced similarly to the Spanish vowels /a e i o u/, and the remaining Hñäñho vowels /ɨ ɛ ɘ ɔ ɜ/ are acoustically distinct from the neighboring Spanish and Hñäñho segments. Contrary to this claim, Figure 1 shows that Spanish /a/ seems to be pronounced acoustically closer to the Hñäñho vowel /ɔ/ instead of the Hñäñho vowel /a/ as expected. Indeed, the phonetic realization of the Hñäñho vowel /ɔ/ is the open back rounded vowel [ɒ], acoustically closer to the Hñäñho vowel /a/ than to the Hñäñho vowel /o/ (Mulík et al. 2021b). This would be in line with the claim that the Hñäñho vowel /ɔ/ is pronounced acoustically closer to /a/ but with slightly rounded lips (Hekking et al. 2010, 2014). This proximity in acoustic space between the Spanish vowel /a/ and the Hñäñho vowels /ɔ/ and /a/ could eventually result in vowel merging and neutralization of the Hñäñho-specific /a – ɔ/ vowel contrast. In fact, this has already been observed in other varieties of Otomi, especially in those pertaining to the northwestern dialects to which Hñäñho belongs (Butragueño 2004).

1.4. The Present Study

While other Otomi varieties (Cadereyta, Jilotepec, Mezquital, and Mintehe Otomi) have undergone a loss of the vowel /ɔ/ (Butragueño 2004), there is evidence that older Hñäñho speakers acoustically maintain the vowel /ɔ/ in their production as a distinct phoneme (Mulík et al. 2021b). What remains unclear is the exact status of the Hñäñho vowel /ɔ/ for younger HHS, especially considering the ongoing language shift from Hñäñho towards Spanish that is at play among HHS. Therefore, the aim of this study is to present novel data on the perceptual abilities of HHS towards the Hñäñho vowel /ɔ/ by examining how HHS categorize Hñäñho vowels /a/, /ɔ/, and /o/. More specifically, this work

investigates whether HHS accurately identify all three Hñäñho vowels or whether their categorization is influenced by their dominant Spanish vowel system.

In order to meet these objectives, we recruited a group of HHS and a group of MSM who listened to four Hñäñho words, corresponding to three distinct vowels from two Hñäñho-specific vowel contrasts /a – ɔ/ and /ɔ – o/, and categorized them among the vowels of their respective mother tongue (Hñäñho for HHS and Spanish for MSM). The results of this experiment enable us to evaluate the ability of HHS to correctly categorize not only the Hñäñho words /pa/ and /do/ that contain vowels that exist in Spanish, but also the Hñäñho words /pɔ/ and /dɔ/ that contain the vowel /ɔ/ relevant for Hñäñho but not for Spanish. We hypothesize that HHS will show a similar proportion of correct categorization counts for all three Hñäñho vowels, which would confirm the notion that HS can maintain the phonology of their HL despite not using it regularly (Kupisch 2020; Polinsky and Scontras 2020). Contrary to this hypothesis, HHS could alternatively perceive the vowel /ɔ/ as /a/, which would point towards a possible perceptual loss of this vowel in HHS due to pervasive influence from Spanish. Additionally, the categorization results of the Hñäñho vowel /ɔ/ obtained from MSM will help to clarify the exact status of this vowel in its relation to monolingual Mexican Spanish.

2. Methodology

2.1. Participants

The perceptual experiment was conducted with a total of 24 participants. Half of the participants belonged to the HHS group, which consisted of 12 Hñäñho–Spanish bilinguals with an age range of 18–43 years (mean age = 29.9, SD = 8.9). All participants in the HHS group were native Hñäñho speakers who had acquired Spanish either simultaneously with Hñäñho or as an early-onset L2. Their ages of L2 Spanish acquisition ranged from 0 to 11 years (mean age = 4.6, SD = 3.9). The second group of participants consisted of 12 MSM with an age range of 18–42 years (mean age = 29.4, SD = 7.0). All participants in the MSM group exclusively spoke Spanish and had never been exposed to Hñäñho. In order to ensure that the two groups were comparable, they were matched in terms of age and educational level. All participants were right-handed and reported normal or corrected-to-normal vision and no hearing problems. Before the experiment took place, they signed an informed consent form.

The Bilingual Language Profile (BLP) questionnaire was used to assess the language dominance of HHS (Birdsong et al. 2012). The BLP uses a self-report to produce a general bilingual profile and a continuous dominance score. The four modules of the BLP (language history, language use, language proficiency, and language attitudes) receive equal weighting, and the dominance score is calculated by subtracting the Spanish score from the Hñäñho score, with positive numbers yielding Hñäñho-dominance, negative numbers yielding Spanish-dominance, and numbers close to zero yielding balanced Hñäñho–Spanish bilingualism (Gertken et al. 2014). According to the BLP, the HHS participant group was Spanish-dominant, since their average dominance score was –60 (SD = 35) on a scale from –218 (completely Spanish-dominant) to 218 (completely Hñäñho-dominant).

2.2. Materials

Audio recordings of four monosyllabic Hñäñho words bearing low tone were used as auditory experimental stimuli. One minimal pair was carefully selected for each of the two studied contrasts so that the words in each pair would only differ in the vowel of interest (*Hñäñho spelling*/phonological transcription/'English translation'): *do*/do/'rock' and *da̲*/dɔ/'eye' for the /o – ɔ/ contrast; *pa*/pa/'day' and *pa̲*/pɔ/'snake' for the /a – ɔ/ contrast. Three different female native speakers of Hñäñho (aged 50, 54, and 62) recorded 20 instances of all four Hñäñho words. According to the BLP, they were balanced Hñäñho–Spanish bilinguals, since their average dominance score was –8 (SD = 52) on a scale from –218 (completely Spanish-dominant) to 218 (completely Hñäñho-dominant). The recording took place in a sound-attenuated booth with the speakers comfortably seated at the same

table as the researcher. The stimuli were recorded using a head-mounted microphone (Shure SM10A) and a solid-state digital recorder (Marantz PMD660), digitized (44 kHz, 16-bit quantization), and computer-edited for subsequent acoustic analysis. All tokens were automatically extracted in *Praat* (Boersma and Weenink 2020), and two acoustic realizations were selected for each of the four Hñäñho words, so that each contrast contained recordings from two different speakers. This selection was based on the vowel formant values closest to the F1 and F2 mean for each recorded vowel category, as well as on similarities regarding vowel pitch (f0), both speaker-internally and across speakers. The eight selected experimental tokens were adjusted for volume intensity (Praat Vocal Toolkit: function *Normalize*) and, for the recordings to sound as natural as possible, a fade-out effect was added to the last 50 ms of the 200 ms stimulus (Praat Vocal Toolkit: function *Fade* . . .). The experimental stimuli are represented in Figure 2 in terms of vowel formants F1 and F2.

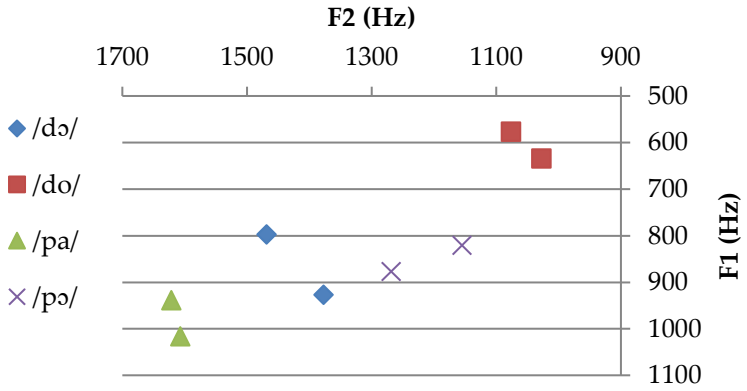


Figure 2. The stimuli used in the experiment. The Hñäñho vowels contained in the stimuli are plotted in terms of the vowel formants F1 and F2.

2.3. Procedure

Before the experiment, the participants belonging to the HHS group filled out the BLP language dominance questionnaire (Birdsong et al. 2012). In the experiment, all 24 participants sat in front of a computer screen in a sound-attenuated room and completed the experimental task in an individual session. The auditory stimuli were delivered by means of earphone inserts (Compumedics NeuroScan, Charlotte, CA, USA), and the instructions were presented at the center of the screen in white font on a black background. Participants' responses were recorded by means of a Cedrus Response Pad RB740 (Cedrus Corporation, San Pedro, CA, USA).

In the task, HHS and MSM were evaluated on the categorization of the four Hñäñho words containing the three selected Hñäñho vowel phonemes /a/, /ɔ/, and /o/ among the vowels of either Hñäñho (HHS) or Spanish (MSM). Participants listened to the four Hñäñho words containing the vowels of interest (/pa/, /pɔ/, /do/, and /dɔ/) pronounced by three native Hñäñho speakers. MSM decided which Spanish vowel from their mother tongue was the most similar to the vowel contained in the Hñäñho word they just heard, while HHS decided which Hñäñho vowel was contained in the Hñäñho word they just heard. The words were played through the earphones one by one, and the whole set of words was repeated three times in a randomized order. After hearing each word, participants pressed a button on the Response Pad according to their decision. For HHS, each of the seven buttons was assigned one of the seven vowels of Hñäñho that were the closest to the vowels from the studied contrasts (/ã a ɔ o ə u ɛ/), whereas for MSM only five buttons were used since Spanish has five vowels in total (/a e o i u/). Monosyllabic words containing the vowel of interest were written above the buttons for both Hñäñho (Table 1) and Spanish (Table 2). For Hñäñho only, the Hñäñho words were illustrated by simple pictures placed below the buttons to avoid any confusion. In order to assure that correct vowels were being understood by these visual aids, participants read all the words and/or named the pictures, translated them into Spanish, and were asked to identify the vowel of interest in each word

before carrying out the task. After the experiment, percentages of the assigned vowels from participants' respective native language were calculated for both words in each vowel contrast.

Table 1. The Response Pad visual aid in Hñäñho for the HHS group.

	Button 1	**Button 2**	**Button 3**	**Button 4**	**Button 5**	**Button 6**	**Button 7**
Hñäñho word	*ñä*	*wa*	*xa*	*'yo*	*ngo*	*gu*	*'ye*
Pronunciation	/ɲã/	/wa/	/ʃɔ/	/ʔjo/	/ngɵ/	/gu/	/ʔjɛ/
English translation	'head'	'foot'	'fingernail'	'dog'	'meat'	'ear'	'hand'

Table 2. The Response Pad visual aid in Spanish for the MSM group.

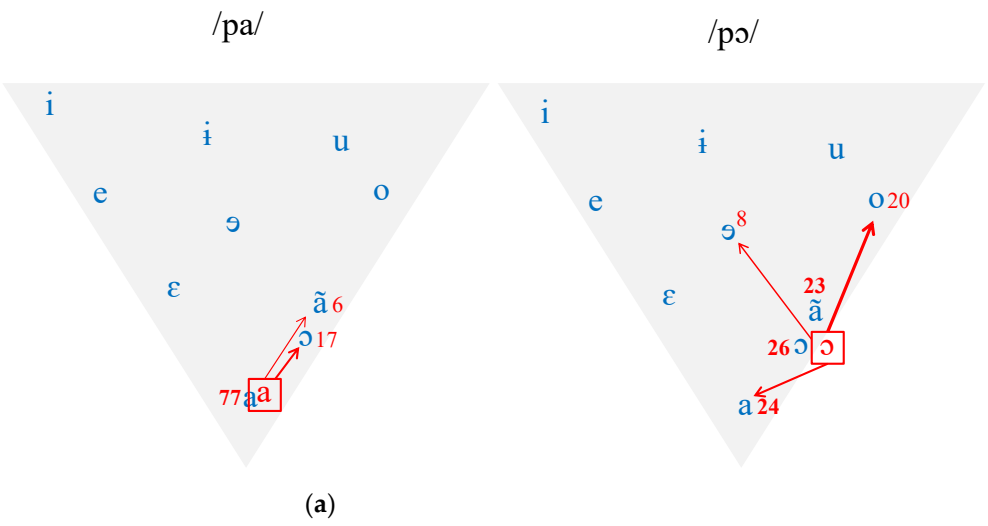
	Button 1	**Button 2**	**Button 3**	**Button 4**	**Button 5**	**Button 6**	**Button 7**
Spanish syllable	-	*sa*	*se*	*so*	*si*	*su*	-
Pronunciation	-	/sa/	/se/	/so/	/si/	/su/	-

2.4. Data Analysis

The data obtained from the experiment were analyzed for each participant group separately. Data from one HHS participant were removed from the analysis due to the participant not having carried out the task correctly (i.e., did not seem to understand the task and randomly pressed all available buttons independent of the auditory stimulus that was presented). The percentage of total categorization counts for each vowel was calculated by dividing the total of counts for each vowel among all participants in each group by the total of counts for all vowels in each language.

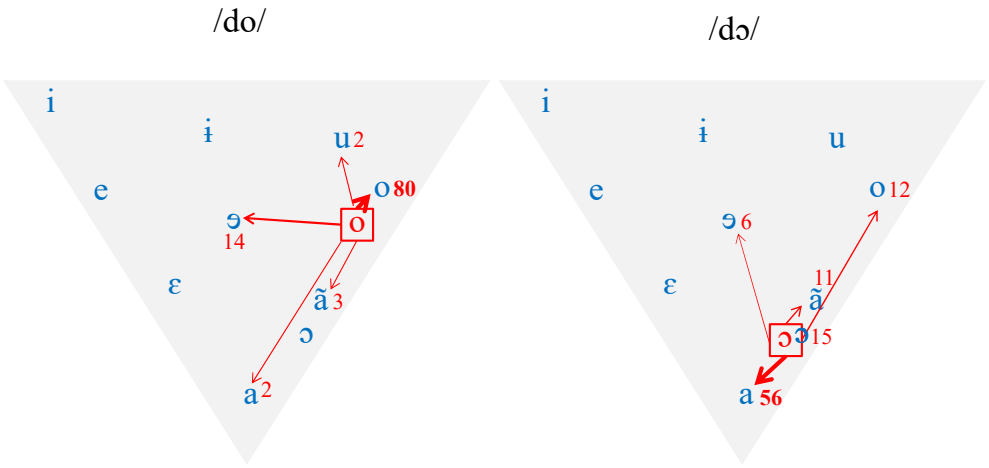
3. Results

Figures 3 and 4 show the vowel categorization results for the HHS group and the MSM group, respectively. The spatial distribution of the blue vowels in these figures is based on the bilingual data plotted in Figure 1. The spatial distribution of the red vowels reflects the mean values of the actual stimuli used in the experiment, plotted in Figure 2.



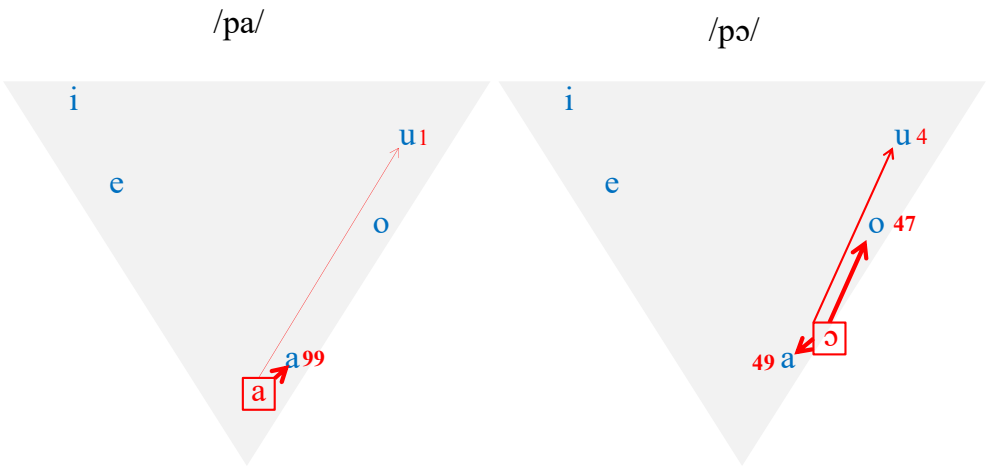
(**a**)

Figure 3. *Cont.*

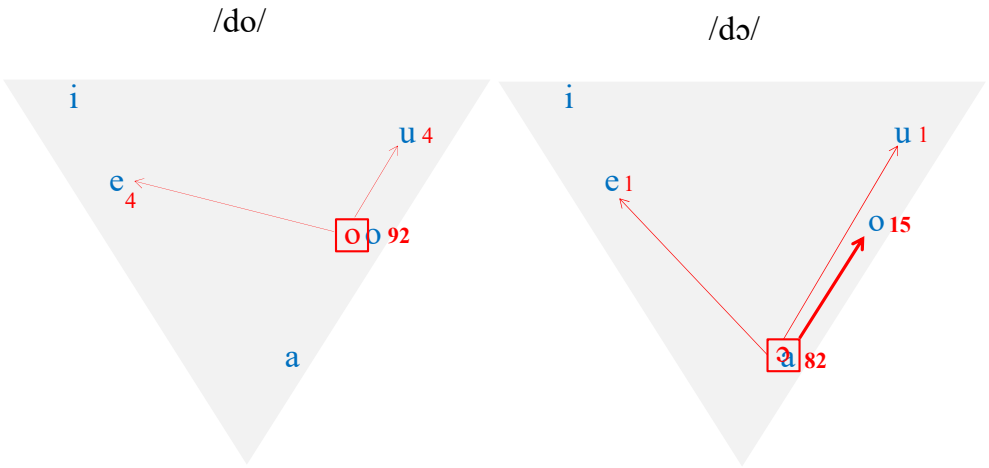


(**b**)

Figure 3. The percentage of Hñäñho words categorized as containing Hñäñho vowels by Hñäñho heritage speakers (HHS): (**a**) the /a – ɔ/ vowel contrast; (**b**) the /o – ɔ/ vowel contrast.



(**a**)



(**b**)

Figure 4. The percentage of Hñäñho words categorized as containing Spanish vowels by Mexican Spanish monolinguals (MSM): (**a**) the /a – ɔ/ vowel contrast; (**b**) the /o – ɔ/ vowel contrast.

3.1. The / a – ɔ */ Vowel Contrast*

Figure 3 shows that HHS categorized the Hñäñho word /pa/ as containing the Hñäñho vowel /a/ more accurately (77%) than the word /pɔ/ as containing the Hñäñho vowel /ɔ/ (26%). The Hñäñho vowel /a/ in /pa/ was also categorized by HHS as the Hñäñho vowel /ɔ/ (17%) and the only Hñäñho nasal vowel /ã/ (6%), while the Hñäñho vowel /ɔ/ in /pɔ/ was also categorized by HHS as the Hñäñho vowels /a/ (24%), /o/ (20%), and /ã/ (23%). In other words, HHS showed a clear tendency to correctly categorize the Hñäñho vowel /a/, but they were much more hesitant in their categorization of the Hñäñho vowel /ɔ/, which on average received similar percentages within four different Hñäñho vowel categories (/ɔ/, /a/, /o/, and /ã/). However, individual HHS participants provided very heterogeneous responses. These results suggest that HHS do not accurately perceive the Hñäñho vowel /ɔ/, or at least that there is much variability in the categorization of the HHS who participated in this study. Both of these notions were confirmed by the higher variability of answers for /ɔ/ than for /a/ in the categorization data of the individual participants from the HHS group.

On the other hand, MSM (Figure 4) categorized the Hñäñho vowel /a/ contained in the Hñäñho word /pa/ almost exclusively as the Spanish vowel /a/ (99%), whereas most instances of the Hñäñho vowel /ɔ/ contained in the Hñäñho word /pɔ/ were categorized by MSM either as the Spanish vowel /a/ (49%) or the Spanish vowel /o/ (47%). These findings have a few interesting implications. Firstly, the Hñäñho vowel /ɔ/, as produced in the Hñäñho word /pɔ/, seems to be acoustically perceived as a vowel roughly half-way between the Spanish vowels /a/ and /o/, which is not in line with previous observations that place the Hñäñho vowel /ɔ/ acoustically closer to the Spanish vowel /a/. Secondly, the proportions of the Hñäñho vowel /ɔ/ categorized as the neighboring vowels were very similar for the HHS (24%, 26%, 20%, and 23% for /a/, /ɔ/, /o/, and /ã/, respectively) and for the MSM (49% and 47% for /a/ and /o/, respectively), implying that both participant groups do not possess Hñäñho /ɔ/ in their vowel inventory, and, as a result, both participant groups categorize this vowel as any other available neighboring sound in their vowel system during the categorization task. This would suggest that HHS do not maintain the same Hñäñho vowel system in this perception task as the older Hñäñho speakers who produced the words used in the present study (Figures 1 and 2).

*3.2. The /*o – ɔ*/ Vowel Contrast*

Figure 3 shows that the HHS group categorized the Hñäñho word /do/ as containing the Hñäñho vowel /o/ more accurately (80%) than the word /dɔ/ as containing the Hñäñho vowel /ɔ/ (15%). This finding is in line with the results of the /a – ɔ/ vowel contrast categorization. However, the Hñäñho vowel /ɔ/ in /dɔ/ was most commonly categorized by HHS as the Hñäñho vowel /a/ (56%). These results suggest that, similarly to the Hñäñho vowel /a/, HHS perceive the Hñäñho vowel /o/ as such; however, this is not the case of the Hñäñho vowel /ɔ/ in /dɔ/, which seems to be perceived by HHS mostly as /a/. It is interesting to note that this result does not completely mirror our results on the perception of the Hñäñho vowel /ɔ/ as produced in /pɔ/ when contrasted with /a/ in /pa/, in that /ɔ/ in /dɔ/ is perceived acoustically closer to /a/ than in the case of /ɔ/ in /pɔ/. This implies that both the production and perception of the Hñäñho vowel /ɔ/ is inherently variable and especially difficult to categorize accurately.

As shown in Figure 4, MSM categorized the Hñäñho vowel /o/ from the Hñäñho word /do/ almost exclusively as the Spanish vowel /o/ (92%), whereas most instances of the Hñäñho vowel /ɔ/ contained in the Hñäñho word /dɔ/ were categorized by MSM as the Spanish vowel /a/ (82%), followed by the Spanish vowel /o/ (15%). These results reveal similarities in the proportion of the Hñäñho vowel /ɔ/ categorized as the vowels /a/ and /o/ for both the HHS (56% vs. 12%) and for the MSM (82% vs. 15%). In addition, the data show that both the HHS and MSM speakers perceived the Hñäñho vowel /ɔ/, produced in the Hñäñho word /dɔ/, as a vowel that is acoustically close to the Spanish vowel /a/, which is in line with the previous observations that place the Hñäñho vowel

/ɔ/ close to the Spanish vowel /a/. Even though this result was not as robust in the case of the Hñäñho vowel /ɔ/ when produced in the Hñäñho word /pɔ/, the variability in the categorization of this vowel in each stimulus provides further evidence that the boundaries of the marginally contrastive Hñäñho vowels /ɔ – o/ and /ɔ – a/ are fuzzy, resulting in perceptual difficulties when categorizing the Hñäñho-specific vowel /ɔ/.

4. Discussion and Conclusions

The main aim of this work was to examine the perception of Hñäñho-specific vowel contrasts and particularly to better understand the current status of the Hñäñho vowel /ɔ/ in its relationship to other Hñäñho and Mexican Spanish vowels. By means of a perceptual experiment, we investigated how HHS and MSM categorize Hñäñho vowels /a/, /ɔ/, and /o/ belonging to two Hñäñho-specific vowel contrasts /a – ɔ/ and /o – ɔ/. The results showed that HHS are capable of correctly categorizing Hñäñho vowels /a/ and /o/, which also exist in Spanish, whereas they are not as accurate categorizing the Hñäñho vowel /ɔ/, which does not exist in Spanish. Therefore, these findings do not confirm the hypothesis that HS maintain the phonology of their HL (Kupisch 2020; Polinsky and Scontras 2020). In this case, the Hñäñho vowel categorization seems to be influenced by the dominant Spanish vowel system of the HHS, which they use more regularly than their HL.

The HHS and MSM showed similar behavioral patterns in terms of the proportion of /ɔ/ categorized as either /a/ and /o/. For the /a – ɔ/ vowel contrast, the Hñäñho vowel /ɔ/ was categorized evenly among /a/ and /o/ by both participant groups, whereas for the /o – ɔ/ vowel contrast, the Hñäñho vowel /ɔ/ was mostly categorized as /a/ by both participant groups. This result shows that the HHS are unable to categorize /ɔ/ accurately and that their perceptual patterns resemble those of the MSM speakers (who had never been exposed to Hñäñho). These findings demonstrate that there is high variability in the categorization of the Hñäñho-specific /ɔ/ vowel, and that the boundaries of this vowel phoneme with the neighboring acoustic segments are fuzzy, and therefore vulnerable to contact-induced change resulting in the loss of these Hñäñho vowel contrasts. In this categorization task, both participant groups seem to have used the same vowel system (of Spanish, their dominant language) to categorize the Hñäñho vowels, which would be in line with the effects of language shift on the vowels of two languages in contact (Amengual and Chamorro 2015; Bullock and Gerfen 2004; Guion 2003), in which there is a simplification of the Hñäñho vowel system to become more Spanish-like. The results of this experiment also show that the Spanish vowels /a/ and /o/ and the Hñäñho vowels /a/ and /o/ are perceived as being acoustically very similar as suggested by Hekking et al. (2010, 2014).

In a recent production study with older native Hñäñho speakers (Mulík et al. 2021b) there was no evidence of a simplification of their Hñäñho vowel system. It is important to note that the participants in Mulík et al. (2021b) were balanced Hñäñho–Spanish bilinguals from a generation earlier than that of the HHS who participated in the present study. These results suggest that there is a rapid intergenerational language shift from Hñäñho towards Spanish in the Hñäñho-speaking community in Querétaro, which matches the situation that has already been reported among Ñäñhos residing in Mexico City (Canuto Castillo 2015).

It could be also argued that poor perceptual categorization of the Hñäñho vowel /ɔ/ in comparison to the Hñäñho vowels /a/ and /o/ by HHS might occur in combination with or in addition to contact-induced change from Spanish due to Hñäñho-internal, phonetic factors. For the present-day generation of HHS, the acoustic proximity of the Spanish vowel /a/ and the Hñäñho vowels /ɔ/ and /a/ may already be causing vowel merging and neutralization of the Hñäñho-specific /a – ɔ/ vowel contrast, previously reported in other northwestern Otomi dialects (Butragueño 2004). This would result in correct perceptual categorization of the Hñäñho vowels /a/ and /o/ and poor perceptual categorization of the Hñäñho vowel /ɔ/, as observed in this categorization experiment.

Theoretical models of bilingual speech perception have postulated that not only L2 perception but also L1 perception can change during lifetime as a function of the amount of linguistic input received in both languages of the bilingual individual (Best and Tyler 2007; Flege and Bohn 2020; Elvin and Escudero 2019). The results of the present study suggest that HHS may not have received sufficient and sustained input in their HL to be able to maintain the perceptual sensitivity to native Hñäñho speech sounds they may have once possessed as children. This points towards the importance of the linguistic input in the HL to be not only *early*, but also *constant* during the lifespan of the HS.

Whether the apparent loss of the perceptual abilities of the HHS for the Hñäñho vowel /ɔ/ is caused by language-internal factors or by changes in the vowel system as a result of extensive contact with Spanish and a shift in Spanish language dominance in the Hñäñho-speaking community in Querétaro should be tested by collecting production and perceptual categorization data from younger native Hñäñho speakers who reside in Santiago Mexquititlán. This language shift towards Spanish seems to be occurring even in the native Ñäñho community of Santiago Mexquititlán, albeit probably not as rapidly as in the cities (Bermeo 2011). In such a case, both urban and rural HHS would continue to be important perpetuators of the Ñäñho culture as well as the most valuable source of information on this vulnerable Mexican indigenous language. It is therefore important to recognize their status as HS and build on the research available in the field of HS and HL. A limitation of this study is the relatively reduced number of experimental tokens that examined two phonological contexts for the vowel of interest, namely /pV/ and /dV/. Perceptual studies that include /ɔ/ in other phonetic environments, using nonce words, will enable a more fine-grained analysis of the perceptual difficulties that have been presented in the current study to confirm that these HHS seem to be unable to categorize this Hñäñho-specific vowel accurately. Additionally, future work will benefit from the use of other research methods for the study of vowel perception, such as the Event Related Potentials (ERPs), to investigate the perceptual abilities of HS of Mexican indigenous languages in a manner similar to how they are used with other bilingual speakers of majority languages (Dehaene-Lambertz 1997; Frenck-Mestre et al. 2005; García and Froud 2018; Näätänen et al. 1997; Rivera-Gaxiola et al. 2000) since they not only provide information on the end state of the cognitive processes that underlie vowel perception, but will also inform us on their time course and their distribution in the brain.

The results reported in the present study have implications for Mexican Indigenous bilingualism, as well as for speech perception in heritage speakers more generally. In the absence of monolingual or balanced bilingual speakers of Mexican indigenous languages, HS are able to provide relevant data on these HL that are in the process of language shift towards Spanish. The findings in this study suggest that being an HS of an endangered indigenous language in the urban Mexican context does not seem to be sufficient for the maintenance of some perceptual abilities in the HL. This observation may be linked to language-internal phonetic factors, the contact-induced change from Mexican indigenous languages towards Spanish, or the situation of social, cultural, and linguistic conflict their speakers experience. In closing, Mexican Indigenous bilingualism as a field of study should not only consider the dynamic and unbalanced character of HS and HL, but also aim at helping to preserve and revitalize these languages which, together with their speakers, represent the country's invaluable (yet vulnerable) cultural and linguistic heritage.

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