Optionality and locality: Evidence from Navajo sibilant harmony

Abstract: While many phonological processes are local, consonant harmony is of interest phonologically because it can occur non-locally. Sibilant harmony in Navajo requires that sibilants within a word have matching anteriority specifications. The process is described as being sometimes mandatory and sometimes optional, but neither the statistical nature of the occurrence in optional settings nor the factors contributing to the optionality are fully understood. This paper provides preliminary investigation into these issues using the first person possessive morpheme, which is underlyingly /ʃi-/ but may harmonize to [si-]. Experiment 1, an online grammaticality judgment survey, reveals that the harmonized prefix is dispreferred in all environments. Experiment 2 presents acoustic data from three Navajo speakers: though none harmonize overtly, the spectral mean and lower bound of frication energy of the prefixal fricative are affected by the presence of [+anterior] sibilants in noun stems. The overall implication of these findings is that harmony is not only optional but is dispreferred or wholly absent for some speakers. While multiple factors are investigated, the only one that consistently affects harmony is adjacency of the trigger and target, indicating that, although consonant harmony may indeed be a non-local process, its occurrence is heavily mediated by distance.

1 Introduction

Sibilant harmony in Navajo is a phonological phenomenon requiring sibilants within a word to have identical specifications for anteriority, such that a word can contain alveolar sibilants or palatal sibilants but may not contain both. This has been referred to as a distance-dependent process, occurring mandatorily when sibilants are adjacent to one another and optionally when they are non-adjacent (Sapir and Hoijer 1967). Neither the factors contributing to the optionality nor the statistical nature of the variation in optional settings is fully understood, however. Two studies designed to investigate the extent to which harmony occurs in optional settings are presented herein.
The existing literature on consonant harmony commonly recognizes that harmony relationships are predicated on some shared degree of similarity (Hansson 2001; Rose and Walker 2004; Wayment 2009), and that first-order nonlocal harmony processes – meaning those wherein the harmony trigger and target may be separated by vowels but not by intervening consonants – are privileged over second-order nonlocal processes (those wherein additional consonants may intervene between target and trigger) (Finley 2011). Thus while sibilants in general are involved in the harmony relationship in Navajo, it might be expected that optional harmony is more likely to occur when sibilants are nearer to one another, separated only by vowels, and are most similar to one another.

The most startling finding presented herein is that harmony is far less robust in Navajo than expected. Grammaticality judgments elicited from native speakers reveal that harmony is dispreferred across the board, but is deemed less ungrammatical when the trigger and target are in adjacent syllables, separated only by vowels. These findings raise a critical point. Consonant harmony in general – and sibilant harmony in Navajo in particular – commonly enter the dialogue about non-local and optional processes, but such discussion should be undertaken with care. In the absence of quantitative data regarding such processes, we cannot make assumptions about the robustness with which they occur.

1.1 Consonant harmony

Broadly, harmony systems within languages require participating segments to agree with regards to specific features. Vowel harmony systems, which have been well-documented, may require some or all vowels in a word to agree for backness, roundness, or advancement of tongue root (Bakovic 2000). Consonant harmony is a less common phenomenon, the characteristics of which – including the type of segments that are affected and the reach of the agreement constraints imposed by harmony – vary crosslinguistically. A key feature of this phonological process, however, is that intervening segments not involved in the harmony relationship are unaffected (Hansson 2001; Rose and Walker 2004). This is illustrated in (1) with an example of nasal assimilation from Kikongo, a Bantu language.

(1) a. m-[bud-id]
   ‘I hit’
   b. tu-[nik-ini]
   ‘we ground’ (from Piggott 1996, in Rose and Walker 2004: 475)
In (1a) and (1b), brackets enclose stems and suffixes. As seen above, the voiced oral stop in the suffix assimilates in nasality when a voiced nasal appears earlier in the stem. The intervening segments do not block the process; the only segments that participate are the nasal, which is the trigger, and the voiced oral stop, which is the target. It is important to note that distance can be measured in various ways – by segments, by syllables, by morphemes, and so on. In Kikongo, the number of intervening segments within the stem does not matter, but the stem boundary does: the trigger can be at any distance from the target as long as it is within the domain of the stem. As seen in (1a), nasals outside of the stem do not trigger harmony. Note that the example seen in (1b) is an illustration of second order non-local harmony as defined by Finley (2011): the harmony trigger and target are separated not only by vowels but also by the intervening [k], which neither participates in nor blocks the harmony process.

In a typology of attested consonant harmony systems, Hansson (2001: 55) finds sibilant harmony to be the predominant type of consonant harmony, accounting for roughly one third of the harmony systems surveyed. The indigenous North American language families most often discussed with regards to sibilant harmony are the Chumashan family and the Athabaskan family, of which Navajo is a member.

### 1.2 Sibilant harmony in Navajo

Navajo is an indigenous North American language spoken in what is now the southwest corner of the United States. It is useful to present some facts about Navajo that will come back up in the discussion with regards to their possible influence on the findings presented herein: namely, Navajo is an endangered language, and revitalization efforts are underway. The Ethnologue reported 149,000 speakers of Navajo based on figures from the 1990 U.S. Census, and an increase to 171,000 speakers based on the 2010 U.S. Census. Currently, revitalization efforts include Navajo language classes and bilingual/biliterate instruction at the elementary, intermediate, and high school levels (Medina 1998; Benally and Viri 2005; Shepard 2012).

While the Census data regarding speaker numbers is a positive sign, and seems to indicate that the language is growing stronger or healthier rather than continuing to diminish, the Ethnologue still lists the language’s status as “threatened”, and Navajo scholars and linguists are cautious. This caution is on display when Schaengold writes in the abstract of a 2004 dissertation on bilingual Navajo that “enormous efforts are being made in Navajoland to slow the language’s decline” (ii). The sense is that while the number of speakers may be on
the rise, Navajo remains vulnerable. The pressure exerted on Navajo by English is ever-present, and perhaps increasing, due at least in part to the influences of mass media and public education (Benally and Viri 2005), and most speakers are bilingual. Only 7,600 of the 171,000 speakers cited in the Ethnologue are monolingual. Again, issues such as the possible influence of bilingualism, pressure from English, and learning Navajo in school rather than in the home will become important in later discussion.

A general phonotactic constraint within Navajo disallows sibilants of conflicting anteriority values within a word (McDonough 2003; Martin 2005). Participating segments are presented in (2).

(2) Navajo sibilants

\[
\begin{align*}
\text{[+anterior]} & /s/ /z/ /\text{'s}/ /\text{'s}h/ /\text{'s}'/ \\
\text{[−anterior]} & /ʃ/ /ʒ/ /\text{'ʃ}/ /\text{'ʃ}h/ /\text{'ʃ}′/
\end{align*}
\]

In this paper, [+anterior] and \textit{alveolar} are used interchangeably, as are [−anterior] and \textit{palatal}. This constraint functions as a morpheme structure constraint, ensuring that roots containing a mismatch such as *[tsoof] or *[tʃoos] do not exist in Navajo. Furthermore, when morpheme concatenation creates a disagreement in a word, prefixal sibilants assimilate to match the anteriority of following sibilants. The process is overwhelmingly anticipatory in Navajo, with the rightmost sibilant in a word controlling the anteriority specification of all other sibilants. If the root contains no sibilants, prefixes may assimilate to the anteriority value of subsequent prefixes.

Harmony is commonly discussed as being mandatory in some environments in Navajo – within certain domains of verbal morphology, for example (Fountain 1998; McDonough 2003; Weisser 2008) – but disharmony is sometimes tolerated. Sapir and Hoijer (1967: 14) note that harmony is “not compulsory,” stating that it is in part “conditioned by the distance between the prefix consonant and that to which it is assimilated.” This is demonstrated in (3–5). Triggers are underlined with a single line, and targets with a double line.

(3) a. [yiʃtʃid]

‘to scratch it’

b. [yiʃtsiʃs]

‘to drag it’ (from McDonough 2003, p. 50)

\footnote{[−anterior] segments in Navajo are sometimes referred to as postalveolar, but I consistently use the term palatal.}
(4) a. [siʔą́]  
   ‘a round object lies’

b. [ʃi-ʔaa]  
   ‘a mass lies’ (from Sapir and Hoijer 1967, p. 15)

The underlyingly palatal sibilant in the prefix surfaces faithfully in (3a), but harmonizes to [s] when affixation causes it to be adjacent to an alveolar sibilant in (3b). In (4), the underlyingly alveolar [s] in the prefix surfaces faithfully in (4a), but harmonizes when affixed to a stem containing a palatal sibilant in (4b). Note that in (3b), the sibilants are adjacent to one another segmentally, while in (4b) the sibilants are in adjacent syllables. Sapir and Hoijer (1967: 14–15) make no distinction between these two types of adjacency, saying only that “assimilation nearly always occurs when the two consonants are close together, but it occurs less often when the two consonants are at a greater distance.” The example in (4b), however, can be referred to as local harmony, as no consonant intervenes between the trigger and target.

Examples (3) and (4) can be contrasted with (5), in which harmony is optional.

(5) a. [ʔa-ʃii-ɬtáás]  
   ‘he (4th p.) bends things’

OR

b. [ʔa-sii-ɬtáás]  
   ‘he (4th p.) bends things’ (from Sapir and Hoijer 1967, p. 15)

This is an instance of a nonlocal harmony environment: the underlying palatal sibilant in the prefix in (5) is at a distance from the sibilants in the root, and is separated by both consonants and vowels. In this environment, harmony is optional. A nonlocal anteriority mismatch is not dispreferred to the same degree as a local mismatch, however, and so the prefix may surface faithfully, as in (5a), or the anteriority mismatch may be repaired by assimilation, as seen in (5b).

The optional harmony environment yields both morphophonological variation and gradient optionality. Variation is used here as defined by Coetzee and Pater (2011: 1), referring to “the situation in which a single morpheme can be realized in more than one phonetic form in a single environment.” This is seen in (5), and may manifest both within the productions of a single speaker and across speakers. Gradience is used, broadly, to refer to anything that is not categorical. Consider phonotactics, for example. Some forms are wholly illegal and are simply prohibited; a form like [ŋih] is disallowed in English. Other forms are not disallowed but are dispreferred – [sf] is not an illegal onset cluster in English, yet it
is underrepresented in the lexicon, making words like *sphinx* and *sphere* unusual rather than ungrammatical (Hammond 2004). Sibilant harmony restrictions in Navajo can be viewed as gradient because mismatches are not simply allowed or disallowed; rather, local or adjacent anteriority mismatches are less tolerated, while nonlocal/nonadjacent mismatches are more tolerated.

### 1.3 Variation and gradience in phonology

Gradience presents a challenge to phonological theories wherein rules or constraints are conceived of as being categorical (Boersma and Hayes 2001; Frisch and Zawaydeh 2001; Hammond 2004). In both the traditional rule-based generative phonology framework and in the original incarnation of Optimality Theory (Prince and Smolensky 1993), rigid phonotactic generalizations lead to a black-and-white assessment of forms as being absolutely grammatical or absolutely ungrammatical. Yet languages are full of gradience; absolute grammaticality and absolute ungrammaticality are perhaps best thought of as opposite ends of a single spectrum, with a whole range of gradience in between. Various models have been proposed for dealing with gradience. In Stochastic Optimality Theory (Boersma 1997; Boersma and Hayes 2001), for example, phonological constraints occupy a bell-shaped probability distribution. Distributions overlap to greater or lesser degrees, and a constraint’s ranking may fall anywhere within its distribution in a given instance. Thus the specific ranking of constraints can vary each time a form is generated.

The functional result of such a model is variation; multiple phonetic forms may emerge depending on the specific ranking evoked. Variation is relevant here because an individual speaker of Navajo may produce different forms of a word in optional sibilant harmony environments. Recall, for example, the words given in (5). If we posit the existence of both a markedness constraint that penalizes sibilant anteriority mismatches and a faithfulness constraint that penalizes departures from the underlying representation, then the unassimilated form in (5a) will surface when the faithfulness constraint outranks the markedness constraint, and the assimilated form in (5b) will surface when the ranking is reversed. Models like Stochastic Optimality Theory can account for the existence of variation in individual speaker data because different constraint rankings can be generated in different instances of production. This paper uses an accumulation of individual speaker data to shed light on gradient trends in the lexicon as a whole.

In the growing body of work that deals with phonological gradience, a great deal of investigation focuses on the relationship between gradient grammaticality judgments and the statistical composition of the lexicon. It has been well es-
established that speakers give gradient responses when asked to judge the well-formedness or wordlikeness of nonsense words (Ohala and Ohala 1986; Frisch, Large, and Pisoni 2000; Hammond 2004), and that such judgments are affected by factors like phonological and semantic neighborhood density (Ohala and Ohala 1986; Coleman 1996; Bailey and Hahn 2001). Current research is leading to a more and more nuanced picture of the factors affecting gradience. It is reasonable to ask whether the factors that affect gradience in other linguistic areas affect trigger strength as well, thereby contributing to the variation found in optional harmony settings. Three phonologically relevant factors – distance, similarity, and salience – are addressed in the following sections.

1.3.1 Distance

In addition to eliciting grammaticality judgments of phonological wellformedness, phonological gradience has also been investigated via statistical analyses of dictionaries and lexicons, with several recent works demonstrating that distance-related gradience is reflected in the statistical make-up of the lexicon. In looking at constraints dealing with Obligatory Contour Principle (OCP) violations related to place of articulation of consonants in Arabic roots, Frisch et al. (2004) searched an online Arabic lexicon and found that while roots like *ssm are most strongly prohibited, additional smaller-scale, more gradient patterns also exist. Namely, adjacent homorganicity is dispreferred in roots, so forms like stm are underrepresented. Nonadjacent homorganicity is dispreferred as well, but to a lesser degree; thus roots like smt are underrepresented, but not to the same degree as roots like stm. That distance affects gradience, then, is statistically evident within the Arabic lexicon. Frisch and Zawaydeh (2001) utilized a grammaticality judgment task to investigate speaker awareness of gradience in the lexicon. By eliciting wellformedness judgments of novel verbs from native speakers of Jordanian Arabic, they found that speakers were aware of the OCP-Place constraints in Arabic and that the gradience found in previous dictionary-based studies was reflected in speakers’ grammaticality judgments.

Distance-related gradience occurs in the English lexicon as well. Berkley (2000) reports that pairs of similar consonants near one another are not found as often as would be predicted by chance alone in English and Latin words. Berkley refers to this as the OCP effect; it is most evident when the consonants in question are separated by a single vowel, and is less pronounced as additional segments intervene. In her words, “the closer two consonants are to each other stringwise, the less likely it is for them to be similar to each other” (iii). The number of segments intervening between a pair of consonants is not the only relevant factor,
however; the OCP effect is weaker across syllable and morpheme boundaries, highlighting the fact that distance can be calculated by different metrics – in this case, by segments, by morphemes, and by syllables.

Distance-related gradience has been investigated in Navajo, as well. Recall that Sapir and Hoijer (1967) made reference to distance in their commentary about sibilant harmony in Navajo, stating that it was mandatory when sibilants were near one another and optional when they were more distant from one another. Martin (2005) used an online Navajo lexicon to investigate gradience, with a focus on Navajo compounds. When Navajo noun stems that contain sibilants with conflicting anteriority values are compounded, the resulting phonotactic violation can be dealt with in multiple ways. Two options are that one stem can assimilate to repair the violation, or the violation can be tolerated. A third alternative is that compounds with underlying sibilant anteriority disagreement can be avoided. When Martin searched an online Navajo lexicon composed of 11,000+ words, he found 211 compounds that contained exactly one sibilant in each root. Forms with underlying sibilant disagreement were statistically underrepresented, suggesting that avoidance of a violation through non-formation of a compound is a viable choice. In compounds that contained underlying anteriority mismatches, however, distance plays a role in determining which fix is employed.

Words which contained sibilants in adjacent syllables showed anteriority agreement 70% of the time. In words containing sibilants in nonadjacent syllables, however, anteriority agreement was found only 44% of the time. This means that an anteriority mismatch was tolerated more than 50% of the time when the sibilants were in nonadjacent syllables (Martin 2005: 16). These findings show a bias towards assimilation when the sibilants in a compound are in adjacent syllables, but no such bias when they are not. An anteriority mismatch in adjacent syllables is worse than one in nonadjacent syllables, and is more often repaired through assimilation. A nonadjacent mismatch is not as bad, and is more often tolerated.

Martin also analyzed how best to calculate distance in Navajo. For two sibilants separated by three intervening segments, those in adjacent syllables agreed with regards to anteriority 72% of the time, while those in nonadjacent syllables agreed 27% of the time (18). Martin also assessed assimilation rates of sibilants in adjacent syllables separated by varying numbers of segments, and found no significant difference in agreement rates as the number of intervening segments increased. This indicates that when considering distance-related gradience in Navajo sibilant harmony, distance should be measured by syllable and not by segment.

That said, a discussion of distance as it relates to consonant harmony systems must also include reference to the aforementioned distinction between first- and second-order nonlocal harmony as outlined by Finley (2011). In first-order
nonlocal harmony, the trigger and target may be separated by vowels but intervening consonants not involved in the harmony relationship block assimilation. In second-order nonlocal harmony, the trigger and target may be separated by both consonants and vowels. An example of first-order harmony in Navajo is illustrated in (6a), where the trigger and target are separated by a single vowel; second-order harmony is shown in (6b), where the trigger and target are separated by vowels and, crucially, a non-interacting consonant, [b], which does not block the harmony.

(6) a. /ʃɪ-/+ tsili → sɪtsɪli
   ‘my younger brother’

b. /ʃɪ-/+ béeso → sɪbēeso
   ‘my money’

In Finley’s research, participants were exposed to nonce words that exhibited either first-order or second-order harmony. Those trained on first-order nonce words – of the form CVsV or CVJV, suffixed with -su and -ʃu to yield forms like dusi-su, beʃa-ʃu (all examples from Finley 2011: 78) – extended the pattern to novel first-order words when tested but not to second-order items. When trained on second-order nonce words, however – of the form of ʃVCV or sVCV, suffixed as sema-su/*semaʃu – participants extended the pattern not only to novel second-order items, but to first-order items as well. That is to say, a participant exposed only to words like sema-su during training nonetheless favored forms like dusi-su during testing with significantly greater than chance levels. Those trained on forms like dusi-su, however, did not favor sema-su over sema-ʃu. These results indicate that a first-order nonlocal pattern was inferred from learning a second-order pattern, but the reverse was not true.

This aligns with the typological observation that while some languages allow only first-order nonlocal harmony and others allow both first- and second-order nonlocal harmony, no languages have been found that require second-order but not first-order nonlocal harmony (Finley 2011: 75). In both types, harmony applies to elements which are nonadjacent segmentally; in the first, however, triggers and targets may only be separated by vowels, while in the other they may be separated by consonants as well. The functional result of allowing both consonants and vowels to separate interacting segments is that it increases the number of syllable boundaries which may potentially occur between trigger and target, thereby creating the potential for increased syllable-based distance. Viewed in this way, first-order processes are more proximate, second-order processes less so. Typologically, then – and in Finley’s experimental results – presence of a process that can operate across a greater distance implies the presence of a process
that can operate over a lesser distance, but the reverse is not true. This underscores the importance of proximity, even in a nonlocal process like consonant harmony (Finley 2011).

The idea that pressure for assimilation in consonant harmony systems increases as distance decreases is not new; rather, this is a new incarnation of an idea that has been oft-noted (Sapir and Hoijer 1967; Hansson 2001; Rose and Walker 2004; Wayment 2009). For the purposes of the present studies, the general idea may be framed as follows: the nearer a trigger and target are to one another, the greater the pressure for assimilation. Taken together, then, the above studies highlight distance as one factor that contributes to gradience in general as well as playing a role in the typology of consonant harmony systems. We turn now to similarity, which is of import in a number of phonological domains, as another factor that may affect the occurrence of harmony in optional settings.

1.3.2 Similarity

Similarity arises repeatedly as a factor of phonological relevance. Recall, for example, the OCP-Place restrictions in Arabic verbal roots referred to in the previous section (Pierrehumbert 1993; Frisch and Zawaydeh 2001). Within OCP-Place research, place of articulation groupings are further divided; coronals in Arabic, for example, can be broken into sonorants, obstruent stops, and obstruent fricatives, and verbal root restrictions in Arabic most strongly prohibit consonant-consonant sequences that share both place and manner of articulation. In other words, consonant pairs are more strongly prohibited when the consonants are more similar to one another. Thus a root like *stm which has a pair of similar consonants – i.e., consonants that are homorganic but that differ with regards to manner of articulation – is dispreferred, but is not as strongly prohibited as a sequence which shares both place and manner specifications (Frisch et al. 2004; Coetzee and Pater 2008).

Similar findings are reported for the western Austronesian language Muna, with statistical analysis of a Muna lexicon revealing influence from gradient OCP-Place restrictions (Coetzee and Pater 2008). The strength of the restriction is related to the similarity of the consonants involved; sequences of homorganic consonants are gradiently restricted, and the gradience is influenced not only by place of articulation but also by manner and by voicing specification. Voicing has not been shown to play a strong role in the Arabic data, wherein sonorancy agreement is a strong predictor of underrepresentation, but in Muna, consonants with voicing agreement are treated as more similar to one another than consonants with the same manner of articulation but contrasting voicing specifications. Thus
ND sequences are more underrepresented than DT sequences, which in turn are more underrepresented than NT sequences. In Muna, then, place, manner, and voicing each contribute to determining overall similarity.

The Arabic and Muna data help illustrate that the metric by which similarity is calculated may vary between languages. Berkley (2000) shows that while gradient OCP effects limit the occurrence of ‘similar’ consonant pairs in both English and Latin words, similarity is calculated differently in the two languages. In Latin, coronal consonants that are close to one another violate the OCP, and words containing two coronal consonants near one another are underrepresented in the lexicon. Analysis of the English lexicon indicates that while pairs of coronal consonants near one another are somewhat underrepresented, thereby showing evidence of OCP effects, coronals are further subdivided into sonorants and obstruents; words containing two coronal sonorants or two coronal obstruents near one another are more underattested than words containing a coronal sonorant and a coronal obstruent near one another. In calculating similarity, then, Latin is sensitive to place and English to both place and manner.

Similarity is also of critical importance in the aggressive reduplication constraint proposed by Zuraw (2002), who notes the pseudo-repairs made to words with built-in similarity – examples include orangutan, which is ‘repaired’ to orangutang, and Okefenokee, which is repaired to Okeefonokee. Zuraw posits that these altered forms arise when the word already contains “sufficient internal phonological self-similarity” (396). A reduplication constraint that establishes and enforces a correspondence between similar strings is proposed, and loan-word phonology in Tagalog is investigated. In Tagalog, the mid vowels [o] and [e] are generally found only in word-final syllables for native words. When mid vowels are moved into penultimate syllables through suffixation, vowel raising to [u] and [i] often occurs. Mid-vowels in non-ultimate positions are more tolerated in loanwords than in native words, however, and Zuraw finds that the vowel-raising customarily found in native words is blocked in loan words that contain other mid vowels. To satisfy the reduplication constraint, then, mid vowels are rendered tolerable in positions where they would typically be ungrammatical by the presence of a mid vowel elsewhere in the word – particularly in an adjacent syllable, and when the two mid vowels match with regards to backness.

It is also the case that similarity is a hallmark characteristic of consonant harmony systems – that consonants involved in harmony relationships have a high degree of similarity. Dental/alveolar harmony systems affect only stops, for instance, while sibilant harmony systems involve only sibilant fricatives and affricates – which are highly similar to one another and distinct from other classes of consonants because of the high-frequency energy which characterizes them acoustically (Rose and Walker 2004). Hansson (2001: 1) notes that while
many kinds of harmony systems exist, and the features for which they require segments to match vary widely, they are “frequently sensitive to the relative similarity of the interacting consonants.” Wayment (2009: 2) refers to this as prerequisite feature similarity: the specific features on which segments must agree and the degree of similarity required may vary from one language to the next, but establishment of a trigger-target relationship between segments is consistently and universally predicated on some shared degree of similarity.

The reduplication and consonant harmony data are of interest because they highlight an area wherein similarity serves as the basis for a correspondence rather than a restriction (as with OCP-Place restrictions); in these types of processes, a degree of shared similarity institutes a requirement for identity rather than an avoidance of similarity. Consider coronal harmony systems: consonants which are already articulatorily similar assimilate for place and manner specifications which are only relevant to coronals. The process takes segments which are already similar and enforces an identical featural specification.

We turn now to a discussion of the role of salience in phonology, which is particularly apropos when considering sibilant harmony given that it is the predominant type of consonant harmony attested in the world's languages (Hansson 2001). It is worth considering that this predominance arises precisely because sibilants are exceptionally salient segments. They are characterized acoustically by intense high-frequency energy; this energy distinguishes them from other classes of consonants and serves as a strong perceptual cue, rendering sibilants highly salient.

1.3.3 Salience

The term salience is used here in a broad manner, indicating anything that is especially noticeable or important. This definition could include features, segments, or word or syllable positions, and may be likened to what Beckman (1998: viii) refers to as “perceptually or psycholinguistically prominent.” Beckman notes a number of positional asymmetries, in terms of both contrast neutralization and preservation, and in terms of segments which serve as triggers for or targets of phonological processes. Segments in root initial syllables, stressed syllables, and syllable onset position, for example, often retain featural contrasts that are lost elsewhere; segments in these positions are also more likely to be triggers for and less likely to be targets of processes such as vowel harmony.

The salience of the syllable as a phonological unit has been revealed in research focused on speech perception. In a review of such work, Sendlmeier (1995: 131) determined that while listeners are able to shift their focus to smaller
or larger units depending on the task at hand, “as a default case, the syllable serves as the primary perceptual unit.” This is a nice complement to the syllable-based measure of distance supported by the findings discussed in Section 1.3.1 (Berkley 2000; Martin 2005).

With regards to syllable position, findings from production and perception experiments as well as first language acquisition research focused on the development of phonological awareness have indicated that onsets are more salient than codas. Berkley (2000) found that both word and syllable position affect gradient OCP effects in the English lexicon; her analysis indicated that OCP effects are strongest when one consonant in a pair is located in onset position of a word-initial syllable. Pairs of similar consonants in onset and coda positions of a first syllable or in onset position in the first and second syllables in a word are more underrepresented in the English lexicon than consonant pairs located in onset and coda position of the second syllable of a word. This indicates the salience not only of onset position, but also of word-initial onset position. It also eliminates one potential interpretation: if onset-onset pairs were most heavily penalized, the effect could be due to either the salience of onset position or the similarity gained by sharing a syllable position. Onset-coda pairs in an initial syllable are more underrepresented than onset-onset pairs, however, which in turn are more underrepresented than second syllable onset-coda pairs. This pattern cannot be due to similarity alone; to fully understand it, we must appeal to the salience of word-initial onset position for an explanation. More evidence related to the salience of onsets comes from Treiman et al. (1995), who found that for undergraduate students playing games involving novel disyllabic and trisyllabic words, onset consonants were more salient than coda consonants. Further, onsets of stressed syllables were more salient than those of unstressed syllables. Thus both Berkley (2000) and Treiman et al. (1995) highlight an important fact: the overall salience of a segment may be derived from multiple factors (e.g., word position and syllable position or syllable position and stress).

Moving beyond the syllable, we may also wonder whether certain manners of articulation are particularly salient. One answer may be found in the arena of child language research, wherein phonological awareness testing using a phoneme recognition task reveals that children are better at identifying noncontinuants than continuants (Treiman et al. 1998). In the present work, and in line with Clements (1999), affricates are consistently referred to as noncontinuants due to the features they share with stops. The descriptor *continuant*, then, refers to sibilant fricatives like \([s, z, ʃ, ʒ]\) in Navajo, while *noncontinuant* refers to sibilant affricates like \([tʃ, dʒ, dʒ\]). Several key works on the affricate-fricative distinction demarcate affricates from fricatives because, like stops, they have a release burst; fricatives do not (Shinn 1985). One way to interpret the Treiman et al. (1998) study...
is to posit that noncontinuants may be more salient than continuants, and in fact Raphael and Isenberg (1980) noted the perceptual salience of the release burst in a study about fricative/affricate perception in word-final position. While these studies do not deal directly with the strength of noncontinuants as triggers for phonological processes, they do raise the possibility of noncontinuants being more salient, perhaps due to the associated release burst. That said, while fricatives lack a release burst, they may benefit from the fact that they feature longer frication duration than affricates. The question of which of the two – a release burst or increased frication duration – is more salient remains open. The present work contributes a new piece of information to this puzzle by investigating the effect of a trigger’s manner of articulation on the occurrence of harmony in optional settings.

The final factor discussed in relation to salience is referred to as trigger count by Hayes and Londe (2006) and as count effect by Hayes et al. (2009). The claim is relatively straightforward: namely, multiple segments acting together are a stronger trigger for phonological processes than a single segment. The above-mentioned studies center on Hungarian vowel harmony, a process wherein neutral (meaning front unrounded) vowels are weaker triggers for frontness than back vowels are for backness. When two neutral vowels team up, however, their strength increases. In fact, in the domain of vowel harmony there are cases where harmony only applies when two triggers are present (Walker 2001). If this phenomenon is mirrored in consonant harmony, then the presence of multiple triggers will render them more salient, thereby increasing the likelihood of harmony applying in an optional setting.

This section has reviewed some of the factors known to influence gradience in the lexicon, as reflected in dictionaries and word lists, and in speakers’ mental grammars, as reflected by measures ranging from grammaticality judgments and speech errors to perception and production tasks. Factors addressed included distance, similarity, and salience. Salient factors included syllable position and manner of articulation among others.

1.4 The current project

Optional sibilant harmony in Navajo presents an opportunity to investigate optionality and gradience, for if harmony is sometimes mandatory and sometimes optional, then the ungrammaticality of sibilant anteriority mismatch cannot be categorical. Rather, anteriority mismatches may be severe enough in some instances that they must be repaired and mild enough in others that they may be tolerated. We lack a clear understanding of this gradience, however; we know
neither how often harmony applies in optional settings nor which factors contribute to gradience.

One hint might be found in Martin (2005). A search of an online Navajo lexicon for words containing exactly two sibilants returned a total of 589 words; in the 276 words that contained one sibilant in an affix and the other in a root, anteriority agreement reached almost 100%. Some of those words must have had no underlying mismatch: those that did, however, assimilated. They showed none of the distance-related gradience that was evident in Martin’s findings for compound words (see Section 1.3.1).

These findings make it look as though harmony was always mandatory, for to achieve a near-100% agreement rate harmony must have applied nearly every time the chance arose. If it is true that sibilant harmony is optional in certain environments in Navajo, however – as is widely accepted – then harmony is either optional but extremely frequent, as is the case for flapping in English (Patterson and Connine 2001), or dictionary results do not accurately reflect real-world language use. An important question to ask, then, is how often harmony applies in optional settings in real-world language use. Furthermore, if the expected optionality is revealed, then the factors that contribute to the occurrence of harmony in optional environments can be investigated.

Two related studies are presented in the following sections. First, an online survey is used to elicit grammaticality judgments of assimilated and unassimilated forms of nouns inflected for the first person possessive. The results indicate that, although the unassimilated form of the prefix is heavily favored in all environments, three factors – distance, manner of articulation, and syllable position of the trigger – affect the grammaticality of assimilated forms. In the second study, acoustic analyses of recordings of three native speakers of Navajo reveal that the presence of alveolar sibilants in the stem can affect the prefixal sibilant in perceptually undetectable but acoustically measurable ways. In both studies, first-order nonlocal harmony is privileged over second-order nonlocal harmony: segments in nonadjacent syllables, separated from harmony targets by intervening consonants that do not participate in the harmony relationship, are highly unlikely to trigger harmony.

2 Experiment 1: The grammaticality of assimilated forms

Sibilant harmony is referred to as a sometimes-mandatory and sometimes-optional process in Navajo, but data regarding the perceived grammaticality of
harmonized forms are rare at best and nonexistent at worst. To address this, an online survey was designed to elicit information about patterns of assimilation in optional harmony environments from fluent users of Navajo. The morpheme targeted here is the first-person possessive /ʃɪ-/.

Since assimilation is reflected orthographically in Navajo, the prefix is spelled shi- when it surfaces faithfully and si- when it harmonizes to match an alveolar sibilant.

This morpheme is underlyingly palatal and harmonizes to alveolar, and it is a nominal affix rather than a verbal affix. Thus by focusing on the behavior of this morpheme in the following studies, we gain only one piece of the picture. The choice to use a single morpheme as a starting point was made in order to render the present study feasible, with the belief that a piece of the picture is better than no piece at all. The data presented here is intended to serve as a beginning, and will be complemented by future research that investigates the behavior of multiple morphemes – including both verbal affixes and morphemes which contain underlyingly alveolar sibilants.

The survey, in which participants were asked to provide grammaticality judgments of nouns inflected for the first person possessive, was designed to address two major questions:

1. Do grammaticality judgments elicited from users of Navajo confirm that harmony is mandatory in some settings and optional in others? In other words: are unharmonized forms worse in some instances than in others?
2. If so, do the factors of distance, similarity, or salience influence variability in perceived grammaticality?

2.1 Predictions

Predictions about both the overall pattern and each of the factors under investigation can be made.

2.1.1 Acceptability of faithful and harmonized forms

Nouns containing alveolar sibilants (as in (7), henceforth, targets) will be deemed ungrammatical when affixed with the faithful shi- and grammatical when affixed with the harmonized si-. Those containing no sibilants (as in (8a), henceforth, neutral fillers) contain no trigger for harmony and will be deemed ungrammatical when affixed with the harmonized si- and grammatical when affixed with the faithful shi-. Those containing palatal sibilants (as in (8b), henceforth, palatal fillers) are similar to neutral fillers in that they contain no alveolar sibilant. They
differ from neutral fillers, however, in that they contain palatal sibilants. As such, harmonized si- forms should be deemed ungrammatical – and potentially even more ungrammatical than si- forms of neutral fillers, for si- forms of palatal fillers would contain both a harmonized prefix in the absence of a trigger and active disharmony between trigger and target. Faithful shi- forms of palatal fillers should be deemed grammatical. Neutral and palatal fillers will be treated differently unless statistical analysis indicates that they can be grouped together.

(7) Target: /ʃɨ-/ + tsili → sitsili, *shitsili ‘my younger brother’

   b. Palatal filler: /ʃɨ-/ + gish → shigish, *sigish ‘my cane’

2.1.2 Adjacency

The target in (7) is an example of first-order nonlocal harmony. An example of second-order nonlocal harmony appears in (9), where the trigger and target are separated by a noninteracting consonant. This is the distance factor, à la Martin (2005) and Finley (2011). First-order nonlocal harmony is predicted to be privileged over second-order nonlocal harmony, meaning that unharmonized forms of targets containing an alveolar sibilant in a syllable adjacent to the prefix (henceforth, adjacent stems) will be deemed worse than those containing alveolar sibilants in nonadjacent syllables (henceforth, nonadjacent stems).

(9) Optional: /ʃɨ-/ + béeso → sibéeso, shibéeso ‘my money’

2.1.3 Continuancy

If similarity outweighs salience in determining trigger strength, unharmonized forms of nouns containing [s, z] will be deemed less grammatical than those containing [ts, dz] because the prefixal sibilant is a continuant. If the unharmonized forms of nouns containing the noncontinuants [ts, dz] are deemed less grammatical than those containing the continuants [s, z], on the other hand, then at least two potential interpretations arise. This is because the factors of continuancy and syllable position cannot be untangled at present: noncontinuants only appear as syllable onsets, while continuants appear in both onset and coda position. Higher grammaticality ratings for noncontinuant stems, then, may indicate that the noncontinuants serve as more salient triggers, but it may also indicate that onset is a more salient trigger position.
2.1.4 Syllable position

A prediction of stem sibilants in onset position acting as stronger triggers is supported both because the prefixal sibilant is in onset position, and because onset is a particularly salient syllable position (see Section 1.3.3). As such, unassimilated forms of stems containing alveolar sibilants in syllable onset position (henceforth, onset stems) will be judged worse than those containing alveolar sibilants in coda position (henceforth, coda stems).

2.1.5 Voicing

Trigger-target similarity is expected to affect the grammaticality of unharmonized forms. Unharmonized forms of targets with greater trigger-target similarity are expected to be deemed less grammatical. As the prefixal sibilant is voiceless, unharmonized forms of nouns containing [s] and [ts] will receive lower grammaticality ratings than those containing [z] and [dz].

2.1.6 Number of stem sibilants

There is power in numbers, à la Hayes and Londe (2006) and Hayes et al. (2009). Multiple sibilants in a stem pool their strength, resulting in increased salience and exerting greater pressure to assimilate than a single stem sibilant. As such, unharmonized forms of stems that contain multiple sibilants (henceforth, multiple sibilant stems) will be judged worse than those that contain a single sibilant (single sibilant stems).

2.2 Procedure and materials

2.2.1 Noun list

To test these predictions, a list of 75 Navajo nouns was compiled from the noun list in Young, Morgan and Midgette’s (1992) *Analytical Lexicon of Navajo, the New Oxford Navajo-English Picture Dictionary*, Wall and Morgan’s (1994) *Navajo-English Dictionary*, and a bilingual children’s book by J. B. Enochs entitled *Little Man’s Family* (Appendix A). Included are 50 targets, which contain alveolar sibilants, and 25 fillers. Fillers are of two types: 13 palatal fillers contain palatal sibilants, and 12 neutral fillers contain no sibilants – in both cases, there is no trigger
for assimilation and forms affixed with the harmonized si- should be deemed ungrammatical. The question of whether palatal and neutral fillers pattern together or separately is addressed in the next section. None of the nouns require accent marks or nasal hooks. Some are quite common; others are somewhat less common. Additional commentary on individual nouns is found in Appendix B.

While this was briefly touched on in Section 2.1.3, it is important before continuing to note the potential conflation of the factors being analyzed herein. In a word like shik’is, ‘my friend,’ the stem sibilant is a continuant in coda position in a syllable adjacent to the prefix. This means that k’is is not only a continuant stem, but also a coda stem and an adjacent stem, and this is true for all stems – each may be categorized in a number of different ways. Syllable structure constraints come into play as well; as readers can observe in the noun lists found in Appendixes A and B, noncontinuants only appear in onset position. Thus when comparing assimilation rates of noncontinuant with continuant stems, the noncontinuant stem group contains only sibilants in syllable onsets, while the continuant stem group contains continuants in both onset and coda position. Manner of articulation and syllable position are therefore confounded. This is an important issue, and while sample sizes in the present work do not allow for the disentanglement of these factors it remains to be addressed in future work.

### 2.2.2 Survey and participants

The survey took two forms, and was created with Qualtrics Survey Software (Qualtrics Labs, Inc. 2010). It can be found at http://kuclas.qualtrics.com/SE?SID=SV_0HuPHOLzLezGtZq. In its first form, participants were asked to provide the first-person possessed forms of various nouns, as seen in Figure 1, and to provide grammaticality judgments for both assimilated and unassimilated possessed

![Example A: In Example A below, you are given the Navajo word meaning 'his plan.' To respond to this question, type the Navajo word that means 'my plan' in the blank below.

his plan: binahat'a

my plan: ](image)  

Fig. 1: Qualtrics© Survey: version 1 screenshot.

2 Use of Qualtrics was made possible by an agreement entered into by Qualtrics and the University of Kansas College of Liberal Arts and Sciences.
forms, as in Figure 2. The grammaticality judgment scale ran from 1 to 7, with 1 signifying a terrible, ungrammatical word and 7 signifying a perfect, grammatical word.

Participants were recruited via Facebook, MySpace, and the Linguistic Society of America’s Linguistlist, Athapbascan, and Endangered Languages list-servs. Participants completed an Internet Consent Form (University of Kansas Human Subjects Committee Approval #17707). Seven responses were gathered in as many months; filled in responses overwhelmingly favored the faithful shi-prefix. The survey was then shortened so that participants only provided grammaticality judgments (as in Figure 2), yielding an additional 13 responses. An independent samples t-test showed no significant differences between respondents’ grammaticality ratings on version 1 and version 2 of the survey, with $p > 0.10$, so they were grouped for a total of 20 (6 male, 13 female, 1 undeclared). Twelve female participants reported their age, which is shown in Figure 3. Their mean age was 39.9 years.

![Fig. 2: Qualtrics© Survey: version 2 screenshot](image1)

![Fig. 3: Age of survey respondents (10-year ranges).](image2)
The 75 words from the noun list appeared in both the assimilated and un-assimilated affixed forms, so participants provided grammaticality judgments on a total of 150 words which can be divided as in Table 1. **SHI-FILLERS** should be deemed grammatical, as there is no trigger for assimilation, while **SI-FILLERS** should be deemed ungrammatical for the same reason. Palatal fillers should pattern the same way, though **SI-PALATALS** are overtly disharmonious and as such may be deemed even worse than **SI-FILLERS**. Any variation seen should be in the targets, such as *k’os*, ‘neck,’ for which either *sik’os* or *shik’os* may be acceptable.

### Table 1: Survey word types.

<table>
<thead>
<tr>
<th>Word type</th>
<th>Example</th>
<th>Nickname</th>
</tr>
</thead>
<tbody>
<tr>
<td>target affixed with <strong>shi</strong>-</td>
<td>shik’os</td>
<td>‘my neck’</td>
</tr>
<tr>
<td>target affixed with <strong>si</strong>-</td>
<td>sik’os</td>
<td>‘my neck’</td>
</tr>
<tr>
<td>palatal filler with <strong>shi</strong>-</td>
<td>shichaii</td>
<td>‘my grandfather’</td>
</tr>
<tr>
<td>palatal filler with <strong>si</strong>-</td>
<td>*sichaii</td>
<td>‘my grandfather’</td>
</tr>
<tr>
<td>neutral filler with <strong>shi</strong>-</td>
<td>shibid</td>
<td>‘my stomach’</td>
</tr>
<tr>
<td>neutral filler with <strong>si</strong>-</td>
<td>*sibid</td>
<td>‘my stomach’</td>
</tr>
</tbody>
</table>

2.3 Results

#### 2.3.1 Palatal fillers vs. neutral fillers

A paired samples *t*-test was conducted to determine whether palatal and neutral fillers pattern as a single group, or whether they are in fact treated differently. The test revealed no significant differences between respondents’ grammaticality ratings of **SI-PALATALS** (*M* = 1.8765, *SD* = 0.1791) and **SI-FILLERS** (*M* = 1.7882, *SD* = 0.1260), with *t*(11) = 1.47 and *p* = 0.085. The two groups of fillers behave identically, in other words. One way to consider these results is as follows: speakers judge an unfaithful prefix in the absence of a harmony trigger and the overt disharmony present in a harmonized palatal filler to be equally ungrammatical. That said, note that the difference between the harmonized neutral and palatal fillers is marginal (*p* = 0.085), and that whereas we may have expected **SI-PALATALS** to be worse – precisely because they contain an anteriority mismatch – the numerical values in fact diverge in the unexpected direction. This alone is interesting, and bears investigation in future work. Here, however, the important point
moving forward is that the palatal and neutral fillers pattern together. Accordingly, they are henceforth grouped and referred to simply as FILLERS.

### 2.3.2 Targets vs. fillers

To set the baseline, mean grammaticality judgments were determined for the groups SHI-FILLER, SI-FILLER, SHI-TARGET, and SI-TARGET. Mean grammaticality ratings for these basic groups appear in Figure 4.

A startling observation can be made immediately: the unassimilated shi-form is always preferred. This is unexpected, but the prediction that si- would be deemed less grammatical when affixed to fillers and shi- when affixed to targets appears to be supported, even with the relatively low ratings for harmonized forms. Paired-samples $t$-tests were not viable due to skewed distributions, so the nonparametric Wilcoxon Signed-Ranks Test was conducted and confirmed that this is indeed the case. Targets affixed with shi- were deemed significantly less grammatical than fillers affixed with shi- ($z = -3.245, p < 0.001$), with a large effect size ($r = 0.5$). Similarly, the mean grammaticality of SI-FILLERS was significantly lower than SI-TARGETS ($z = -2.25, p = 0.012, r = -0.44$). The major take-home message, then, is that faithful forms are always preferred over harmonized forms, but – as predicted – faithful targets are worse than faithful fillers and harmonized targets are better than harmonized fillers.

Having established that the difference between the mean grammaticality judgments of targets and fillers is statistically significant and in the expected directions, we can now focus exclusively on target words affixed with the assimilated si- prefix to determine whether variability in grammaticality judgments can be traced to the factors of continuancy, adjacency, syllable position, voicing, and/or number of stem sibilants. Mean grammaticality ratings for each of these groupings are seen in Figure 5.
Recall that ‘2’ is a very low rating; all si-forms were deemed ungrammatical. In essence, then, the relative degree of ‘badness’ of these forms is assessed based on the groupings shown above. Neither the voicing nor the number of stem sibilants proved significant, but adjacency, continuancy, and syllable position triggered significant differences in grammaticality ratings. Paired-samples t-tests revealed that the harmonized prefix was more acceptable in adjacent stems ($M = 2.3249, SD = 1.65472$) than in nonadjacent stems ($M = 1.9003, SD = 1.24813$), with $t(19) = 1.807, p = 0.044$, and a medium effect size ($r = 0.38$). In other words, although the harmonized prefix received low grammaticality ratings in general, it was relatively more acceptable when less distance intervened between triggers and targets: first-order nonlocal harmony was more acceptable than second-order nonlocal harmony.

Assimilated noncontinuant stems were deemed significantly more grammatical ($M = 2.325, SD = 1.655$) than assimilated continuant stems ($M = 2.119, SD = 1.344$), with $t(19) = -2.023, p = 0.029$ and a medium to large effect size ($r = 0.42$). One interpretation of this finding is that affricates are stronger triggers for harmony in optional settings, rendering harmonized forms of stems containing affricates more acceptable than those containing fricatives. Recall, however, that manner of articulation and syllable position are confounded in the present results: noncontinuants only appear in onset position while continuants appear in both onset and coda position. Until these effects can be disentangled, then, we should be cautious about interpreting this result as providing support for the claim that noncontinuants are stronger triggers. It is a possibility, but it is not the only possibility.
Finally, assimilated forms of onset stems ($M = 2.2457$, $SD = 1.51834$) were rated significantly better than coda stems ($M = 2.0679$, $SD = 1.36822$), with $t(19) = 2.263$, $p = 0.018$. The effect size was large ($r = 0.46$). Harmonized targets, in other words, were more acceptable when triggers were in onset than in coda position. All significant results were in the expected direction.

### 2.4 Experiment 1b: Harmony in online language use

The above data indicate that the faithful – or unassimilated – *shi-* prefix is favored in all contexts; words affixed with *si-* receive low grammaticality ratings across the board. This is surprising given that harmony is expected to be mandatory in some settings. An analysis of harmony in online language use, however, confirms that the first person possessive morpheme harmonizes less often than anticipated.

After compiling a list of 157 Navajo nouns that contained at least one [+anterior] sibilant, the QueryGoogle software package developed by Bruce Hayes and Kie Zuraw was used to look for tokens affixed with the assimilated *si-* and the unassimilated *shi-* forms of the first person possessive prefix. Online Navajo data proved less robust than anticipated, and QueryGoogle returned hits for the 28 nouns which appear in Appendix B. These 28 nouns were subjected to a search by hand. For example, QueryGoogle showed two hits for *shilatsini* ‘my bracelet’, and a by-hand search revealed two tokens of *shilatsini* on Navajo language web pages. (Note that *látsíní* in fact contains all high-toned vowels, but the online hits contained no accents.)

A total of 1,669 tokens were found. Sample data are shown in Table 2, with full results in Appendix B. The raw assimilation rate for each word can be found in the Proportions column, where the total number of assimilated forms found by Google is the numerator and the total number of hits (assimilated and unassimilated) is the denominator.

Consider the word *ziiz* ‘belt.’ Google returned 142 hits for the assimilated *siziiz* and three for the unassimilated *shiziiz*, making the raw assimilation rate $142/145$ or 0.98. Meanwhile, *za’azis* ‘pocket’ appeared twice, taking the form *siza’azis*

---

3 The internet can provide an excellent arena for investigating the language use of current speakers in electronic interactions, but it is only useful for languages that are well-represented online. Navajo has more speakers than any other Indigenous North American language, yet neither a Navajo corpus nor any great reserve of Navajo-language web pages exists. Navajo language use may be on the rise thanks to social networking sites, however; if this trend continues, the internet may become an increasingly useful source of data.
both times and therefore yielding a raw assimilation rate of 2/2 or 1.0. The problem is that on an intuitive level, 100% of two instances and 98.62% of 145 instances do not seem to hold equal weight. In fact, it has been shown that we trust things less and are less willing to make phonological generalizations when we have very little evidence, while we trust things more and are more willing to make generalizations when we see many attestations (Albright, Andrade, and Hayes 2001; Pierrehumbert 2006). We therefore turn to the concept of Adjusted Reliability proposed by Mikheev (1997) and utilized by Albright et al. (2001). Adjusted Reliability accounts for the fact that “we intuitively give greater credence when testimony is more abundant” (Albright et al. 2001: 121). The intuition here is that assimilation rates should be adjusted to reflect the strength of the evidence, which in this case is total number of hits. Following Albright et al. (2001), Adjusted Reliability is defined as the lower limit of the 0.75 confidence interval for each proportion.

The Google search falls in line with the grammaticality judgment ratings elicited in Experiment 1. The adjusted assimilation rate mean was low overall ($M = 0.348$, $SD = 0.27$). Independent samples $t$-tests indicated that assimilation rates were affected only by adjacency. Nouns containing an alveolar sibilant in a syllable adjacent to the prefix ($N = 19$) showed significantly higher adjusted assimilation rates (0.437) than those whose alveolar sibilant was in a nonadjacent syllable ($N = 6$, adjusted assimilation = 0.045), with $t(23) = 6.736$ and $p < 0.001$. Assumptions of normal distribution were not met for the adjacency condition, and so a Mann-Whitney $U$ test was conducted to determine the effect size (Tabachnick and Fidell 2007). The results were significant and in the expected direction, $z = 3.312$, $p = 0.001$. Nonadjacent stems had a mean rank of 4.33, while adjacent stems had a mean rank of 15.74.

The results from Experiment 1 highlight the critical role of distance in Navajo optional sibilant harmony – in keeping with all previous work. They diverge from past work, however, by revealing that harmony is never mandatory in online Navajo use of the first person possessive morpheme. What is surprising in the

Table 2: Sample Google results.

<table>
<thead>
<tr>
<th>Word</th>
<th>Proportions (si-forms/total number of tokens)</th>
<th>Assimilation rates adjusted for reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>naaltsoos</td>
<td>‘book’</td>
<td>0/9</td>
</tr>
<tr>
<td>-tsa</td>
<td>‘body’</td>
<td>4/6</td>
</tr>
<tr>
<td>-zaad</td>
<td>‘language’</td>
<td>1/104</td>
</tr>
<tr>
<td>za’azis</td>
<td>‘pocket’</td>
<td>2/2</td>
</tr>
<tr>
<td>-ziiz</td>
<td>‘belt’</td>
<td>142/145</td>
</tr>
</tbody>
</table>
present results is the finding that harmony is actually disfavored in all contexts. This was truly unexpected, given the previous literature on the phenomenon of sibilant harmony in Navajo. Nonetheless, harmony does occur significantly more often when the stem sibilant is in an adjacent syllable. This is in keeping with the widely acknowledged role of distance in phonological gradience (Berkley 2000; Frisch and Zawaydeh 2001; Frisch et al. 2004; Martin 2005), and also supports the claim made by Finley (2011) that locality matters even in nonlocal processes: here, first-order nonlocal harmony occurs with significantly greater frequency than second-order nonlocal frequency.

2.5 Discussion

The most basic observation we can make when considering the results of Experiments 1 and 1b is that sibilant harmony in general is far less frequent online than is indicated in dictionaries. There is no evidence of a mandatory assimilation environment, at least with regards to the first person possessive morpheme and at least in the domain of online language use and grammaticality judgments elicited orthographically. Users of Navajo tolerated sibilant anteriority mismatches online even when the conflicting sibilants were in adjacent syllables. Furthermore, assimilation rates are relatively low, with the overall adjusted assimilation rate hovering around 35%. This contrasts with the near-100% anteriority agreement rates found by Martin (2005) for affixed words in the online Young, Morgan, and Midgette (1992) lexicon, and indicates that assimilation patterns differ between dictionary and real-life use.

Several factors need to be kept in mind when interpreting these results. Importantly, both experiments relied on orthography: it is possible that participants who favor the faithful prefix in writing harmonize in speech, and this will be investigated in Experiment 2. In addition, the online Navajo use reported in Experiment 1b must be interpreted with care; hits may represent language used by fluent Navajo speakers, but they may also originate with passive users of Navajo who have incorporated a few words or phrases into websites or blogs; in these instances, they may be copying words as chunks rather than concatenating morphemes themselves. Several people create Navajo graphics and greeting cards which can be sent over MySpace and Facebook; hypothetically, then, if one individual creates a graphic with an unassimilated form of a possessed noun on it, and the card is copied onto 50 peoples’ homepages, the faithful form is being propagated by chance rather than by choice. This complicates the scenario.

It is also possible – perhaps even probable – that the Navajo found online, and the grammaticality judgments garnered online, are representative of a
Optionality and locality

younger generation, in which case the present results may indicate an age effect. Perhaps harmony is less frequent, and even dispreferred, for younger but not for older speakers. This is particularly relevant given the discussion in Section 1.2 regarding the status of Navajo as an endangered language. While Navajo is still learned in the home to some extent, the method of transmission is shifting to include more in-school instruction. Many children entered school as monolingual Navajo speakers in the 1980s, but children entering schools today are either monolingual English speakers or English-dominant bilinguals (Benally and Viri 2005). The three native-language consultants who contributed most heavily to this research learned Navajo in the home, but also studied Navajo in school – where, they told me, they were taught that the first person possessive morpheme was shì-. This raises the distinct possibility that if there is an age effect contributing to the lack of overt harmony in the first person possessive morpheme, it could be because of overt instruction regarding this particular morpheme.

To investigate this possibility, a repeated measures ANOVA was conducted on the grammaticality judgment data from Experiment 1. The test was not significant: age did not significantly affect grammaticality ratings. In fact, in the first version of the survey – wherein participants were asked to fill in possessed versions of nouns – only two out of seven participants used the harmonized si- prefix, and then only sporadically. One of these respondents was over 60 years of age; the other was 21. The implication is that the results cannot be explained by age: it is not the case in the present data that older speakers harmonize and younger speakers do not. Rather, harmony is underrepresented overall by younger and older speakers alike.

The survey data reveals that, regardless of age, respondents simply did not like assimilated forms. Very few individuals rated assimilated forms as ‘good’ – in fact, only one respondent had an overall average for si-target forms above the Likert Scale midpoint of 4. (This respondent was a 63-year-old female with a mean rating of 4.44. For comparison, another 53-year-old female gave si-targets a mean rating of 1.02, indicating that harmonized forms were simply ungrammatical for her.) For all other respondents, assimilated forms were never good; some were simply less bad than others, suggesting that harmony is not only optional but is actually dispreferred.

One way to consider the overall findings is to say that although the strength of the harmony constraint may well be weakening – harmony is dispreferred throughout, after all – there are factors which render an alveolar sibilant in the stem a more salient trigger. This results in certain circumstances where speakers are more willing to tolerate harmony and judge harmonized forms less harshly. Significant differences in the mean grammaticality of assimilated forms were found based on adjacency, manner of articulation, and syllable position of the
stem sibilants. Accordingly, noncontinuancy, being in an adjacent syllable, and being in syllable onset position gave triggers a boost and enhanced pressure for assimilation. Importantly, while future investigation may reveal significant interactions between these three factors, the current set of data is not large enough to support such an analysis.

In fact, adjacency emerged as a significant factor in both Experiment 1 and Experiment 1b. This is noteworthy because harmony in adjacent stems and harmony in nonadjacent stems represent distinct kinds of nonlocal processes. These results tell us that first-order nonlocal harmony is better tolerated in terms of grammaticality judgments and occurs more frequently in online language use than second-order nonlocal harmony. Recall that Finley (2011) found that participants exposed to first-order nonlocal harmony in an artificial language-learning experiment did not extend the pattern to second-order nonlocal environments, but that participants exposed to second-order nonlocal harmony data did extend the pattern to first-order harmony environments. The results from Experiments 1 and 1b are in line with Finley’s findings, and provide added support for the hypothesis put forward in Finley (2011) that locality matters even in nonlocal processes. Sibilant harmony in Navajo is a nonlocal phonological process, but the empirical data collected herein indicate that distance plays a key role even in this nonlocal process: harmony can occur at a distance, but triggers are rendered much weaker when separated from targets by consonants in addition to vowels.

Experiments 1 and 1b used online, written language to investigate gradience in Navajo sibilant harmony. This was possible because assimilation has orthographic consequences in Navajo. Another question we may ask, however, is whether similar patterns occur in spoken language. There is no room for partial harmonization in written language, but is it possible that traces of harmony not reflected in written language are present in speaker productions? McDonough (2003: 49) touches on this point in *The Navajo Sound System*, wherein the following question is posed: “Is [harmony] a purely phonological alternation in which consonants have been outright replaced by a harmonized reflex, or is it a more phonetically based and defined alternation in which there is a more gradient effect?” Experiment 2 was designed to investigate this possibility.

3 Experiment 2: An acoustic study of Navajo sibilant (non)harmony

Three Navajo/English bilinguals were recorded producing a randomized list of nouns in the first-person possessed form. Acoustic analysis was then performed
to determine whether the presence of alveolar sibilants in the noun stem produces measurable acoustic effects in the prefixal sibilant.

3.1 The acoustic properties of [s] and [ʃ]

If harmony triggers acoustically detectable effects, then we expect the morpheme-initial fricative in the first-person possessive shi- to be more [s]-like when affixed to stems that contain alveolar sibilants (targets) than when affixed to stems that do not (fillers). In order to establish what a more [s]-like [ʃ] will look like, a brief review of the acoustic properties of the two fricatives is presented with reference to Navajo (McDonough 2003), English (Behrens and Blumstein 1988; Wilde 1993; Evers, Reetz, and Lahiri 1998; Jongman, Wayland, and Wong 2000; Fox and Nissen 2005), and a crosslinguistic examination of voiceless fricatives in seven languages, two of which belong to the same language family as Navajo (Gordon, Barthmaier, and Sands 2002).

Measurements taken in Experiment 2 include spectral mean and the lower bound of the frication energy of the prefixal fricative. Prior studies have indicated that the onset of the second formant in a vowel can be affected by the place of articulation of the preceding consonant, and so the onset of F2 in the vowel following the prefixal fricative was also measured and is referred to herein as F2 transition. Detailed explanation of how each of these measures was taken appears in Section 3.3.

Spectral mean, or center of gravity, is consistently reported to be significantly higher for [s] than for [ʃ]. This is true in English (Behrens and Blumstein 1988; Evers et al. 1998; Jongman et al. 2000); in Apache, Chickasaw, Scottish Gaelic, and Montana Salish (Gordon et al. 2002); and in Navajo (McDonough 2003). Jongman et al. (2000: 1257) report means of 6133 Hz for English [s, z] and 4229 Hz for English [ʃ, ʒ]. McDonough’s (2003: 134) findings for Navajo are similar, with a mean difference of several thousand Hz. As such, a more [s]-like [ʃ] will have a higher spectral mean.

McDonough (2003: 130–131) also notes that Navajo [s] and [ʃ] are easily distinguished by “the lower edge of the energy bands” in the spectrum, and this is consistent with the general observation that the spectral energy of [ʃ] extends down into lower frequency ranges than that of [s] (Kent and Read 2002). This parameter, referred to herein as the lower bound of the frication energy, is described in more detail in Section 3.3, but in short, the lower bound of the frication energy for a more [s]-like [ʃ] will be higher than that of a pure [ʃ].
Formant transitions can sometimes distinguish between fricatives; in Anong, for example, they can be used to distinguish between [s] and [ʂ] (Thurgood 2009). Jongman et al. (2000) report a significantly lower mean F2 onset following [s, z] than following [ʃ, ʒ] in English. If this held for Navajo, then a more [s]-like [ʃ] would have a lower F2 transition than a pure [ʃ].

Duration is not considered here. In an analysis of 14 Navajo speakers (10 female, 4 male), McDonough (2003) reports no significant durational differences between fricatives. This is consistent with findings which show no durational difference between [s] and [ʃ] in English (Behrens and Blumstein 1988; Fox and Nissen 2005) and in Apache, Chickasaw, Montana Salish, and Toda (Gordon et al. 2002).

In short, then, both spectral mean and the lower bound of frication energy are higher for [s] than for [ʃ], while F2 transition is lower. The expectation in Experiment 2 is that spectral mean and the lower bound of frication energy will be higher in a more [s]-like [ʃ] while F2 transition will be lower.

### 3.2 Predictions

- **Targets/Fillers.** If the target/filler distinction produces measurable effects in the prefixal sibilant, then the spectral mean and the lower bound of frication energy will be higher before targets than before either palatal or neutral fillers while the F2 transitions will be lower.
- **Adjacency.** As adjacency – or distance – proved significant in Experiments 1 and 1b, the prefixal sibilant will exhibit more [s]-like properties when affixed to adjacent stems than to nonadjacent stems.
- **Continuancy.** Speakers judged assimilated forms less harshly when they contained noncontinuants in Experiment 1. Accordingly, noncontinuants are expected to trigger more [s]-like properties in the prefixal sibilant than continuant stems.
- **Syllable position.** Speakers judged assimilated forms of onset stems less harshly than coda stems in Experiment I. Thus we expect to see more [s]-like properties in the prefixal fricative when affixed to onset stems than when affixed to coda stems.
- **Voicing.** As the voicing of the stem sibilant triggered no differences in Experiment 1, acoustic differences in the prefixal sibilant based on stem-sibilant voicing are not predicted.
- **Number of stem sibilants.** No trigger count effects emerged in Experiment 1. Therefore, no significant differences based on this factor are expected.
3.3 Methods

3.3.1 Subjects

Word of mouth recruitment of subjects resulted in a total of three speakers, one male and two female Navajo/English bilinguals. Prior to beginning the recording, participants completed a signed consent form (KU Human Subjects Committee Approval #17707) and a questionnaire that gathered demographic information and details about their Navajo language use (Appendix C). All speakers grew up in the northeast corner of the Navajo Nation in the northeast corner of the state of Arizona, were in their late twenties at the time of the recording, and spoke Navajo in the home while growing up. At the time of the recordings, Female 1 reported using Navajo language a little bit with her parents and with her siblings and/or friends, while Male 1 and Female 2 reported speaking Navajo a lot with their parents and grandparents and a little bit with their siblings and/or friends. All native speakers who showed interest were recorded.4

3.3.2 Stimuli

The stimuli consisted of 89 Navajo nouns – 62 targets, which contained one or more alveolar sibilant, 15 palatal fillers (which contain palatal sibilants), and 12 neutral fillers (which contain no sibilants). As in Experiment 1, palatal and neutral fillers are treated as separate groups unless statistical analysis reveals that they pattern identically. The nouns in Table 3 were added to the 75 nouns from

Table 3: Acoustic study noun list – additions to Appendix B.

<table>
<thead>
<tr>
<th>béeso</th>
<th>‘money’</th>
</tr>
</thead>
<tbody>
<tr>
<td>chídí</td>
<td>‘car’</td>
</tr>
<tr>
<td>dzí’izí</td>
<td>‘bike’</td>
</tr>
<tr>
<td>dzí’izís佐</td>
<td>‘motorcycle’</td>
</tr>
<tr>
<td>‘éénééž’</td>
<td>‘overcoat’</td>
</tr>
<tr>
<td>‘éétsoh’</td>
<td>‘coat’</td>
</tr>
<tr>
<td>géeso</td>
<td>‘cheese’</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>jéí</th>
<th>‘heart’</th>
</tr>
</thead>
<tbody>
<tr>
<td>kááz</td>
<td>‘gland’, ‘tonsil’</td>
</tr>
<tr>
<td>látsíní</td>
<td>‘bracelet’</td>
</tr>
<tr>
<td>máazo</td>
<td>‘marble’</td>
</tr>
<tr>
<td>mósí</td>
<td>‘cat’</td>
</tr>
<tr>
<td>tsats’ósí</td>
<td>‘needle’</td>
</tr>
<tr>
<td>tsásk’eh</td>
<td>‘bed’</td>
</tr>
</tbody>
</table>

4 None of the participants harmonized the first person possessive morpheme in a way that was audibly apparent to the experimenter, who is a native speaker of English. This is anecdotal, of course, and is reported here only for the sake of interest. Future instrumental analysis or perception experiments could shed additional light on the perceptual distinctness (or lack thereof) of the prefixal fricatives in harmonizing and nonharmonizing contexts.
the online survey (Appendix B). Each was repeated three times, yielding a randomized list of 267 tokens.

The researcher presented stimuli to participants verbally in English, as illustrated in (10). This conversational format was adopted because it put participants significantly more at ease than computer presentation of stimuli in Navajo. While the use of English in elicitation was not our first choice, the researcher does not speak Navajo and creating a comfortable elicitation environment for participants was deemed of key importance.

(10) Elicitation of stimuli
Researcher: How do you say ‘cat’ in Navajo?
Participant: mósí
Researcher: And how do you say ‘my cat’ in Navajo?
Participant: shimósí

Some words – such as doolghas ‘scallop’ or t’iis ‘Cottonwood tree’ – are very uncommon, geographically specific, or both. Participants were instructed to skip words they did not know, and in all instances this resulted in a reduced number of total usable tokens. Participants occasionally produced something other than the intended target, and in these instances the researcher made no additional attempt to elicit the intended word. It was sometimes provided inadvertently, however, as in (11).

(11) Elicitation of ‘my cat’
Researcher: How do say ‘my cat’ in Navajo? (desired response: shimósí)
Participant: Shigidi. Well, some people would say mósí, shimósí, but I say gidi.

It was also the case that a speaker’s pronunciations sometimes affected categorization of the targets. For example, one speaker consistently pronounced the word ‘prayer’ tsodizin, with an initial noncontinuant, rather than sodizin, as it appeared in the wordlist. For this speaker, then, tsodizin was considered a noncontinuant stem, while for the speakers who pronounced sodizin it was a continuant stem. This means that the specific members of a category varied from speaker to speaker.

3.3.3 Recording and acoustic analysis
Speakers were recorded onto a flash disc using an Electro-Voice N/D 767 cardioid microphone and a Marantz Portable Solid State Recorder (PMD 671) at a sampling
rate of 22.05 kHz in the anechoic chamber at the University of Kansas, Lawrence. The digitized recordings were imported into PRAAT (Boersma and Weenink 2010), allowing for simultaneous examination of the waveform and (wide-band) spectrogram of each token. Acoustic measurements included spectral mean and the lower bound of frication energy, and the F2 transition into the following vowel.

3.3.3.1 Measurements: Spectral mean, lower bound of frication energy, F2 transition
Spectral mean was measured from the 40 millisecond window in the exact center of the fricative. PRAAT was used to take a spectral slice and calculate the spectral mean from the spectrum.

The spectrogram generated by PRAAT was used to determine the lower bound of frication energy for each sibilant as shown in Figure 6, where the band of high frequency energy associated with the prefixal sibilant in shizid, ‘my liver,’ is consistently present starting at 1619 Hz. Measurement of the divergence in lower-bound energy is adopted with reference to McDonough (2003: 130), who specifically notes that Navajo [s] and [ʃ] are easily distinguished by “the lower edge of the energy bands”.

---

5 The lower bound of frication energy measurements in the present study were taken by hand in PRAAT on the same computer with all settings held constant. If a similar measure is taken in future studies that entail more subjects, rendering by-hand measurements less feasible, use of a different quantification technique, such as the one-half power drop-off commonly used in bandwidth measures, can be adopted.
3.4 Results

Overall averages for each participant are presented in Table 4. Filler measurements are taken from the prefixal sibilant in words with no alveolar sibilants like *shikee*’ ‘my knee.’ Paired samples t-tests indicated that values for the prefixal fricative in palatal fillers and neutral fillers did not differ from one another statistically. This was true for spectral mean ($t(20) = 0.24$, $p = 0.41$), the lower bound of frication energy ($t(20) = 0.8$, $p = 0.43$), and for F2 transition ($t(20) = −0.31$, $p = 0.38$). Acoustically, then, the prefixal fricative before both types of fillers patterns together, and so, as in Experiment 1, the two types are grouped and are referred to throughout the rest of Experiment 2 as Fillers.

Target measurements are taken from the [ʃ] in words with alveolar sibilants like *shímósí* ‘my cat.’ Measurements for [s] come from those tokens in each participant’s productions where an [s] was produced in isolation – from the first production of *mósi* ‘cat’ in (11), for instance, when the word was produced without the prefix.

Independent samples t-tests indicated that values marked with an asterisk were significantly different than SHI-Filler values, with $p < 0.001$. Thus the SHI-Target values marked with asterisks are those that are more [s]-like. Note that F2 transition into the following vowel does not differ significantly based on the place of articulation of the preceding sibilant, so this measurement is excluded from the rest of the analysis. Spectral mean and lower bound of frication energy,

---

**Table 4**: Mean acoustic measurements for Female 1, Female 2, and Male 1.

<table>
<thead>
<tr>
<th>Measures (in Hz)</th>
<th>Female 1</th>
<th>Female 2</th>
<th>Male 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[ʃ]-Target</td>
<td>[ʃ]-Filler</td>
<td>[ʃ]-Target</td>
</tr>
<tr>
<td>Spectral mean</td>
<td>5329</td>
<td>5329</td>
<td>5329</td>
</tr>
<tr>
<td>Lower bound fric. energy</td>
<td>1621</td>
<td>1621</td>
<td>1621</td>
</tr>
</tbody>
</table>

---

6 The means presented in Table 4 are very representative: the range and standard deviation for each measure for Female 1 are as follows: spectral mean (Range: 4609–5984 Hz; $SD = 337$ Hz), Frication Energy Onset (Range: 1434–1829 Hz; $SD = 123$ Hz), F2 Transition (Range: 1838–2086 Hz; $SD = 58$ Hz). Female 2 and Male 1 show extremely similar patterns. It is not the case, then, that the prefix harmonizes in one or two tokens and nowhere else. Rather, there are no instances where harmony occurs.
meanwhile, are significantly higher for [s] than [ʃ] for all speakers, as predicted, so these are addressed moving forward.

It is immediately apparent that the difference between FILLER and TARGET values is small in comparison to the difference between [s] and [ʃ] values. Thus a basic observation can be made: the prefixal fricative is clearly more [ʃ]-like than [s]-like, even before targets. Based on these values, then, the acoustic results indicate that harmony does not occur, echoing the findings from Experiment 1.

A series of FILLER-TARGET pairwise comparisons was conducted to determine whether the small differences observed were significant. The significance level was set at 0.05 and the Levene statistic was used to test the homogeneity of variance; the Bonferroni post hoc procedure was utilized to reduce the risk of a Type I error (Field 2005: 340).

When analyzed individually, no significant differences between acoustic measurements in the prefixal sibilant before targets and fillers emerged for Female 1. Female 2, on the other hand, showed a difference in the lower bound of frication energy, while Male 1 showed a difference in spectral mean.

Female 2 produced a total of 82 words – 57 targets and 25 fillers. One-way ANOVAs were conducted to assess the relationship between stem sibilants and the acoustic properties of the prefixal sibilant. The first test compared the prefixal [ʃ] preceding targets (i.e., Navajo stems that contained alveolar sibilants) and fillers (i.e., stems that did not). As seen in Table 5, the lower bound of frication energy in the prefixal sibilant was significantly higher before targets than before fillers.

Next, the target group was divided according to the features of interest – voicing, continuancy, adjacency, syllable position, and number of stem sibilants – and a series of ANOVAs was conducted. In these, the independent variable included three levels: fillers, in which the stems included no alveolar sibilants, as well as each specification for the feature being assessed. For voicing, then, the three levels were fillers, voiced stems, and voiceless stems. Dependent variables included spectral mean and the lower bound of frication energy of the prefixal sibilant. These follow-up tests revealed nothing of significance for Female 2:

<table>
<thead>
<tr>
<th>Table 5: Female 2: Target vs. Filler ANOVAs.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>M</strong></td>
</tr>
<tr>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>Spectral mean (Hz)</td>
</tr>
<tr>
<td>Lower bound of frication energy (Hz)</td>
</tr>
</tbody>
</table>

The raw text is formatted in a readable manner, with all text appearing as paragraphs. The table is presented in a tabular format with clear headings and values. The text is double-spaced, and all necessary formatting is maintained. The information is presented in a clear and concise manner, making it easy to understand and follow.
presence of an alveolar in the stem triggers a change, but no differences based on continuancy, adjacency, and so forth emerge.

This was not the case for Male 1, however, who produced 24 targets and 28 fillers for a total of 52 words. For him, the spectral mean of the prefixal fricative was affected by adjacency, with $F(2,44) = 3.82$ and $p = 0.029$. The Bonferroni post hoc procedure confirmed that the spectral mean of the prefixal sibilant was significantly higher before adjacent stems ($M = 4097.38$ Hz, $SD = 291.14$ Hz) than before nonadjacent stems ($M = 3779.76$ Hz, $SD = 168.23$ Hz), with $p = 0.031$. An alveolar sibilant in a syllable adjacent to the stem triggers an increase in the spectral mean of the prefixal $[\mathfrak{s}]$. Spectral mean is affected in the first-order nonlocal environment, in other words, but not in the second-order nonlocal environment.

### 3.5 Discussion

Impressionistically, the subjects reported here do not perform sibilant harmony. Having investigated several acoustic measures of the prefixal sibilant in potential harmony environments, we can now state that this is truly the case for Female 1. Acoustically, for the parameters reported herein, an $[\mathfrak{s}]$ is an $[\mathfrak{s}]$. For Female 2, however, the presence of alveolar sibilants in the stem triggers acoustic changes in the lower bound of frication energy of the prefixal $[\mathfrak{s}]$. Finally, Male 1 produces the prefixal fricative with a higher spectral mean when the trigger is in an adjacent syllable than when it is in a nonadjacent syllable. This is not surprising given the widely acknowledged role played by distance in Navajo sibilant harmony (Sapir and Hoijer 1967; Martin 2005) and other phonological domains (Berkley 2000; Frisch et al. 2004).

A larger sample size would have increased statistical power, but recruiting more participants for the current experiment was not possible. The data presented here constitute an important starting point, however, and Female 2 and Male 1 pattern together in an important way; they evidence acoustic effects of a phonological pattern which they do not overtly practice. While the prefixal fricatives are more $[\mathfrak{s}]$-like than $[\mathfrak{s}]$-like before both targets and fillers, indicating that harmony does not occur, there are nevertheless acoustic differences in fricatives preceding nouns that contain alveolar sibilants as compared with those that precede nouns which do not.

We may wonder if this is in fact merely coarticulation, rather than a remnant of harmony. I would argue that it is both: that the recession of harmony back into coarticulation gives us an important insight into the origins of sibilant harmony in Navajo. The results from Male 1 indicate that sibilants in adjacent syllables have a measurable coarticulatory effect on the prefixal sibilant, but that
this effect is blocked by an intervening consonant. This needs to be investigated in additional speakers, and across additional morphemes, but it raises an interesting possibility. Recall that while second-order nonlocal harmony still applies occasionally, as in Experiment 1b, it occurs far less frequently than first-order nonlocal harmony, is deemed less grammatical than first-order harmony in Experiment 1, and fails to have a coarticulatory effect on the prefixal sibilant in Male 1’s production data. Taken together, the suggestion is that if sibilant harmony began as coarticulation and was eventually extended to a nonlocal process in both first- and second-order environments, then it may now be receding in a similar way. Furthermore, even if the effects seen in Female 2 and Male 1’s speech can be attributed to coarticulation, the pressure to coarticulate cannot be unavoidable. Coarticulation is not mandatory, in other words: we know this because Female 1 does not coarticulate.

The question of whether the effects found in Experiment 2 are related to dialect cannot be answered definitively at present. The participants in this study are from different towns in the northeast corner of the Navajo Nation in Arizona. Whether this constitutes a single dialect area is unknown: while it is well established that there are a variety of dialect areas on the Navajo reservation (Reichard 1945; Peterson 1997), no dialect map exists at this point. Participants do, however, show distinct acoustic patterns, and their idiolects clearly differ. They did not produce entirely identical words – one provided yoostsah as the word for ‘ring,’ for example, while another provided ɬatsa. They also disagreed on the possessability of several words. For one speaker, neither ‘firewood’ nor ‘insect bite’ could be possessed; instead of ‘my insect bite,’ the speaker said the equivalent of ‘the insect bites me,’ and the thought of saying ‘my firewood’ caused a gale of laughter. A second speaker reported that she would not say ‘my firewood,’ but that she had heard other people say it. The third speaker said ‘my firewood’ without pause.

While empirical data regarding harmony patterns in additional morphemes and across distinct age groups and dialect areas is to be desired, the data reported here provide an important starting point. The experiments reported herein indicate that sibilant harmony applies rarely for some speakers and never for others: harmony in optional settings is either diminishing or was never as robust as previously reported.

4 Discussion

This paper set out to investigate the extent to which sibilant harmony applies in optional settings in Navajo, and the factors contributing to the optionality. The
grammaticality judgments elicited in Experiment 1 showed a preference for the unassimilated shi-form of possessed nouns in all instances; si-forms were dispreferred across the board. Still, continuancy, adjacency, and syllable position significantly altered grammaticality ratings: of the assimilated forms, grammaticality ratings were higher for noncontinuant stems than continuant stems, for adjacent stems than nonadjacent stems, and for onset stems than coda stems.

In Experiment 1b, harmony applied significantly more often with adjacent stems than with nonadjacent stems in online language use. Experiment 2 showed that, for Female 2, the prefixal sibilant had a significantly higher lower bound of friction energy before targets than before fillers; for Male 1, spectral mean was higher before adjacent stems than before nonadjacent stems. The theme that emerges repeatedly is that adjacency – or locality – matters even though harmony in optional settings is either disappearing from first-person possessed nouns in Navajo or never occurred as robustly as may have been intimated in the literature.

The original goals of this paper were to investigate the statistical nature of sibilant harmony in optional settings in Navajo, and to explore the factors which contribute to that variation. As we have seen, while optional harmony obtains far less frequently than anticipated, it is still a gradient phenomenon: certain factors contribute to the likelihood of whether disharmony is tolerated in an optional context. Sections 1.3.1–1.3.3. presented discussion of the importance of similarity, distance, and salience in phonological processes at large. The findings reveal that it is distance alone which consistently impacts the occurrence or grammaticality of harmonized forms.

The relevance of distance is not surprising given its importance in phonology in general. Discussion of the role of distance in phonology in Section 1.3.1 mainly focused on OCP-Place violations in Arabic, English, Latin, and Muna (Berkley 2000; Frisch et al. 2004; Coetzee and Pater 2008). Within the realm of consonant harmony, we can consider the role of distance in Kinyarwanda; in this Bantu language, regressive harmony is mandatory for sibilants in adjacent syllables but optional for those in nonadjacent syllables (Walker, Byrd, and Mpiranya 2008), a scenario which is not uncommon. In fact, consonant harmony constraints are often invariable in the root (i.e., they are visible as morpheme structure constraints) but optional beyond the root. Indeed, Navajo roots are subject to a morpheme structure constraint (MCS) that disallows sibilants with mismatching anteriority values within a root. The present findings suggest that the occurrence of assimilation in optional contexts may be declining, but to the best of our knowledge the MCS holds: disharmonious roots are still disallowed in Navajo.

Furthermore, distance is repeatedly mentioned in reference to Navajo sibilant harmony; more than four decades ago, Sapir and Hoijer (1967: 14–15) observed
that sibilant harmony in Navajo “occurs less often when the two consonants are at a greater distance”. Recall also that Finley (2011) found that adults in an artificial grammar learning experiment who were exposed to a second-order nonlocal harmony pattern extended the pattern to first-order nonlocal environments, while those exposed to first-order nonlocal harmony did not extend the pattern to second-order nonlocal environments. The resulting argument – that locality, or proximity, is privileged even when dealing with nonlocal processes – is further supported by the experiments reported herein. Multiple factors that may have been expected to contribute to the occurrence of harmony in optional settings were investigated, but only distance proved significant in three settings: grammaticality judgments, online language use, and instrumental acoustic analysis. First-order nonlocal harmony was better tolerated in Experiment 1 and more frequent in Experiment 1b. The first-order nonlocal environment triggered measurable acoustic effects in Male 1’s speech. Though harmony is said to be optional in the second-order nonlocal environment, it was dispreferred in Experiment 1, occurred minimally in Experiment 2, and triggered no acoustic effects in Male 1’s speech.

Given the Navajo results herein, it would be interesting to conduct an analysis of harmony in Kinyarwanda to determine how often harmony actually obtains in optional settings: if it patterns like Navajo, it may be the case that harmony in optional settings occurs very rarely indeed. Harmony between sibilants in nonadjacent syllables – that is, second-order nonlocal harmony – is optional in Kinyarwanda as it is in Navajo, but as in Navajo optional harmony may not be robust at all. Gathering specific data regarding the occurrence of these optional processes is critical because we refer to them repeatedly as outliers: nonlocal processes are not the phonological norm. Phonological theory must be able to account for nonlocal processes, for they do occur, but it may be the case that we misrepresent the robustness of their occurrence. Analysis of the occurrence of optional harmony in Kinyarwanda, or in other consonant harmony systems with both mandatory and optional settings, may reveal further evidence in support of the prominence of first-order over second-order nonlocal processes.

4.1 Additional factors

Factors which have not been addressed herein include frequency effects, the statistical composition of the Navajo lexicon, and the Palatal Bias. The current lack of a searchable Navajo corpus or dictionary makes it functionally impossible to obtain Navajo frequency data, but it has been shown that neighborhood
density contributes to gradient grammaticality judgments (Ohala and Ohala 1986; Coleman 1996; Bailey and Hahn 2001). Such data is therefore desirable, and should be sought in future work. Nor can we discuss the statistical make-up of the lexicon in the absence of a searchable corpus or dictionary, yet we know from previous dictionary- and word list-based studies that such analyses can yield helpful results (Zuraw 2002; Frisch et al. 2004; Coetzee and Pater 2008). Analysis of the frequency with which palatal and alveolar sibilants appear in Navajo nouns could enable a more nuanced understanding of the bias against harmony found in this paper.

This is particularly relevant because of the Palatal Bias, a term which refers to asymmetries observed in the errors that are made in speech production (Stemberger 1991) and perception (Pouplier and Goldstein 2005). Briefly, alveolar segments like /s/ and /t/ are much more often mistakenly replaced with palatal segments like /ʃ/ and /tʃ/ in English speech errors than vice versa, this despite the fact that alveolar segments are higher-frequency (Stemberger 1991; Hansson 2001). Hansson reports that the same phenomenon has been found for German (Berg 1988) and Hebrew (Bolozky 1978); he also reports that there are startling similarities between consonant harmony and speech errors, and finds evidence of a Palatal Bias in the typology of consonant harmony systems.

Such systems may be either symmetric or asymmetric. Symmetric harmony systems are those in which anteriority can spread both ways – underlying /s/ can become /ʃ/, and underlying /ʃ/ can become /s/. In asymmetric harmony systems, however, harmony goes in only one direction; i.e., /s/ may be a target and /ʃ/ a trigger, but never the reverse. Alternatively, /ʃ/ may be a target and /s/ a trigger, but not the reverse. The typology of asymmetric consonant harmony systems shows a clear imbalance in keeping with the Palatal Bias; Hansson (2011: 472) reports 16 languages that display /s/ to /ʃ/ asymmetric harmony, and only one – Tlachichilco Tepehua – that exhibits the reverse. Typologically, then, /s/ is far more likely to serve as a target than as a trigger; conversely, /ʃ/ is a more likely trigger than target.

Navajo is reported to exhibit symmetric harmony; alveolar segments may act as both triggers and targets, and the same is true for palatals. This research has looked at the likelihood of /ʃ/ surfacing as [s], but our understanding of the true nature of sibilant harmony as it exists in Navajo today cannot be complete without determining whether there are asymmetries in the behavior of underlying /s/ surfacing as [ʃ]. Navajo sibilant harmony may exhibit a Palatal Bias: underlying /s/ may harmonize more commonly in optional settings than underlying /ʃ/, in which case the findings herein related to the robustness of optional harmony may be only one piece of a larger picture. To determine whether this is the case, future
investigation of a morpheme that contains an underlyingly alveolar sibilant is needed.

### 4.2 A disappearing phenomenon: Potential causes

Aside from the possible influence of the Palatal Bias on the findings presented herein, one of the major, as yet unaddressed questions we may consider deals with the factors underlying the shift away from consonant harmony implied by the findings herein. Informally, I have been told that students in some high school Navajo language classes are taught that the first person possessive morpheme is *shi-* , always and only. This information is anecdotal and replete with complications, and so is not discussed in detail, but it should not be dismissed as a potential contributor to language change. The exposure gained in classroom learning differs from that of typical first language acquisition in terms of amount and content; the reading and writing instruction usually involved is absent from the mode of transmission found in typical first language acquisition. Considering just the first person possessive, consistent use of the unharmonized form means that students will only be exposed to *shi-* in the classroom; they will never see the *si-* form written. That sibilant harmony is visible in written Navajo has been useful in this work because it enabled investigation of language in online domains, but the ways in which orthography influences spoken Navajo remain to be studied. Those issues aside, neither the influence of classroom learning nor the issues related to orthography should be relevant to the findings of Experiment 3; the three participants recorded therein acquired Navajo in their homes as children.

A review of language-external factors cannot neglect the influence of other languages, and of English in particular. As mentioned previously, Navajo is an endangered language; child acquisition of Navajo is declining, while English language use is increasing (Holm and Holm 1995; Schaengold 2004). Schaengold (2004) reports that a nonstandard variety of Navajo referred to as “Bilingual Navajo” is increasingly common on the Navajo Nation, particularly for young people in urban areas around the edges of the Nation. Bilingual Navajo is heavily influenced by English and includes many English lexical items, and while it does not hold high social prestige at present, it is reportedly becoming less socially marked as time passes. Schaengold notes that not all speakers apply sibilant harmony to lexical items in Bilingual Navajo; she also notes, however, that it is not uncommon to hear speakers produce ‘just’ as [dzas] or ‘Jesus’ as [dzi:zas] (90). (Notice that both examples given show first-order nonlocal harmony.)
It is not surprising to see productions in one language being modified by the phonology of another language: experimental work by Flege, for example, has revealed interaction between bilinguals’ first and second language grammars at the level of phonetics. In a 1987 study, for example, Flege investigated the production of [t] by L1 English/L2 French bilinguals living in Paris and L1 French/L2 English bilinguals living in Chicago. [t] is produced with a short positive voice onset time (VOT) by monolingual French speakers and a long positive VOT by monolingual English speakers: Flege found that both groups of bilinguals produced [t] in English and in French with shorter VOTs than English monolinguals and longer VOTs than French monolinguals (Flege 1987). For both groups, then, acquisition of phonetic categories in the second language modified phonetic categories in the first language. The possibility we must entertain with regards to Bilingual Navajo, then, is that the influence runs in both directions. If this is the case, then the take-home message is simple: English does not exhibit sibilant harmony, and this may contribute to the minimal sibilant harmony found in this paper.

Although her work on the sound system of Navajo deals almost exclusively with verbs, rather than consonant harmony, McDonough (2003) does touch on a number of points of interest related to harmony. She observes that because sibilant harmony neutralizes a place of articulation contrast, it further limits an already limited set of place of articulation contrasts. McDonough goes on to ask, “why would a language with an already reduced set of place of articulation contrasts further reduce its phonemic inventory by disallowing contrasts among the coronal consonants?” (49). This is interesting to consider, yet the neutralizations triggered by sibilant harmony are not unique in Navajo, a language in which the full inventory of sounds can be realized in very few locations within words (namely verb and noun stems), and wherein neutralization occurs in many contexts.

Language internally, another possibility that can be considered deals with exposure. This research has focused on a nominal affix, in part because noun morphology involves fewer instances of fusion than verbal morphology in Navajo – affixes remain more easily separable, in other words, thereby presenting a useful realm in which to initiate preliminary investigation. Verbs are more numerous than pure nouns in Navajo, however (McDonough 2003; Oberly 2008), and noun-like elements are often built from verbs; the Young, Morgan, and Midgette lexicon lists 265 noun stems, versus approximately 4,000 nouns derived either through nominalization of verbs or through compounding of verbal and noun stems (Young and Morgan 1992, as quoted in Gentner and Boroditsky 2009). Furthermore, nouns show less productive morphology than verbs do (Gentner and Boroditsky 2009). As such, it is at least possible that learners have limited exposure to optional sibilant harmony operating in the nominal domain, in which case they
may simply resist making generalizations. It is therefore important for future research to target optional sibilant harmony in the verbal domain.

5 Conclusion

Although discussion of sibilant harmony in Navajo typically refers to the presence of both mandatory and optional harmony environments, the present results reveal that there is no mandatory harmony environment for the first person possessive morpheme. Is harmony disappearing, and if so, why? The questions remain open for now. For a full understanding of the state of sibilant harmony in Navajo, investigation of the process in verbal domains and of an underlyingly alveolar morpheme which harmonizes to a palatal are needed. Nonetheless, the results presented in this paper reveal that harmony is always optional. Moreover, the effect of locality is evident: first-order nonlocal harmony is not terribly robust, and second-order nonlocal harmony is almost nonexistent.

Acknowledgments: This work would not have been possible without the assistance of four Navajo language consultants who were generous with their time, knowledge, and endless good humor. The author’s sincere gratitude goes to Dr. Jie Zhang, Dr. Allard Jongman, and Dr. Joan Sereno at the University of Kansas. Audiences at the 2012 Annual Meeting of the Society for the Study of the Indigenous Languages of the Americas, the 4th Annual Oklahoma Workshop on Native American Languages, and the 16th Annual Midcontinental Workshop on Phonology provided valuable feedback, as did two anonymous reviewers whose commentary and suggestions strengthened this piece immeasurably. Thank you. As always, any errors are mine alone.

References


Weisser, Eric W. 2008. Ashkii Bizaad: verbal morphology loss in one young speaker’s Navajo. Undergraduate linguistics honors project, Macalester College, St Paul, MN.
Appendix A: Qualtrics survey noun list

For general commentary on nouns, see the notes at the end of this Appendix. Nouns requiring specific commentary are annotated with asterisks.

**Neutral fillers**

1. *awoo'* ‘tooth’
2. *bid* ‘stomach’
3. *daa’* ‘lip’
4. *doh* ‘muscle’
5. *gaan* ‘arm’
6. *gish* ‘walking stick’
7. *god* ‘knee’
8. *hooghan* ‘home’
9. *k’a’* ‘arrow’
10. *kee’* ‘foot’
11. *nii’* ‘face’
12. *yid* ‘chest’
13. *yih* ‘breath’

**Palatal fillers**

14. *ach’oozhlaa’* ‘elbow’
15. *ajaa’* ‘ear’
16. *ch’ah* ‘hat’
17. *ch’osh hashhash* ‘insect bite’
18. *ch’ozh* ‘calf’
19. *chaii* ‘maternal grandfather’
20. *chizh* ‘firewood’
21. *honishgish* ‘fire poker’
22. *jeeh* ‘chewing gum’
23. *jizhgish* ‘cut’
24. *naanish* ‘work’
25. *zhi’* ‘torso’
Targets

26.  agaanstiin  ‘guitar’
27.  ak’inaazt’i’  ‘harness’
28.  atsoosk’id  ‘thigh’
29.  ayaats’iin  ‘chin’
30.  bii’dees’eex  ‘stirrup’
31.  bis  ‘clay’
32.  bits’a’  ‘peapod’
33.  bizis  ‘pack’ (of gum, cigarettes, etc.)
34.  dahts’aar  ‘mistletoe’
35.  das  ‘weight’
36.  dikos  ‘cough’
37.  dikos’azee’  ‘cough syrup’
38.  doolghas  ‘scallop’
39.  dziil  ‘strength’
40.  (ha)st’e’  ‘(his) lunch’
41.  hatsi’  ‘daughter’
42.  haza’aleetsoh  ‘wild celery’
43.  haza’aaleeh  ‘herbs’
44.  heeneez*  ‘rectangle’
45.  hootso  ‘pasture’
46.  k’iiz  ‘side’
47.  k’is  ‘sibling, friend’
48.  k’os  ‘neck’
49.  kaz  ‘cane’
50.  naaltsoos  ‘book’
51.  naaltsoos azis  ‘shopping bag’
52.  sin  ‘song’
53.  sodizin  ‘prayer’
54.  t’iis  ‘Cottonwood tree’
55.  ta’azis  ‘pocket’
56.  tin sikaad*  ‘rink’ (for ice skating, etc)
57.  ts’aa  ‘basket’
58.  ts’iizis  ‘head basket’
59.  ts’in  ‘bones’
60.  ts’oos  ‘nerve’
61.  tsah  ‘needle’
62.  tsee’  ‘tailbone’
63.  tsii’  ‘hair’
64.  tsiiits’in  ‘skull’
There was debate amongst my consultants about which nouns could be possessed and which could not. At least one consultant considered each of the following words unpossessable, ungrammatical, or both: *ch’osh hashhash* ‘insect bite’, *chizh* ‘firewood’, *jizhgish* ‘cut’, *heeneez* ‘rectangle’, *tin sikaad* ‘(skating) rink’. I did not exclude these words from the list because one or more of my consultants considered the possessed form to be grammatical. In some cases this meant they had used a possessed form themselves; in others, they had simply heard or seen a possessed form used by someone else.

*Note.* The adjacent stem group contains a few coda stems, which involve second-order and not first-order harmony. This means that the mapping between the two is not perfect, and, added to the fact that distance in Navajo is more accurately measured by syllable than by segment (Martin 2005), it calls for a deeper investigation of the relationship between distance and first- vs. second-order harmony in future work.
**Appendix B: QueryGoogle noun list and assimilation rates**

<table>
<thead>
<tr>
<th>Navajo word</th>
<th>Proportions (si-forms/total # of tokens for stem)</th>
<th>Assimilation rate</th>
<th>Adjusted reliability*</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘azee</td>
<td>0/1</td>
<td>.00</td>
<td>0.07</td>
</tr>
<tr>
<td>béeso</td>
<td>0/70</td>
<td>.00</td>
<td>0.00</td>
</tr>
<tr>
<td>bis</td>
<td>20/52</td>
<td>.39</td>
<td>0.31</td>
</tr>
<tr>
<td>-dziil</td>
<td>12/20</td>
<td>.60</td>
<td>0.47</td>
</tr>
<tr>
<td>k’is</td>
<td>488/886</td>
<td>.55</td>
<td>0.53</td>
</tr>
<tr>
<td>k’os</td>
<td>1/2</td>
<td>.50</td>
<td>0.22</td>
</tr>
<tr>
<td>kaz</td>
<td>3/4</td>
<td>.75</td>
<td>0.44</td>
</tr>
<tr>
<td>látshíí</td>
<td>0/1</td>
<td>.00</td>
<td>0.07</td>
</tr>
<tr>
<td>nósí</td>
<td>1/9</td>
<td>.11</td>
<td>0.06</td>
</tr>
<tr>
<td>naaltsoos</td>
<td>0/9</td>
<td>.00</td>
<td>0.01</td>
</tr>
<tr>
<td>-tsa</td>
<td>4/6</td>
<td>.67</td>
<td>0.43</td>
</tr>
<tr>
<td>tsásk’eh</td>
<td>1/1</td>
<td>1.00</td>
<td>0.35</td>
</tr>
<tr>
<td>tsii’</td>
<td>9/20</td>
<td>.45</td>
<td>0.33</td>
</tr>
<tr>
<td>tsiliits’iín</td>
<td>12/16</td>
<td>.75</td>
<td>0.60</td>
</tr>
<tr>
<td>tsili</td>
<td>131/168</td>
<td>.78</td>
<td>0.74</td>
</tr>
<tr>
<td>–tsis</td>
<td>5/5</td>
<td>1.00</td>
<td>0.71</td>
</tr>
<tr>
<td>tsoi</td>
<td>78/87</td>
<td>.90</td>
<td>0.85</td>
</tr>
<tr>
<td>too</td>
<td>2/5</td>
<td>.29</td>
<td>0.22</td>
</tr>
<tr>
<td>wos</td>
<td>2/5</td>
<td>.40</td>
<td>0.22</td>
</tr>
<tr>
<td>yaats’iín</td>
<td>0/1</td>
<td>.00</td>
<td>0.07</td>
</tr>
<tr>
<td>-zaad</td>
<td>1/104</td>
<td>.01</td>
<td>0.01</td>
</tr>
<tr>
<td>za’azis</td>
<td>2/2</td>
<td>1.00</td>
<td>0.50</td>
</tr>
<tr>
<td>zagi</td>
<td>3/3</td>
<td>1.00</td>
<td>0.60</td>
</tr>
<tr>
<td>zazi</td>
<td>1/2</td>
<td>.50</td>
<td>0.22</td>
</tr>
<tr>
<td>-zee</td>
<td>9/15</td>
<td>.60</td>
<td>0.45</td>
</tr>
<tr>
<td>zeedi</td>
<td>3/16</td>
<td>.19</td>
<td>0.12</td>
</tr>
<tr>
<td>zid</td>
<td>7/14</td>
<td>.50</td>
<td>0.36</td>
</tr>
<tr>
<td>ziiz</td>
<td>142/145</td>
<td>.98</td>
<td>0.96</td>
</tr>
</tbody>
</table>

* Adjusted Reliability: Lower Confidence Limit (α = 0.75); calculated exact confidence intervals for proportions, http://www.causascientia.org/math_stat/ProportionCI.html
Appendix C: Acoustic study personal information questionnaire

The following questionnaire is intended to collect personal information. Neither your name nor any other personal information will be associated in any way with the data collected in this experiment, or with the research findings from this study. The researcher will use a participant number, initials, or a pseudonym instead of your name.

1. I speak Navajo with my parents.
   a lot  a little  not at all  This question doesn't apply to me.

2. I speak Navajo with my grandparents.
   a lot  a little  not at all  This question doesn't apply to me.

3. I speak Navajo with my siblings and/or friends.
   a lot  a little  not at all  This question doesn't apply to me.

4. We spoke Navajo in my home when I was growing up.
   a lot  a little  not at all  This question doesn't apply to me.

5. I can read and write in Navajo.
   a lot  a little  not at all  This question doesn't apply to me.

6. Reading and writing in Navajo is
   easy  kind of easy  okay  kind of hard  hard

7. I am _____________ years old.

8. I am male.  I am female.  (please circle one)

9. What town/city (or towns/cities) did you grow up in?