ARTICULATION WITHOUT ACOUSTICS: "SOUNDLESS" VOWELS IN BLACKFOOT*

Heather Bliss[1] and Bryan Gick[1,2]
University of British Columbia[1] and Haskins Laboratories[2]

1. Introduction

This paper reports on the results of two experiments demonstrating that Blackfoot final voiceless vowels are distinguished articulatorily but not acoustically.

1.1 The Debate about Speech Targets

In the speech literature, there is a bias towards acoustic models of speech production (e.g. Guenther et al 1998, 1999). Under this type of model, articulations are not viewed as targets of speech production, but rather the means by which speakers can strive to reach speech production targets that are defined purely by acoustic factors.

For example, Guenther et al (1999) look at articulatory variability in the production of the American English phoneme /r/. They observe significant and systematic differences in vocal tract shape during /r/ productions for different speakers, as well as in different phonetic contexts. They conclude that these articulatory tradeoffs function to reduce acoustic variability, a finding that they argue supports a model of acoustic targets of speech production. The tradeoffs are taken as evidence that articulations are not targets themselves, but rather serve as the vehicle for reaching acoustic targets.

In contrast with the acoustic model, Browman and Goldstein (1989; 1992) advocate an articulatory account of speech production, under which speech sounds are represented as gestures rather than acoustic signals. Evidence for this claim comes from a range of data in which tongue movements are attested even when the acoustic signal is obscured. Browman and Goldstein cite word boundaries in fast connected speech, such as the [t] in the utterance "perfect memory," as an example in which articulators reach their intended targets even when there is no acoustic realization of the articulation. Similarly, errors in speech production are shown to be gradient, ranging from "accidental"

* We gratefully acknowledge Rachel Ermineskin and Noreen Breaker for participating in the experiments, and Beatrice Bullshields for her input on experimental design. We would also like to thank Meagan Louie for providing the artwork for the perception experiment, and Sara Johansson and Betsy Ritter for technical and administrative support for the experiments. Thanks to Donald Derrick, Beth Rogers, Jennifer Glougie, Murray Schellenberg, and Martin Oberg for their assistance with various technical details, and to Doug Pulleyblank and Martina Wiltschko for helpful feedback.

Actes du congrès annuel de l'Association canadienne de linguistique 2009.
Proceedings of the 2009 annual conference of the Canadian Linguistic Association.

muscle activity without acoustic consequence to an acoustically realized speech sound where one is not expected.

Similarly, Tremblay et al (2003) argue in favour of a gestural account, based on their findings in a jaw perturbation study. They observed that, when a mechanical perturbation alters the motion path of the jaw, speakers make systematic compensatory adjustments to their jaw movements, even when the perturbation does not affect the associated acoustic output. Tremblay et al conclude that "…the positions of speech articulators and associated somatosensory inputs constitute a goal of speech movements that is wholly separate from the sounds produced" (p. 866).

Both Browman and Goldstein's and Tremblay et al's studies demonstrate that, in the absence of salient acoustic goals, speakers nevertheless strive to meet articulatory goals. What this suggests is that the targets of speech production cannot be exclusively acoustic. A more balanced model, then, is one that recognizes the validity of both acoustic and articulatory targets.

Returning to the question of articulatory tradeoffs, even these can be shown to support a model that recognizes both acoustic and articulatory targets. For example, Ménard et al (2008) look at the production (and perception) of vowel contrasts for congenitally blind versus sighted adult speakers of Canadian French. They find that blind speakers do not use lip protrusion to encode roundness contrasts to the same degree that sighted speakers do. Rather, roundness distinctions are encoded along the horizontal (front-back) dimension. The fact that the acoustic production is achieved for both groups suggests that there is an acoustic target. Yet, the tradeoff between lip protrusion (a visible articulator) and tongue movement (an invisible articulator) suggests that visual deprivation influences speech production, and this is consistent with a model that recognizes the importance of gestures (or at least visually perceptible gestures) in speech production. The fact that blind and sighted speakers consistently use different articulators, and that the sighted speakers consistently make use of lip protrusion, the visible articulator, to encode roundness, speaks to the saliency of the articulatory target.

In sum, there is compelling evidence in favour of a dual model of speech production that recognizes both acoustic and articulatory targets.

1.2 Systematically Encoded Articulatory Targets

Under the view that the targets of speech production can be articulatory as well as acoustic, we predict that there will exist languages in which purely articulatory distinctions are phonologized. Gick et al (2006) argue that Oneida (Iroquoian) is such a language. They demonstrate that utterance-final voiceless vowels in Oneida are indeed "soundless," in that phonologically distinct vowels are articulatorily but not acoustically distinct. Acoustic and articulatory data for three word-final vowels, /e/, /u/, and /ʌ/, were collected, and significant differences for at least one of the vowels was found at each articulatory location measured, namely the lips, and the palatal, velar, and pharyngeal points of contact. Importantly, these articulatory differences did not correlate with acoustic differences; little evidence of coarticulation was observed. That articulatory distinctions can be systematically encoded without any acoustic realization suggests that, at least in some cases, the targets of speech production can be articulatory.

1.3 Soundless Vowels in Blackfoot

Like Oneida, Blackfoot (Plains Algonquian: Southern Alberta) has voiceless vowels in its phonetic inventory. In particular, short vowels are systematically devoiced in utterance-final position (Frantz 1991). Although visually perceptible, these voiceless vowels are typically inaudible (Van Der Mark 2003). Blackfoot speakers describe voiceless vowels as “puffs of air” or “silent sounds” and instruct students to “watch their mouths” in order to perceive the sounds they are producing. These types of comments suggest that voiceless vowels in Blackfoot represent articulatory targets.

The current study investigates both the acoustic and articulatory properties of voiceless vowels in this language. Its goals are twofold. The first is to contribute to the debate regarding the targets of speech production with data on voiceless vowels from a language that is genetically and areally distinct from that used in the Gick et al (2006) study (e.g. Oneida). The second goal is to expand on the small collection of studies addressing Blackfoot phonetics, a goal which may be relevant for purposes of language teaching and preservation of this endangered language.

The Blackfoot language consists of four dialects, which vary mostly with respect to lexical and morphological properties. In addition, certain inflections are now purportedly identified with “old Blackfoot,” and are not in frequent use by younger speakers. The morphological differences between ideolects are relevant to the current study, because only some speakers employ the suffixes that yield a systematic morphological distinction between different word-final voiceless vowels (Bliss and Glougie 2009; Frantz 1991).

In the grammar of the Siksiká speakers observed in this study, one of two word-final suffixes, “proximate” *–(w)a* and “obviative” *–(y)i* obligatorily appear on animate nouns for purposes of reference-tracking. When the noun stem is consonant-final, the glide is elided, meaning that the proximate/obviative distinction is encoded solely by the voiceless vowels *–a* and *-i*. In essence, minimal pairs, differing only with respect to the word-final voiceless vowel, are readily available in the grammar. Moreover, the voiceless vowels systematically encode a morphosyntactic distinction.

1.4 Hypotheses and Predictions

Based on native speaker judgments regarding the inaudible character of these vowels, the hypothesis investigated in this study is that, as in Oneida, voiceless vowels in Blackfoot represent articulatory targets.

Using a combination of acoustic, lip aperture, and ultrasound data, the production experiment compares the voiceless vowels *–a* and *–i* to determine whether they are acoustically and/or articulatorily distinct. The prediction is that word-final voiceless vowels *–a* and *-i* will exhibit significant differences for articulatory measures, but not for acoustic measures.

The perception experiment tests whether acoustic differences between words containing voiceless *–a* and *–i* (if present) can be perceived by Blackfoot listeners. The prediction is that the acoustic signal itself will not provide enough information to disambiguate between *–a* and *–i* tokens.

These findings would support a theory of speech production that recognizes the validity of articulatory targets.

2 Production Experiment

The production experiment investigates the acoustic and articulatory properties of nouns that differ only with respect to the final voiceless vowel. The prediction is that voiceless *–a* and *–i* will be articulatorily but not acoustically distinct.

2.1 Production Experiment Methods

The methodology employed in the production experiment parallels that developed by Gick et al (2006).

2.1.1 Subject

The subject is one adult female who is a native speaker of the Siksiká dialect of Blackfoot. At the time of the experiment, she is 74 years old and lives in Calgary, Alberta in a predominantly English-speaking community. She is bilingual with English, but frequently speaks her native language with friends and relatives.

2.1.2 Apparatus

The experiment used a combination of ultrasound, video, and acoustic recordings. The ultrasound system is a Titan SonoSite High Resolution system, with a C11/8-5 MHz transducer. During the experiment, the transducer was attached to a long metal arm connected to a tabletop microphone stand, which allowed the transducer to sit freely at the subject's chin without requiring her to lean forward. The subject sat in a firm chair against a wall. To stabilize the subject's head and avoid extraneous movements, a firm foam wedge was attached to the wall with adhesive tape, and the subject's heat rested against it. In addition to the ultrasound transducer, a lapel microphone was affixed to the metal arm in close proximity to the subject's mouth. Both the ultrasound and audio recordings were taken with a Sony MiniDV HandyCam (model no. DCR-TRV900). Video recordings were taken of the subject's lip movements with a second recorder, a JVC MiniDV Digital Video Camera (model no. 09671902). Photographs of the experimental set-up are depicted in Figure 1 below.

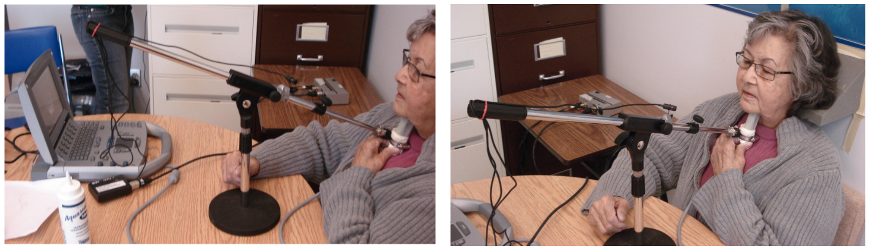


Figure 1. *Photographs of experimental set-up*

2.1.3 Speech Sample

The speech targets consisted of three consonant-final disyllabic nouns with a lexical high tone falling on the second syllable. For each of the nouns, there were two conditions: either the proximate (-*a*) or obviative (-*i*) suffix was added, yielding six forms in total, as listed in Table 1.

Table 1. *Speech targets for proximate (final –*a*) and obviative (final –*i*) conditions*

Proximate (-*a*) Forms	Obviative (-*i*) Forms	English Translation
*si'káán**a***	*si'káán**i***	'blanket'
*ki'sómm**a***	*ki'sómm**i***	'moon'
*miistsís**a***	*miistsís**i***	'tree'

Data was collected for two additional nouns, *oosák* 'back fat,' and *pokón* 'ball.' The former was omitted because of salient acoustic differences in the stop release before the voiceless vowel, and the latter was not included in the present study.

Because the –*a* and –*i* suffixes are morphosyntactically conditioned, the carrier phrase differs slightly for each condition, as follows:

> To elicit proximate –*a* forms:
> Nitsikssta ninaahksinowahsi ana __
> "I want to see that __."
>
> To elicit the obviative –*i* forms:
> Nitsikssta maahksinowahsi ani __
> "I want him/her to see that __."

Each target was repeated in each condition 10 times, yielding 60 tokens.

2.1.4 Procedure

The subject was given information about the experimental setup and the speech targets two days in advance of the experiment. Immediately before commencing the experiment, the subject again reviewed the list of target forms, and was given a paper copy of the list of nouns in their uninflected forms and the two carrier phrases.

The subject was instructed to produce each carrier phrase with each noun and to speak naturally and at a normal speaking rate. For each trial, the subject produced each noun in both conditions, and she silently counted to three between each utterance. There were ten trials in total, and between each trial, the subject removed the transducer from her chin and recording was paused. The procedure was carried out in a private office in the Department of Linguistics at the University of Calgary.

2.1.5 Analysis

Both the ultrasound and lip aperture recordings were digitized using iMovie HD and were exported as DV movies. The audio tracks were exported as WAV files using QuickTime.

Video frames were extracted from both the ultrasound and lip aperture recordings using Final Cut Pro. For *si'káán* and *miistsís* targets, the fourth frame following the last audible acoustic information was extracted for each of the recordings of each of the tokens. For *kisómm* targets, the seventh frame was extracted, to account for the length of the final consonant. In both cases, the aim was to capture the voiceless vowel at midpoint.

Regarding first the ultrasound measurements, the length (measured in pixels and later converted to millimeters) from the centre of the transducer arc to the tongue surface was recorded, at approximately 45°, 60°, 75°, 90°, 105°, 120°, and 135° angles. Measurements were taken using ImageJ. A sample ultrasound frame, with angles marked, is shown in Figure 2.

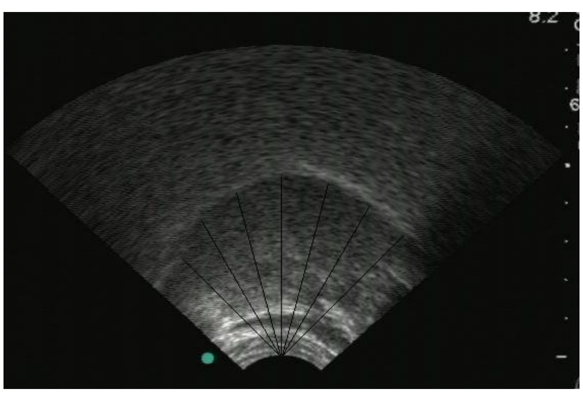


Figure 2. *Sample ultrasound frame (target word:* ki'sómma*), with angled measurements marked; 45° is the rightmost angle, and 135° is the leftmost.*

The lip aperture was also measured using ImageJ. The length (in pixels) was measured from the midpoint of the vermilion border of the upper lip to a prominent vertical wrinkle slightly off the midpoint of the vermilion border of the lower lip. Again, a sample frame, with the measurement marked, is shown below.

Figure 3. *Sample lip aperture frame (target word:* si'kááni*), with angled measurement marked*

Two types of acoustic measurements were taken, both in Praat. First, an auditory and visual inspection was carried out to determine whether the final vowel of each token was indeed devoiced. The visual inspection entailed looking for evidence of a voicing bar or formant structure following the last audible evidence of the preceding consonant on the spectrogram. Second, F1, F2, and F3 values at the end of the last audible vowel were recorded for all remaining tokens. This measurement was taken to determine whether these vowels exhibit anticipatory coarticulation effects of the final voiceless vowel.

Finally, statistical analysis for ultrasound, lip aperture and acoustic data was performed using JMP.

2.2 Production Experiment Results

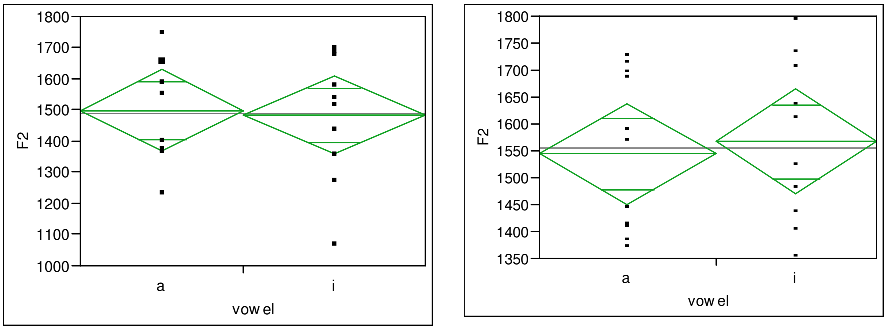
Three of the sixty tokens were omitted because of voicing on the final vowel. A series of Oneway ANOVAs compared articulatory and acoustic measures for the remaining *–a* versus *–i* tokens for each of the three target nouns.

2.2.1 Acoustic Results

Measures of F1, F2 and F3 of the vowel preceding the final voiceless vowel were taken to determine whether coarticulation effects yield an acoustic distinction between final *–a* and *–i.* Only one of the three target nouns, *miistsís*, exhibited differences in F2 and F3 values. F1 differences were not significant for any of the targets.

No significant difference was found for either F2 or F3 values in *ki'sómma* versus *ki'sómmi* tokens [$F(1,17) = 0.038$, $p = 0.849$ for F2, and $F(1,17) = 0.379$, $p = 0.547$ for F3]. Similarly, no significant difference was found for either the F2 or F3 values of the vowel preceding the final vowel in *si'káána* versus *si'kááni* [$F(1,19) = 0.121$, $p = 0.732$ for F2, and $F(1,19) = 0.013$, $p = 0.909$ for F3]. Graphs of the F2 results for *ki'sómm* and *si'káán* are given in

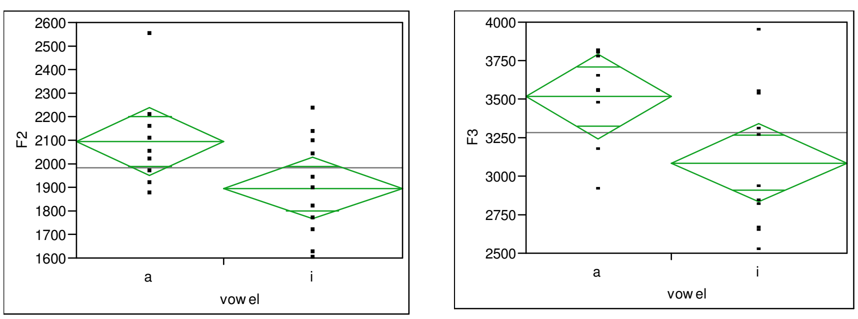
Figure 4 below. (In this and all subsequent graphs in §2, horizontal lines represent 95% confidence intervals, with α = 0.05.)



ki'sómm *si'káán*

Figure 4. *F2 values for* –a *versus* –i *forms of* ki'sómm *and* si'káán

The results for *miistsís* differ from those of *si'káán* and *ki'sómm* because a significant acoustic difference was observed between *–a* and *–i* tokens. Both F2 and F3 values for the vowel preceding the word-final voiceless vowel showed significant differences for *miistsísa* versus *miistsísi* tokens [$F(1,18) = 4.458$, $^*p = 0.049$ for F2, and $F(1,18) = 5.842$, $^*p = 0.027$ for F3]. F2 and F3 results are graphed in Figure 5.



F2 F3

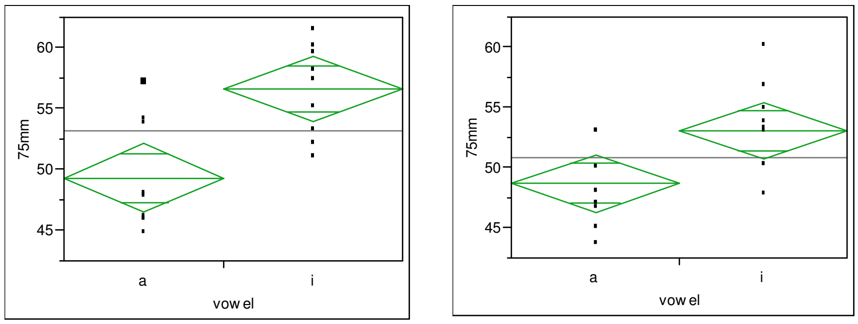
Figure 5. *F2 values for* –a *versus* –i *forms of* miistsís

In sum, a significant difference in F2 and F3 values of the vowel preceding the final vowel was observed for *miistsís*, but not *si'káán* and *ki'sómm.*

2.2.2 Articulatory Results

Measurements of tongue height (at seven different points) and lip aperture were taken to determine whether there is a significant articulatory difference between voiceless *–a* and *–i.* Because *miistsís* showed an acoustic distinction between *–a* and *–i,* its articulatory results are not included here.

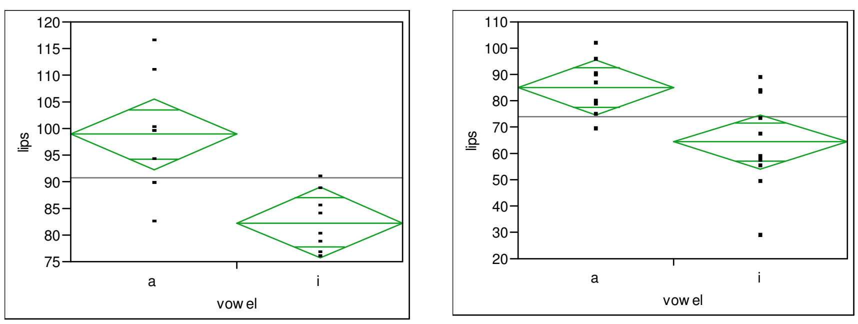
As illustrated in Figure 6, a significant difference in tongue height between –*a* and –*i* tokens was observed at the 75° angle for *ki'sómm* [F(1,17) = 15.612, *p = 0.001] as well as *si'káán* [F(1,18) = 7.748, *p = 0.012]. Measures of tongue height at other angles were not statistically significant.



kisómm *si'káán*

Figure 6. *Comparison of tongue height for* –a *versus* –i *in* kisómm *and* si'káán

A significant difference in lip aperture was observed for *ki'sómma* versus *ki'sómmi* [F(1,14) = 14.729, *p = 0.002] as well as for *si'káána* versus *si'kááni* [F(1,17) = 8.773, *p = 0.009]. The results are plotted in Figure 7.



kisómm *si'káán*

Figure 7. *Comparison of lip aperture for* –a *versus* –i *in* ki'sómm *and* si'káán

2.2.3 Summary

In sum, lip aperture and tongue height at the 75° angle were significantly different for –*a* versus –*i* tokens of *ki'sómm* and *si'káán*, regardless of a lack of significant acoustic differences. Significant acoustic differences were observed for *miistsísa* versus *miistsísi* tokens.

3 Perception Experiment

Acoustic measures in the production study are targeted to look for apparent typical effects of the presence of a vowel, such as voicing, formant structure, and coarticulation on the preceding vowel. The absence of such effects is negative evidence, from which we cannot definitively conclude that there are no acoustic differences (however subtle) between forms with voiceless *–a* versus those with voiceless *–i*. The goal of the perception experiment described in this section investigates the question of whether the acoustic signals themselves can by correctly identified without accompanying articulatory information. The prediction is that the listener will not be able to distinguish proximate *–a* from obviative *–i* forms on the basis of acoustic information alone.

3.1 Perception Experiment Methods

3.1.1 Subject

The acoustic data for the experiment was provided by the same subject as the production experiment. The listener for the perception experiment is a (different) adult female who is a native speaker of the Siksiká dialect of Blackfoot. At the time of the experiment, she is in her early sixties and lives on the Siksiká reserve. She is bilingual with English, but frequently speaks her native language with friends and relatives.

3.1.2 Apparatus

The speech sample was recorded with Audacity onto a 6.7 GHz iMac using a Sony ECM-MS907 microphone with a pre-amp. The tokens were extracted as WAV files in Praat.

The tokens were played for the listener in Windows Media Player on a Lenovo 8922 laptop computer equipped with Altec Lansing AVS 2000 speakers.

The subject's task was to select the appropriate context/carrier phrase for each token. To enable this task, the subject was presented with two drawings that corresponded to the two carrier phrases. These are shown in Figure 8 below.

Figure 8. *Drawings for carrier phrases*

3.1.3 Speech Sample

A subset of the tokens used in the production experiment was re-recorded for use in the perception experiment. Specifically, the noun *si'kaan* 'blanket' was recorded with both word-final proximate *–a*, and word-final obviative *–i*. The carrier phrases are the same as those in the production experiment, as follows:

> To elicit proximate *–a* forms:
> Nitsikssta ninaahksinowahsi ana __
> "I want to see that __."
>
> To elicit the obviative *–i* forms:
> Nitsikssta maahksinowahsi ani __
> "I want him/her to see that __."

To lessen the chance that coarticulation with the final vowel of the demonstrative determiner (proximate *oma* or obviative *omi*) influenced perception of the final vowel of the noun, a nominal prefix *omahk-* 'big' was also added to the noun.

The listener was presented with the proximate and obviative tokens minus the carrier phrases. There was both a control and an experimental condition. In the control condition, the nouns were presented with the demonstrative determiner, and in the experimental condition, the nouns were presented in isolation. Additionally, data was collected for a third condition, in which the speaker recorded the nouns with voicing on the final vowel. These tokens were deemed too artificial by the speaker and the listener, and were therefore omitted from the results. In sumix targets were presented to the subject, as in Table 2.

Table 2. *Speech targets for perception experiment*

Targets	Condition
*oma omahksi'káán**a***	control
*omi omahksi'káán**i***	control
*omahksi'káán**a***	experimental
*omahksi'káán**i***	experimental
*omahksi'káán**aa***	voiced
*omahksi'káán**ii***	voiced

Fifteen tokens of each control target and twenty-four of each experimental target were used in the experiment.

3.1.4 Procedure

The tokens were presented to the subject in three trials. In each trial, the subject listened to thirty-four tokens, five of each of the control set, eight of each of the experimental set, and four of each of the omitted voiced set, presented in a random order. The subject was given a forced choice test to identify whether the token belonged in the proximate (-*a*) or obviative (-*i*) context.

The participant was presented with two drawings that correspond with the two carrier phrases. In addition, the two carrier phrases, including the noun, were played for the subject before the experiment began. Written forms (in English and Blackfoot) were presented alongside the drawings.

A series of practice trials were performed until the listener and the researcher were both confident that the task was understood. The procedure was carried out in a private office at the University of Calgary.

3.1.5 Analysis

The subject's responses were recorded on a score sheet by two different people (the author and an undergraduate research assistant). The experiment was also audio-taped in case of discrepancy between the two score sheets. (No discrepancy was found.) Statistical analysis was performed using JMP.

3.2 Perception Experiment Results

The subject performed with near perfect accuracy on both the proximate -*a* and obviative –*i* forms in the control set. For 26/30 tokens of the control set, she correctly selected the drawing corresponding to the proximate carrier phrase for *oma omahksi'kaana* tokens, and that corresponding to the obviative carrier phrase for *omi omahksi'kaani* tokens.

For the experimental set, the subject selected the drawing corresponding to the proximate carrier phrase for 21/24 proximate *omahksi'kaana* tokens and 21/24 obviative *omahksi'kaani* tokens. She defaulted to the proximate carrier phrase with nearly all tokens in the experimental set. Together, the subject's scores for the experimental set are much lower than that of the control set.

The results were compared using a Chi-square analysis of the number of correct answers. The control experiment results were not significant, as shown in Figure 9 [χ^2 likelihood ratio (1,30) = 1.200, p = .273, α = 0.05].

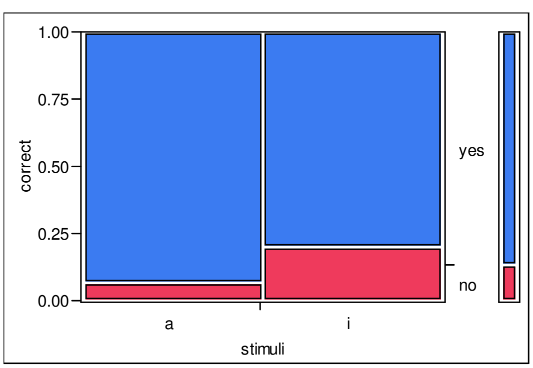


Figure 9. *Comparison of number of correct answers for –*a *versus –*i *tokens in control condition*

In contrast with the control results, the experimental results were significant [$\chi^2(1,48) = 30.372$, $*p < .001$, $\alpha = 0.05$]. This is shown in Figure 10.

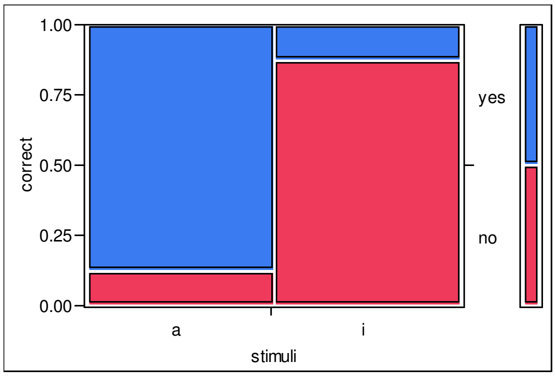


Figure 10. *Comparison of number of correct answers for* –a *versus* –i *tokens in experimental condition*

4 Discussion

The hypothesis made at the outset of this paper was that voiceless vowels in Blackfoot represent articulatory targets. The results of both the production and the perception experiments support this hypothesis.

The production data reveals that final vowels are indeed "soundless." Nevertheless, they do exhibit significant articulatory distinctions. The lip aperture results provide empirical support for the comments reported in the introduction to the paper regarding the visible cues for these vowels. Although not auditory distinguishable, "soundless" *–a* and *–i* are visibly distinguishable because of the lips.

The ultrasound results similarly support an articulatory distinction between soundless *–a* and *–i.* The ultrasound measurements correspond to the height of the tongue; the greater the distance between the transducer arc and the tongue surface at any given point, the higher the tongue is at that point. It was reported in §2.2 that a significant difference in tongue height was observed at the 75° angle, which corresponds approximately to the front of the tongue. That a significant height difference was found at the front of the tongue is consistent with this area being a highly salient articulatory indicator of the distinction between the vowels *–a* and *–i*.

It is important to keep in mind that, although no significant acoustic difference was found between *–a* and *–i* tokens of *ki'sómm* and *si'kaan*, a significant coarticulation effect was observed for *miistsis* tokens. Further, one of the initial target nouns, *oosak* 'back fat,' was omitted from the experiment because it showed acoustic differences in the stop release in the proximate *-a* and obviative *–i* conditions. Thus, the conclusion drawn from the production data is not that word-final vowels in Blackfoot, or the morphosyntactic categories of proximate and obviative, are always and only articulatorily distinguished. Rather, the conclusion that can be drawn from the data is that, in contexts where acoustic signals are obscured, speech productions still have articulatory targets.

From the acoustic measures in the production experiment alone, it is not possible to definitively conclude that there are no acoustic differences in the signal for proximate –*a* versus obviative –*i* nouns. However, the results of the perception experiment indicate that, even if there are subtle acoustic differences between -*a* and -*i* forms, these differences are not perceptible. In the absence of visual information, the listener in the perception experiment was unable to correctly identify –*a* and –*i* tokens, unless she was presented with a disambiguating demonstrative determiner.

That the listener performed at near perfect accuracy when presented with a demonstrative in the control set indicates that the distinction between proximate and obviative is indeed encoded in her grammar. However, that she could not perceive the –*a* versus –i distinction without the determiner and in the absence of a visual signal indicates that any acoustic information encoding the distinction is not perceived by the listener.

Interestingly, when unable to disambiguate between proximate –*a* and obviative –*i* tokens, the listener defaulted to the proximate carrier phrase for 42/48 tokens. We interpret this result as reflecting a morphosyntactic default in the grammar for proximate over obviative. The conditions under which nouns are marked as proximate or obviative are complex (cf. Bliss 2005, Frantz 1991) and beyond the scope of this paper, but it will suffice to note here that, when only one noun or one third person pronoun appears in a clause, it is typically marked proximate by default. Indeed, in some other Algonquian languages, the proximate category is phonologically unmarked, whereas the obviative category is marked by an overt morpheme (Bloomfield 1962 for Menomini; Dahlstrom 1986 for Plains Cree, Rhodes 1976 for Ojibwa). For this reason and others, many Algonquianists have argued that the proximate category is the unmarked in the proximate/obviative opposition (Russell 1996; Wolfart 1978).

That the listener defaulted to the proximate category when presented with both proximate –*a* and obviative –*i* forms demonstrates that she was unable to distinguish them on the basis of acoustic information alone. Coupled with the production data that shows an articulatory difference in these acoustically ambiguous tokens, these results support the hypothesis that these voiceless vowels represent articulatory speech targets.

5 Conclusion

In conclusion, the data presented in this study supports the hypothesis that there are “soundless” vowels in Blackfoot, which are articulatorily but not acoustically distinct. That a purely articulatory speech “sound” can be used to encode a morphosyntactic distinction in the grammar suggests that the targets of speech production can be articulatory, not just acoustic.

References

Bliss, Heather. 2005. Formalizing Point-of-View: The Role of Sentience in Blackfoot's Direct/Inverse System. MA thesis, University of Calgary.

Bliss, Heather, and Jennifer Glougie. 2009. Speaker Variation and the Phonetic Realization of Blackfoot Obviation Marking. Paper presented at WSCLA 14, Purdue University, April 3-5, 2009.

Bloomfield, Leonard. 1962. *The Menomini Language*. New Haven: Yale Press.

Browman, Catherine P., and Louis Goldstein. 1989. Articulatory Gestures as Phonological Units. *Phonology* 6: 201-251.

Browman, Catherine P., and Louis Goldstein. 1992. Articulatory Phonology: An Overview. *Phonetica* 49(3-4): 155-180.

Dahlstrom, Amy. 1991. *Plains Cree Morphosyntax.* New York: Garland.

Frantz, Donald G. 1991. *Blackfoot Grammar*. Toronto: University of Toronto Press.

Gick, Bryan, Karin Michelson, and Bosko Radanov. 2006. *Articulation without Acoustics: A Case Study of Oneida Utterance-final Forms*. Paper presented at the 152nd Meeting of the ASA, Nov-Dec 2006, Honolulu HI.

Guenther, Frank H., Michelle Hampson, and David Johnson. 1998. A Theoretical Investigation of Reference Frames for the Planning of Speech Movements. *Psychological Review* 105: 611-633.

Guenther, Frank, Carol y. Epsy-Wilson, Suzanne E. Boyce, Melanie L. Matthies, Majid Zandipur, and Joseph S. Perkell. 1999. *Articulatory Tradeoffs Reduce Acoustic Variability during American English /r/ Production*. JASA 105(5): 2854-65.

Ménard, Lucie, Annie Leclerc, Amélie Brisebois, Jérôme Aubin, and Annie Brasseur. 2008. Production and Perception of French Vowels by Blind and Sighted Speakers. Stasbourg: ISSP08.

Rhodes, Richard A. The Morphosyntax of the Central Ojibwa Verb. Doctoral dissertation, University of Michigan.

Russell, Kevin. 1996. Does Obviation Mark Point of View? In *nikotwâsik iskwâhtêm, pâskihtêpayih!. Studies in Honour of H.C. Wolfart*, eds. Nichols, John D., and Arden C. Ogg, 367-382.

Tremblay, Stéphanie, Douglas M. Shiller, and David J. Ostry. 2003. Somatosensory Basis of Speech Production. *Nature* 423: 866-69.

Van Der Mark, Sheena. 2003. The Phonetics of Blackfoot Pitch Accent. MA thesis, University of Calgary.

Wolfart, Hans Christoph. 1978. How many Obviatives: Sense and Reference in a Cree Verb Paradigm. In *Linguistic Studies of Native Canada*, eds. Cook, Eung-Do, and Jonathan Kaye, 255-272.Vancouver: UBC Press.