Transformational language games and the representation of Polish nasal vowels*

Joanna Zaleska & Andrew Nevins

University of Leipzig & University College London

1. Introduction

The present study investigates the representation of Polish nasal vowels using an experimentally constructed language game. We show that the nasal portion of those vowels cannot be represented underlyingly as a nasal consonant, and that nasal vowels in Polish may not be representationally equivalent to nasal vowels in other languages.

The novel word game paradigm, developed by Treiman (1983), has been frequently used to shed light on the nature of syllabification in individual languages and in human language in general (e.g. Bertinetto 1987, Derwing et al. 1988, Treiman & Danis 1988, Pierrehumbert & Nair 1995, Krämer & Vogt 2013). It has not, however, been employed to any great extent to study the phonemic representation of complex speech segments until Guimarães & Nevins (2013) used it to examine the underlying representation of nasal vowels in Brazilian Portuguese. They found that, by and large, nasal vowels in Portuguese are represented as a disegmental sequence of an oral vowel plus a nasal consonant. In the experiment described below, we follow the methodology used by Guimarães & Nevins to investigate nasal vowels in Polish. The results of a coda-deletion game in Polish turn out to be diametrically different to those obtained by Guimarães & Nevins for Portuguese. This not only indicates that Polish and Portuguese speakers may represent nasal vowels differently, but also challenges Paradis & Prunet's (2000) claim, based on loanword transfer evidence, that disegmental representations are the default for nasal vowels.

1.1 Polish nasal vowels: background

In addition to six oral vowels, [a ɛ i ɔ u ɨ], Polish has two mid nasal vowels, spelled *ą* and *ę*. The vowels are phonetically asynchronous, consisting of an oral vocalic part, analogous

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to /ɔ/ and /ɛ/, and a nasal part. They have two contextually-dependent realizations; before spirants and word-finally, they are realized as diphthongs [ɔ$^{\tilde{w}}$] and [ɛ$^{\tilde{w}}$] made up of an oral onset and nasalized offglide, (1), although *ę* tends to lose nasality before a word boundary. Before stops and affricates, they are realized as a sequence of an oral vowel and a nasal segment homorganic with the following sound, (2). They do not appear before sonorants or in word-initial position.

(1) ą *and* ę *before fricatives and word-finally: nasalized diphthongs* [ɔ$^{\tilde{w}}$] *and* [ɛ$^{\tilde{w}}$]

wąs	[v**ɔ**$^{\tilde{\mathbf{w}}}$s]	‘moustache’	idą	[id**ɔ**$^{\tilde{\mathbf{w}}}$]	‘they go’
kęs	[k**ɛ**$^{\tilde{\mathbf{w}}}$s]	‘bite’	idę	[id**ɛ**($^{\tilde{w}}$)]	‘I go’
wstążka	[fst**ɔ**$^{\tilde{\mathbf{w}}}$s̨ka]	‘ribbon’ (dim.)			

(2) ą *and* ę *before stops and affricates: oral vowels + nasal stops*

dąb	[d**ɔm**p]	‘oak’
ręka	[r**ɛŋ**ka]	‘hand’
wstędze	[fst**ɛn**d**ʑ**ɛ]	‘ribbon’ (dat.)

Nasal vowels have featured prominently in the Polish phonological literature due to their inconsistent behaviour. It has often been observed that they seem to act like nuclear units with respect to some processes, but like sequences of independent elements with respect to others. Below we present some of the data that have been used to illustrate both types of patterns. A systematic review of other examples that show the variable nature of Polish nasal vowels can be found in Bethin (1988).

The argument often cited as evidence for the unitary character of the nasal vowels is the fact that the rule of Nasal Vowel Backing makes a distinction between nasal vowels (3a) and sequences of vowel plus nasal consonant (3b; see also Bethin 1988, 39–43 and Gussmann 2007, 275–283).

(3) *Nasal Vowel Backing*

a.	węże	[v**ɛ**$^{\tilde{\mathbf{w}}}$zɛ]	‘snake’ (nom.pl)	–	wąż	[v**ɔ**$^{\tilde{\mathbf{w}}}$s̨]	‘snake’ (nom.sg)
	ręka	[r**ɛŋ**ka]	‘hand’ (nom.sg)	–	rąk	[r**ɔŋ**k]	‘hand’ (gen.pl)
b.	sensu	[s**ɛ**nsu]	‘sense’ (gen.sg)	–	sens	[s**ɛ**ns]	‘sense’ (nom.sg)
	renta	[r**ɛ**nta]	‘pension’ (nom.sg)	–	rent	[r**ɛ**nt]	‘pension’ (gen.pl)

The application of the rule changing *ę* into *ą* is restricted to certain morphological environments, subject to exceptions and its context has been defined differently by different authors. Still, the key observation here is that, whatever the particulars of the analysis, this process is different from other vocalic alternations in Polish and crucially does not affect oral vowels even if they stand before nasal consonants. This suggests that nasal vowels are distinct phonological units.

A process often invoked to show that nasal vowels do *not* act as units is related to a vocalic alternation accompanying the formation of imperfective verbs (see e.g. Rubach 1986, 134, Gussmann 2007, 284–286, Bethin 1988, 54–55). When the imperfective suffix

-aj [aj][1] is added to a verb that contains the vowel [ɔ], the vowel is lowered to [a], as shown in (4).

(4) *Derived Imperfective Lowering*

Perfective			Derived Imperfective		
*zapr**o**sić*	[zaprɔɕitɕ]	–	*zapr**a**szać*	[zapraʂatɕ]	‘to invite’
*wyk**o**ńczyć*	[vɨkɔɲtʂɨtɕ]	–	*wyk**a**ńczać*	[vɨkaɲtʂatɕ]	‘to finish off’

The [ɔ]–[a] change, traditionally affecting oral vowels only, is extended to nasal vowels in colloquial speech:

(5) *Innovative Derived Imperfective Lowering*

Perfective			Derived Imperfective		
*wył**ą**czyć*	[vɨwɔ**n**tʂɨtɕ]	–	*wył**ą**czać*[2]	[vɨwa**n**tʂatɕ]	‘to turn off’
*odtr**ą**bić*	[ɔttrɔ**m**bʲitɕ]	–	*odtr**ą**biać*	[ɔttra**m**bʲjatɕ]	‘to trumpet’
*zak**ą**sić*	[zakɔ$^{\tilde{\text{w}}}$ɕitɕ]	–	*zak**ą**szać*	[zaka$^{\tilde{\text{w}}}$ʂatɕ]	‘to have a snack’

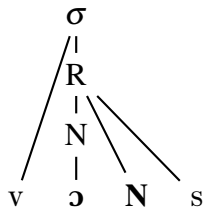
The fact that nasal vowels conform to the pattern found in oral-vowelled words is taken as evidence indicating that they are composed of two independent segments, when the first one, an oral vowel, can undergo the process in question.

1.2 Possible representations

The ambiguous status of nasal vowels has led researchers to propose various underlying representations, which can be broadly divided into three types, illustrated in (6) using the word *wąs* [vɔ$^{\tilde{\text{w}}}$s] ‘moustache’ as an example.

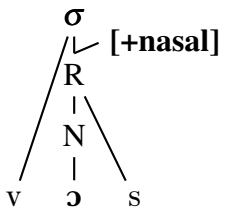
(6) *Possible representations of Polish nasal vowels*

a. disegmental



b. monosegmental

c. autosegmental



The disegmental analysis (6a, assumed, e.g. by Gussmann 1974, 1980, Rubach 1977 and 1984), represents nasal vowels as a sequence of an oral vowel followed by a nasal element (a glide or a nasal stop) occupying the coda position. The monosegmental analysis (6b) treats nasal vowels as inherently nasal units. This encompasses representations in which the feature [+nasal] simply forms part of the featural make-up of the segment, as well

[1]The final glide of the suffix is lost before a consonant.

[2]The innovative forms of derived imperfectives do not have standardized spelling, so the spelling of the traditional form is used in (5).

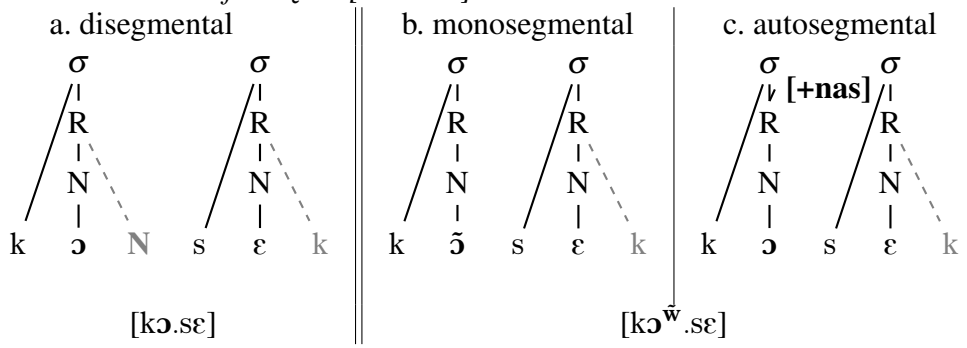
as those in which the structure branches into two sequentially distinct oral and nasal elements at some level below the root node.[3] Such short-diphthongs, or contour vowels, have been posited for Polish pre-spirant vowels by Gussmann (2002, 133–134), and for all nasal vowels by Gussmann (2007, 274), Bethin (1988) and Bloch-Rozmej (1997), although these authors also argue that nasal vowels are at some point subject to a decomposition rule which splits them up into two phonological objects (resulting in representation 6a). Finally, nonlinear models of phonological representation offer the possibility of treating nasality as an autonomous entity, rather than a property of the segment. Under such an approach, the nasal portion of the vowels could be interpreted as an independent autosegment linked to the rhyme node, as shown in (6c).

1.3 Research question

Given the inconclusive nature of language-internal arguments in favour of any of the representations, additional evidence must be sought elsewhere. One way to shed light on this is to use transformational language games (often called *ludlings*; see Laycock 1972), which could alter the phonological string in a way that would help discriminate between the competing analyses.

To decide between the disegmental representation, (6a) on the one hand, and monosegmental/autosegmental on the other (6b and 6c, respectively), we used a game which involved deleting all coda segments in disyllabic words, thus, e.g. turning *marmur* 'marble' [ma**r**.mu**r**] into *mamu* [ma.mu]. The analyses in (6) make different predictions about how the participants will treat words with nasal vowels, such as *kąsek* [kɔ$^{\tilde{w}}$.sɛk] 'morsel'. If they treat the nasal vowel as two units, with an oral vowel occupying the nucleus and the nasal portion occupying the coda position, as in (6a), we expect nasality to be removed, yielding [kɔ.sɛ]. If the nasal element forms part of the nucleus, (6b), or is an autosegment (6c), we expect the nasal portion to be retained, yielding [kɔ$^{\tilde{w}}$.sɛ]. The two possible results are illustrated in (7).

(7) *Possible outcomes for kąsek [kɔ$^{\tilde{w}}$.sɛk] 'morsel'*



If Gussmann (2002, 133–134) is correct that the representation of nasal vowels in words in which they are followed by stops or affricates is different from their representation else-

[3] As Polish has no phonemic distinction in vowel length, representations involving branching nuclei have rarely been suggested.

where, we could expect to find the result exemplified in (7a) in words with pre-noncontinuant nasal vowels and the result shown in (7b/c) in those with pre-spirant nasal vowels. Finally, the fact that the front nasal vowel *ę* but not the back one, *ą*, loses nasality at the end of the word might indicate that the representations of the two nasal vowels are different.

2. The experiment

The experiment described below is based on a similar study on nasal vowels run with speakers of Brazilian Portuguese (Guimarães & Nevins 2013), giving us an opportunity to compare our findings with those obtained for Portuguese.

2.1 Participants

The participants were 20 volunteers, 10 female and 10 male, aged between 21 and 56 (mean age 32.6). They were all native speakers of Polish.

2.2 Factors and conditions

The factors taken into consideration in the study were:

- NASAL VOWEL: *ą – ę*
- FOLLOWING SOUND: *continuant – noncontinuant*

The factor NASAL VOWEL defines the quality of the nasal vowel involved. It has two levels. *ą* refers to items in which the quality of the oral vocalic part is [ɔ] and *ę* to items in which it is [ɛ]. The factor FOLLOWING SOUND indicates the type of sound that follows the nasal vowel. *Continuant* refers to items in which the vowel is followed by a fricative and *noncontinuant* refers to items in which the vowel is followed by a stop or affricate.

The two factors (NASAL VOWEL and FOLLOWING SOUND) were fully crossed to yield 4 conditions, shown in (8).

(8) *Experimental conditions*

Condition	NASAL VOWEL	FOLLOWING SOUND
A	ą	continuant
B	ą	noncontinuant
C	ę	continuant
D	ę	noncontinuant

2.3 Stimuli

The stimulus set consisted of 20 Polish disyllabic words of the shape (C)C$\tilde{\text{V}}$.(C)CV(C)C.[4] All of them were frequently used singular nouns in nominative case. There were 4 items in condition A, 6 in condition B, 6 in condition C and 4 in condition D (the number of items per condition could not be made the same due to gaps in the Polish lexicon.). All experimental items are listed in (9).

(9) *Experimental items*

Word	Gloss	Transcription
Condition A		
wąwóz	'ravine'	[vɔ$^{\tilde{w}}$.vus]
kąsek	'morsel'	[kɔ$^{\tilde{w}}$.sɛk]
chrząszczyk	'beetle' (dim.)	[xʂɔ$^{\tilde{w}}$.ʂ(.)tʂɨk][5]
krążek	'circle' (dim.)	[krɔ$^{\tilde{w}}$.ʐɛ̨k]
Condition B		
kąpiel	'bath'	[kɔm.pʲjɛl]
mądrość	'wisdom'	[mɔn.d(.)rɔɕtɕ]
łączność	'contact'	[wɔn.tʂ(.)nɔɕtɕ]
ciągnik	'tractor'	[tɕɔŋ.g(.)ɲik]
pączek	'doughnut'	[pɔn.tʂɛk]
łącznik	'liaison'	[wɔn.tʂ(.)ɲik]

Word	Gloss	Transcription
Condition C		
księżyc	'moon'	[kɕɛ$^{\tilde{w}}$.ʑɨts]
pięściarz	'boxer'	[pʲjɛ$^{\tilde{w}}$.ɕ(.)tɕaʂ]
męskość	'masculinity'	[mɛ$^{\tilde{w}}$.s(.)kɔɕtɕ]
język	'tongue'	[jɛ$^{\tilde{w}}$.zɨk]
gęstość	'density'	[gɛ$^{\tilde{w}}$.s(.)tɔɕtɕ]
więzień	'prisoner'	[vʲjɛ$^{\tilde{w}}$.ʑɛɲ]
Condition D		
mędrzec	'sage'	[mɛn.d(.)ʐɛ̨ts]
węgiel	'coal'	[vɛŋ.gʲjɛl]
bęben	'drum'	[bɛm.bɛn]
ręcznik	'towel'	[rɛn.tʂ(.)ɲik]

The 20 experimental items were randomly interspersed with 80 fillers. These words contained oral vowels only, but otherwise they had the same characteristics as the experimental words (disyllabic, (C)CV.(C)CV(C)C shape). The list of all 100 items was randomized. The full list of items used in the experiment in the order in which they were presented is included in the online appendix available at `http://home.uni-leipzig.de/zaleska/nels45appendix.pdf`.

2.4 Procedure

The first phase of the experiment was a training session, in which the participants were trained to achieve fluency in the game. In this phase, participants heard oral-vowelled words with varying numbers of syllables, provided verbally by the experimenter; in response to each word they had to perform tasks of increasing difficulty. First, they had to repeat the

[4]The reason the nasal vowel was always in the first syllable is related to *ę*'s tendency to lose nasality word-finally. This meant that an item containing *ę* in the final syllable would most likely be pronounced with a final [ɛ] after coda deletion, regardless of the representation.

[5]As noted by Rubach & Booij (1990, 431–432) and Bethin (1992), although Polish shows a preference for onset maximization, there is some variability in the syllabification of word-medial clusters. In words where more than one syllabification is possible, the alternative syllable boundary is given in parentheses. Note that while the variation in syllabification was not included as a factor in the experiment, a post-hoc analysis comparing words in which onsets were maximized with those in which they were not revealed no significant differences between the two.

words, dividing them into syllables and clapping their hands for each syllable. Next, they were asked to continue clapping out the syllables of the words, but only repeat the vowel in each syllable. These two initial stages were necessary to make the participants feel more at ease and to make sure that they were familiar with the terms "syllable" and "vowel". In the final stage of the training, the participants were asked to repeat each syllable of the words they heard up to the vowel, which, in effect, meant repeating the words without the codas.

The training session was followed by a production phase, in which the participants had to produce a verbal response to items heard through headphones. The stimuli were presented in the same order for all participants. Each item was followed by a 2.5-second silent interval, after which a warning signal indicated the arrival of the next stimulus. At the beginning of the phase, the participants listened to a pre-recorded instruction, in which the rules of the game were repeated and illustrated using the word *marmur* [marmur] 'marble'. This was followed by 100 trials, which included the 20 critical items with nasal vowels. The responses were recorded and later submitted to perceptual inspection and transcription.

3. Results

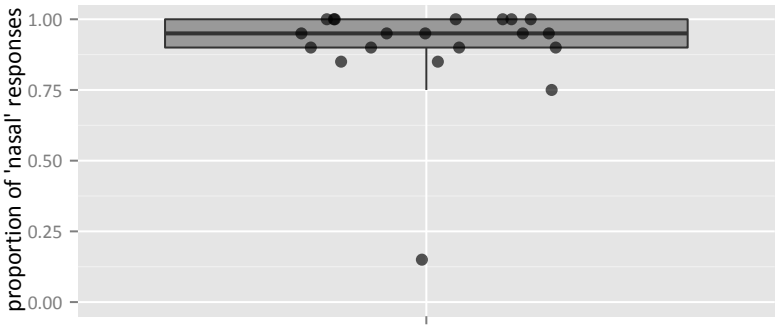
In the experiment, **89.75%** of the vowels in the experimental items were realized as nasal.

(10) *Overall results*

Nasal	Oral	Other
359 (89.75%)	34 (8.5%)	7 (1.75%)

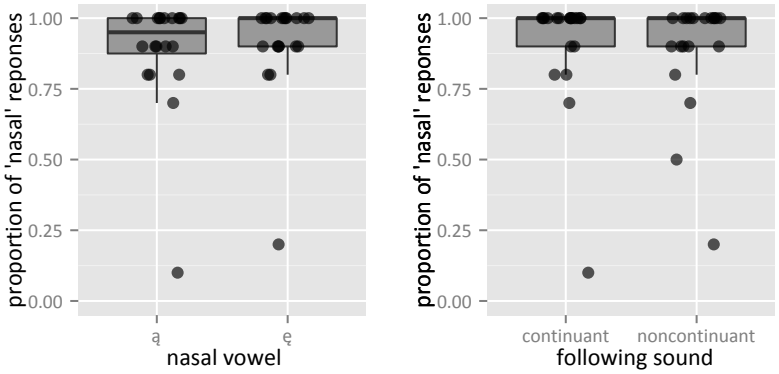
As shown in (11), there was some variation between participants (in the plot, each dot represents the proportion of 'nasal' responses for a single participant; the dots have been jitttered on the x axis). While most participants retained nasality in the majority of the items, there was one outlier, whose proportion of 'nasal' responses was only .15.

(11) *Proportion of 'nasal' responses (n=20)*



The plots in (12) show the proportion of 'nasal' responses broken down by the type of nasal vowel (ą vs. ę) and the type of following sound (continuant vs. noncontinuant).

(12) *Results broken down by type of nasal vowel and following sound*



As shown in (13), a mixed-effects regression model revealed no significant effect for either of the two factors nor their interaction.

(13) *Mixed effects regression model for the whole dataset*

Random effects:					
Groups	Name	Variance	Std.Dev.		
participant	(Intercept)	2.9928	1.7300		
item	(Intercept)	0.5956	0.7718		
Fixed effects:					
	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	3.52574	0.81351	4.334	1.46e-05	*
nasal vowel: ę	-0.05432	0.81486	-0.067	0.947	
following sound: noncont	-0.66310	0.79030	-0.839	0.401	
ę: noncontinuant	0.73648	1.13605	0.648	0.517	

4. Discussion and conclusion

The present study contributes to the growing body of experimental work addressing the representation of nasal vowels in various languages, such as Hindi (Ohala & Ohala 1995) and Pano (Costa & Dorigo 2003). Previous studies on Polish have assumed one of the representations shown in (6) and focussed on the degree of underspecification of the allophonic nasal vowels, or the place of articulation of the underlying nasal consonant. In contrast to those studies, we have assumed that the representation of nasal vowels is an empirical question that can be addressed experimentally.

Our experiment was designed to discriminate between a disegmental representation of nasal vowels, (6a), in which the nasal portion of the vowel occupies the coda position, and monosegmental/autosegmental representation (6b/c), in which the nasal element is either an inherent property of the vowel or an indepentent autosegment. In a coda-deletion game, speakers of Polish were taught to delete all coda consonants in a word. When ex-

posed to nasal-vowelled stimuli, the majority of the participants kept the nasal portion of nasal vowels, while at the same time removing other consonants located in the coda position. Interestingly, there were no differences between any of the conditions: participants retained not only the nasalized offglide in a word like *kąsek* [kɔ$^{\tilde{w}}$.sɛk] 'morsel' but also the first nasal stop in *bęben* [bɛm.bɛn] 'drum', even though on the surface both nasal stops are syllabified into the coda. This indicates that the representation of the nasal vowels is represented differently from their surface form.[6]

The results for Polish speakers are markedly different from the one obtained by Guimarães & Nevins (2013) for Portuguese. In a similar game, ten Brazilian informants consistently realized the nasal vowels /ẽ, ĩ, õ, ũ/ as oral [e, i, o, u], with the average proportion of 'nasal' responses ranging from to .01 for /ĩ/ to .11 for /õ/.[7] This suggests that speakers of Polish, unlike those of Portuguese, do not treat the nasal portion of nasal vowels as being located in the coda. The representation in (6a) can therefore be rejected. Note that this conclusion challenges Paradis & Prunet's (2000) claim, based on loanword transfer evidence, that disegmental representations are the default for nasal vowels.

The question that remains unanswered is whether Polish nasal vowels are represented as inherently nasal units (6b) or as vowels accompanied by an independent nasal autosegment (6c). We investigated this in a separate experiment (not reported here due to space constraints) using Guimarães & Nevins's (2013) vowel-substitution game, which involved replacing all vowels with either [ɔ], [u], [i] or [a], and seeing whether nasal vowels lose their nasality. In this case, the results displayed a great deal of inter- and intra-individual variability that could not be related to any of the factors analyzed. We hypothesize that the fact that the participants (and the one outlier in the experiment described above) diverged in their responses may reflect the very nature of Polish nasal vowels, whose ambiguity could push different learners in different directions. We must leave this issue open for future research.

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[6]Two objections could be raised at this point. First, it could be the case that the participants were orthographically biased, and treated the nasal vowels as inseparable units beause of their spelling (*ą* and *ę*). Second, as pointed out by an anonymous reviewer, it is necessary to compare the rate of deletion of the nasal portion of nasal vowels to the rate of deletion of other codas, to make sure that it is not the case that the participants simply learned to remove less sonorous codas. Both objections are addressed in the online appendix.

[7]There was one principled exception: the average proportion of 'nasal' responses for the low central vowel /ɐ̃/ was .99. This lead Guimarães & Nevins (2013) to conclude that unlike the other vowels, represented as a sequence of an oral vowel plus a nasal consonant, the low vowel is underlyingly an inherently nasal unit.

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Joanna Zaleska & Andrew Nevins
joanna.zaleska@uni-leipzig.de & a.nevins@ucl.ac.uk