Backing vacillating stems: Hungarian vowel harmony in fast speech*

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Vacillating stems in Hungarian allow both back and front allomorphs of the suffixes that are otherwise subject to vowel harmony. In a novel experiment we tested if the probability of producing the back allomorph is modulated by factors such as speech rate, time pressure and cognitive load. Subjects had to solve a multiple-answer quiz, first under time pressure and in the oral modality, and subsequently in a more relaxed condition, in the written modality. Back allomorphs were more numerous in the first condition than in the second one. Our repeated measure design provided a first evidence for the claim that typical Hungarian vacillating stems primarily select the front suffix, while additional factors, such as time pressure, slightly promotes the back allomorph.

1 Vacillating stems in Hungarian vowel harmony

Hungarian suffixation is subject to backness and, to a lower degree, roundedness vowel harmony. Here, we shall only focus on the former:

(1) a. *asztal* [ɒstɒl] 'table' + *–nAk* 'dative' = *asztal**nak***.
b. *függöny* [fygːøɲ] 'curtain' + *–nAk* 'dative' = *függöny**nek***.
c. *fotel* [fotɛl] 'armchair' + *–nAk* 'dative' = *fotel**nak*** ~ *fotel**nek***.

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As a rule (1a-b), the back allomorph [nɒk] of the suffix morpheme *–nAk* is chosen by words with a last syllable containing a phonologically back vowel ([ɒ], [aː], [o], [oː], [u] and [uː]); whereas the front allomorph [nɛk] follows the phonologically front vowels ([ɛ], [eː], [i], [iː], [ø], [øː], [y] and [yː]). Yet, there are many exceptions—and many different kinds of exceptions, at that. For an overview, refer to Rebrus et al. (2012).

A number of Hungarian stems display "vacillation" in vowel harmony (1c). Thus, the dative of *fotel* ('armchair') can be either *fotelnak* or *fotelnek*, allowing both allomorphs of the case suffix *-nAk*. Both forms are considered grammatical by native speakers, and both are amply attested in corpora. Interestingly, some other stems are only "perceptually vacillating": *dzsungelnak* ('jungle + Dative') might be judged as equally grammatical to *dzsungelnek*, but in fact, its corpus frequency is a fraction of the frequency of the front alternative.

These stems are usually composed of back vowels followed by front unrounded (so called, *neutral*) vowels. As the experiment to be reported below confirms, the phenomenon exhibits both inter-speaker and intra-speaker variation: different speakers might have a preference for different suffixes, but even a single speaker may utter both forms. The probability of a back suffix will be referred to as the stem's *backness*.

Phonological and morphological, but possibly also other (e.g., semantic) factors influence if a specific stem vacillates, and if it does, then to what degree it does so. Namely, Hayes and Cziráky Londe (2006) and Hayes et al. (2009) among others have discussed a large number of phonological features of the stem that have greater or slighter effect on the stem's backness. A morphological factor is the presence or absence of compounding, which creates an opaque border to vowel harmony. Take the allegedly vacillating stem *honvéd* (also analysed as such by Hayes et al. 2009). A closer look, however, reveals that front suffix is preferred (even if not strictly required) whenever it is a compound with the meaning '[national defence] soldier', and so the first syllable, the left element of the compound, does not participate in vowel harmony. However, the word is also the name of a sport club in Budapest. Then the morphological boundary is blurred, and this quasi-monomorphemic *honvéd* tends to behave as a vacillating—and in fact, almost as a back—stem. Finally, regarding semantics, a few speakers have the intuition that for them the backness of the ambiguous stem *farmer* depends on its reference: the meaning 'jeans pants' requires back suffixes, whereas 'farm operator' prefers front suffixes. For further semantic, stylistic and diachronic factors, see also Forró (2013).

Even for a specific stem, its backness, the probability of a back suffix, is further modulated by several factors. These include the dialect of the speaker (Blaho & Szeredi 2013), and the suffixed morpheme or case (Péter Rebrus, personal communication; quickly confirmed by any searchable corpus of Hungarian).

Certain syntactic contexts may also influence the allomorphy: when comparing *ennek az X-nAk* 'to this X' to *annak az X-nAk* 'to that X', we find that the first context decreases, while the second one increases the backness of many vacillating stems *X*. Additionally, a priming effect has been found (Biró & Füredi 2016), that is, the suffix choice for other vacillating stems earlier in the context may—at least, in an artificial wug-word experiment—modulate the backness of the current stem. Future research might also reveal a slight difference between formal and causal styles, or the influence of any other discourse and pragmatic factors.

In the current research, we have focused on the effect of a less examined parameter: speech rate. Does the backness—the frequency or probability of choosing the back allomorph—change as speech is accelerated? If so, then in what direction?

First, we explain the various motivations for studying variation in fast speech. Then, we proceed to introduce an experimental paradigm adopted from the work of Maartje Schreuder and Dicky Gilbers (Schreuder 2006; Schreuder & Gilbers 2004), before presenting the results obtained in a pilot experiment and in a subsequent experiment.

2 Speech rate dependent variation

2.1 Backness in normal and fast speech

Let us take a specific stem, such as *fotel* ('armchair') above, to which we shall add a specific suffix, such as the dative case ending *–nAk*. (The capital *A* stands for an underspecified segment.) This bound morpheme has two allomorphs: [nɒk] and [nɛk]. The *backness* is the probability—measured as the frequency—of choosing the back allomorph. Regular back stems are characterised by a backness of 1, whereas regular front stems have backness 0. Vacillating stems' backnesses vary between these two extremes.

As already mentioned, a number of further factors interfere with allomorphy. Thus, different suffixes might have a slight preference for their back or their front allomorphs.[1] So we should rather speak of the backness of a stem-suffix pair. Intervening suffixes also influence the backness, since the suffixes in a suffix chain must agree: *fotel-Ak-nAk*, 'armchair+PLURAL+DATIVE' can be either *foteleknek* or *foteloknak*, but not **foteloknek* or **foteleknak*. Let us also exclude dialectal,

[1] For instance, the following table compares various vacillating stems combined with the two allomorphs of either the dative (*-nAk*), or the inessive (*-bAn*) suffix. Here, we provide the raw frequencies from the *Szószablya* web corpus (Halácsy et al. 2004: http://szotar.mokk.bme.hu/szoszablya/)). Note that the same stems and suffixes will also be used in our experiments. The last column reports the p-value of 2-sample tests for equality of proportions with continuity correction, the null hypothesis being that the probability of the back allomorph of the dative suffix is equal to the corresponding probability for the inessive suffix.

sociolectal and idiolectal variation, as well as syntactic and semantic factors, by focusing on a single speaker producing the singular suffixed word in isolation, or in a fixed context.

The single varying factor will be speech rate: is the stem-and-suffix combination produced in normal conditions, or in fast speech?

2.2 Comparing sets of assumptions

Indeed, the speed of producing this form might influence backness in vowel harmony for a number of reasons. To be more precise, different assumptions about the mechanisms leading to vacillation will predict different effects of fast speech.

First, observe that typical vacillating stems contain back vowels followed by neutral front vowels.[2] They give the impression as if two forces were countering each other: the local harmony of the [front] feature and the distant harmony of the [back] feature (cf. Tableau 1). In Stochastic Optimality Theoretic terms, the two constraints have comparable ranks resulting in variation (Boersma & Hayes 2001). In the mirror situation, with a front vowel followed by a back one (e.g., *beton* 'concrete [material]'), only back suffixes are possible (*betonnak*); hence, local [back] harmony must be a much stronger force, that is, a much higher ranked constraint, than distant [front] harmony.

Tableau 1: Vacillation as the result of conflicting forces or constraints.

/fotel+nAk/	LocalHarmony[**F**]	DistantHarmony[**B**]
[*fotel.nek*]		*
[*fotel.nak*]	*	

Front
fo.tel-nAk
Back

Assuming that vacillation indeed emerges from the interaction of these two forces or constraints, different predictions can be made regarding the distribution of the two forms in fast speech, as compared to their distribution in normal speech.

Lemma	**Gloss**	***-nak***	***-nek***	***-ban***	***-ben***	**p**
hotel	'hotel'	6	57	427	1378	.0139
farmer	'jeans'	8	34	150	175	.0015
fotel	'armchair'	0	19	374	376	< .0001

[2] An exception is the vacillating stem *férfi* ('[male] man'), which displays vacillation between the regular pattern *férfinek* and the irregular pattern *férfinak* stemming from historical reasons. Note that words with non-neutral front vowels /ø/, /y/, or their long counterparts in their last syllable do not vacillate: *sofőrnek* ~ **sofőrnak* 'driver+Dative'.

On the one hand, assuming that phonological phenomena are, at least partially, motivated by phonetics, we can argue that local harmony, related to articulatory ease, is a phonetically more grounded markedness constraint than distant harmony. Adding to our set of assumptions that articulatory ease gains prominence in fast speech, we predict an increase in the frequency of the locally harmonic front suffix (*fotelnek*) as speech is speeded up.

However, an opposite effect can also be argued for. In fast speech, the distance in time between the back vowel and the suffix (as measured in milliseconds) becomes shorter. If (distant) harmony is assumed to be a matter of analogy or priming, then one would expect an effect size inversely correlating with the time elapsed between the prime and the primed, and thus, a relatively increased proportion of the back allomorph (*fotelnak*) in fast speech.

Does backness grow or drop as the speech rate takes off? Empirical results may support one or the other set of assumptions regarding the mechanisms at work.

2.3 Performance modelled by simulated annealing

A further argument for studying fast speech is provided by theories of mental computation in Optimality Theory (Bíró 2006; Smolensky & Legendre 2006). They suggest that (at least some) "performance errors" are the result of imperfect mental computation, and faster computation—less time at the disposal of the algorithm—would result in more "erroneous" outputs. The term *(performance) error* in this approach does not necessarily refer to a form that a native speaker would judge as erroneous. Chomsky's famous "memory limitations, distractions, shifts of attention and interest, and errors (random or characteristic) in applying [the speaker's] knowledge of the language in actual performance" (1965: 3) are modelled as an algorithm implementing the speaker's linguistic knowledge (competence, currently an OT or HG grammar) in such a way that it is prone to ("random or characteristic") errors under the above mentioned conditions.

More precisely, in these *simulated annealing*-based approaches, the competence or mental grammar (the speaker's "knowledge of the language") is modelled by an OT grammar or a Harmonic Grammar,[3] whereas mental computation becomes a search algorithm. The task of the grammar is to predict the 'grammatical form' as the globally optimal element of some candidate set. By searching for it, but not always finding this form, the simulated annealing algorithm reproduces the performance pattern: a distribution over all locally optimal forms. In turn, so-called *performance errors* are forms that are locally, but not globally optimal, and so the optimisation algorithm might return them erroneously: erroneously, in the sense that these forms are different from the one aimed at by the search algorithm.

[3] For HG and simulated annealing, refer to Smolensky and Legendre (2006) and Biró (2009).

Given a dataset (performance pattern), such as two forms with an 0.5 frequency each, one can often come up with two different models: either one of the two forms is the most harmonic ('grammatical') form, and the other is an equally frequently produced local optimum; or vice versa. Currently, depending on which of the two constraints LocalHarmony[**F**] and DistantHarmony[**B**] gets ranked higher in Tableau 1, either *fotel.nek* or *fotel.nak* can be made the 'grammatical form'. Yet, they may emerge with an equal probability, if both are made locally optimal employing a model similar to those in Bíró (2006: Chapter 6) and Biró (2009). In extreme cases (a 'golf-hole landscape'), a more harmonic form may even be less frequently returned by the simulated annealing search algorithm. How should we choose then between the two models, or in OT terms, between the two constraint rankings?

Comparing the distribution of the two forms in normal speech and in fast speech will help us do so. Importantly, as the number of iterations in simulated annealing is reduced, the frequency of the global optimum will (usually) drop, and the frequency of other local optima will increase. (Refer to Bíró 2006 and Biró 2009 for situations in OT in which this is not the case.) The number of iterations can be reduced for several reasons: beside Chomsky's "distractions, shifts of attention and interest" (sharing one's mental computational resources between several tasks), faster mental computation in fast speech is another. Simulated annealing is a search algorithm that can be speeded up, but the price to be paid is increased error rate. Turning the argumentation around, the form whose frequency is found to be lower in fast speech than in normal speech can be argued to be the globally optimal form in an OT or HG model of a native speaker's mental grammar. Constraint ranking must ensure this form is the globally optimal one. At the same time, 'performance errors' will be those that feature relatively more often in fast speech than in normal speech ('normal speech' not including hyper-correctness).

Figure 1 presents the draft of such an OT account of Hungarian vowel harmony. In this model, the two suffixed variants of a vacillating stem would each be locally optimal, that is, more harmonic than their neighbours. The winner of the traditional OT competition, the globally optimal form should be the candidate whose frequency decreases in fast speech, even if this frequency remains above 50%. Therefore, studying slight changes in the frequencies of the alternative forms will also contribute to a proper OT analysis of Hungarian vowel harmony.

3 Experimental design

We ran two experiments in which we compared the suffixed forms produced in fast speech condition to those produced in a more relaxed condition, by the same subject, in the same linguistic context. The first experiment was meant to be a

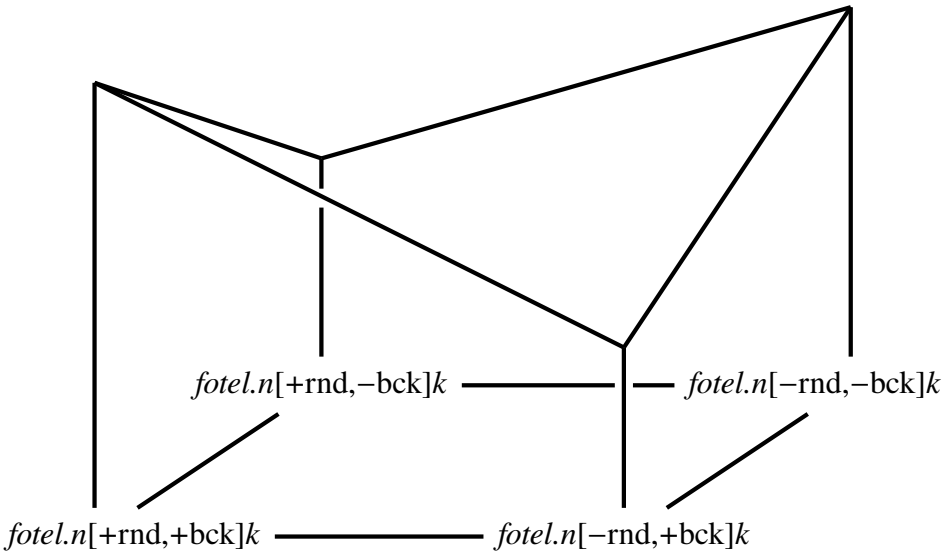


Figure 1: Four candidates for Hungarian vowel harmony, with varying values of features [back] and [round]. Only candidates differing in a single feature are neighbours. The vertical dimension corresponds to harmony, which is locally maximal for both *fotelnak* and *fotelnek*. Which of these two is globally optimal depends on the ranking of constraints LocalHarmony[**F**] and DistantHarmony[**B**] in Tableau 1. Some highly ranked further constraints heavily punish the other two candidates, reducing their harmony.

pilot to the second experiment, and so here we combine the descriptions of the two, noticing the slight differences wherever relevant only.

We adopted an idea from Schreuder and Gilbers (2004) and Schreuder (2006). In order to elicit fast speech data, we followed their paradigm and asked our subjects to participate in a quiz. The participants of our experiments were presented with multiple choice questions on a laptop monitor, such as this one:

(2) *What has armrests?*

(lit.: 'To what are armrests?')

A. *Table.*

B. *Curtain.*

C. *Armchair.*

In the first experiment, they were simply reported the time it took to go through the quiz, whereas in the second experiment they were also given a prize if they finished the quiz faster than the previous subject. The correctness of their answers did not play a role. The questions were presented both visually and auditorily[4] to increase the pressure and the cognitive load on the subjects, while the answers appeared only

[4] Using the same young female voice. The material was recorded by Katalin Mády, and subsequently processed using *Praat* (Boersma & Weenink 2010).

visually. The software created by the first author.recorded the answers pronounced by the subjects.[5]

The subjects were initially told to utter their answers as quickly as possible, and only then to click on the *done* button. (In reality, it had no consequence if a participant clicked too early.) In order to speed the subjects up, the experimental software reported the time elapsed between the moment the question appeared on the screen and the moment they pressed the button. The next experimental item (question and answers) appeared after a second click on the same button (Experiment 1), or automatically after two seconds (Experiment 2).

From the three possible answers, the obviously correct one to each quiz question was a vacillating word. One of the wrong answers took back suffixes, and the other front suffixes. The three words, semantically related and composed of equal or near equal numbers of syllables, were presented in an order randomized across subjects, and in a non-suffixed form, i.e., in the nominative case. Yet, the quiz questions always required an answer in the dative ('to armchair', half of the items) or inessive case ('in armchair', the other half of the target items).

The participants were repeatedly instructed neither to report the letter of the answer, nor the answer as it appears on the screen, but the answer with the correct suffix, such as 'armchair-DATIVE' in the above example. Despite our best efforts, the correct answer or the case to be used were not self-evident to a few subjects for a marginal number of test items, and clearly erroneous answers also happened due to time pressure: in all these cases, the experimenter did not interfere, and the answer was ignored during evaluation.[6] The number of ignored answered can be deducted from the middle columns of Tables 1 and 2 for each target word in the two modalities. For instance, out of 26 subjects, 1 said *hamburgerban* and 24 *hamburgerben* in Experiment 1, that is, 1 answer was discarded. In Experiment 2, out of 62 subjects, 2 respondents uttered a back vowel, and 58 a front vowel for the same input, and 2 answers had to be ignored.

Beside the ten target quiz items in Experiment 1, and twenty in Experiment 2, we also included fillers. Filler items consisted of non-vacillating words in any oblique case (including dative and inessive). Experiment 1 contained five filler quiz questions with a correct answer requiring a back suffix, and five fillers requiring a front suffix; whereas there were nine of each in Experiment 2. The order of presentation was also pseudo-randomised across subjects. It always started with three fillers, followed by a test item, followed by a filler. Subsequently, fillers and test items more or less alternated. (In Experiment 1, adjacent test items occurred twice, and in Experiment 2, four times.) Fillers requiring back and front suffixes

[5] The commercial microphones employed would prove to be of sufficient quality for the native speaker judges to distinguish between the two allomorphs of the suffix.

[6] The experimenter did intervene after the first or second filler item if the subject seemed to have misunderstood the task, and, for instance, did not inflect the nouns.

strictly alternated among themselves. Experiment 1, in which the two meanings of the stem *farmer* ('jeans (clothing)' and 'farmer (profession)') were also compared for backness, a further restriction was that these two items must be sufficiently separated in the sequence.

Following an introductory screen, the quiz lasted for approximately 2-4 minutes, Experiment 2 being twice as long as Experiment 1. Once it was over, the subjects took a rest by filling in a short questionnaire with basic data (gender, age, mother tongue, etc.) in the software. They would thus also familiarise themselves with typing on the experimenter's laptop.

Subsequently, the second part of the experiment began. The same quiz questions and answers were presented to the participants as in the first part, although now both were only presented visually, and not auditorily. Being explicitly told they were not in a hurry any more, our subjects had to type in their answers and click on *done*. Without the auditory modality, the subjects were left to process the questions at their own pace, while typing was also more time consuming. The questions and possible answers were already familiar to them, further reducing the cognitive load.

In this repeated measures design, we tried to minimize the significance of all confounding factors—such as priming and visual effects—that might influence the comparison of the responses in the two parts. Therefore, the quiz items appeared exactly as in the first part: in the same order, with the same fillers, and the three answers also displayed in the same order. The only difference between the two parts was time pressure, or to be more precise, the conditions of mental computation.

Time pressure in the quiz situation and the novelty of the quiz item, the effort of quickly solving the problem and quickly uttering the answer, but also the simultaneity of reading and listening to the quiz question—all these factors, we presume, point to the same direction: increased cognitive load and hence, reduced computational resources available to morpho-phonology in the first part of the experiment. In case we find evidence for a different allomorph distribution in the two conditions, follow-up experiments—such as reversing the order of the two parts—will be needed to distinguish between the effects of time pressure and speech rate, on the one hand, and various problem solving strategies (solving a new quiz question or retrieving a recently computed solution), on the other.

4 Results

The first experiment was run with $N = 26$ subjects (11 males and 15 females), in the age range of 20 to 57, the median being 25. In the second experiment, we had $N = 62$ participants (30 males and 32 females), aged between 18 and 65, with a median of 24. All being native speakers of Hungarian, representing a wide spectrum of educational backgrounds, most of them were born and raised in

different parts of Hungary, while less than 5% of them originated in Hungarian-speaking minorities in neighbouring countries.

In the repeated measures design described in the previous section, an observation pair consisted of a subject's responses in the oral modality and in the written modality to the same quiz item: either the back allomorph or the front allomorph of the (dative or inessive) suffix in each modality, attached to the target word. Four values were possible: BF (*i.e.*, back suffix in the first, oral condition, and front suffix in the second part of the experiment), FB (the reversed case), FF (subject consistently using the front suffix) and BB (subject faithful to the back suffix). After removing wrong answers and non-inflected forms from either modality, we obtained 222 valuable pairs in total in experiment 1, and 1105 pairs in experiment 2.

The written responses were automatically evaluated by the software we developed, whereas the oral responses were judged by the two authors independently (inter-rater agreement > 98%, Cohen's kappa index = 97%).

In the first experiment, we employed ten target words, half of which were tested with the dative (*-nAk*) suffix, and the other half with the inessive (*-bAn*) suffix. We also distinguished between the two meanings of the stem *farmer* ('1. jeans pants; 2. farm operator'), and included words that phonologically could, but did not, or hardly did vacillate, as well as the antiharmonic word *férfi* ('man'). Table 1 summarizes our results: the absolute frequencies of each stem followed by a back or front allomorph, in each of the two conditions. For the sake of comparison, it also includes the absolute frequencies of the corresponding singular forms with the same nominal case in the *Hungarian National Corpus* (http://mnsz.nytud.hu, Oravecz et al. 2014). Finally, it also provides details about the number of subjects (repeated measure data pairs) who stayed consistent, and those who changed the allomorph across the two conditions.[7]

Among the non-alternating words, a single case of *hamburgerban* emerged in the under-stress, fast speech condition. Slightly alternating words displayed some cases of fast speech errors or written modality hyper-corrections. The forms *slágernak* and *dzsungelban* appeared once each in written form, a frequency not significantly different from the corresponding corpus frequencies (very high p-values being returned by Chi-squared tests). Interestingly, even those subjects preferred the front suffix in the first part. *Athén* and *férfi* represent special cases even among the vacillating stems: *Athén* is a geographic name of foreign origin, and so its usage may be determined by further factors, whereas *férfi* vacillates

[7] For instance, FB is the number of subjects uttering the suffix with a front vowel in the oral quiz, but typing subsequently the back variant thereof. Note that if a subject produced a useful form in one condition, but not in the other—e.g., by providing a wrong answer to the quiz, or omitting the suffix—then the useful form will still be taken into account in the middle columns of the table, but not in the last columns.

Table 1: Frequencies of the back (B) and front (F) allomorphs of the dative or inessive case suffix, when appended to the singular forms of the target words in Experiment 1. The first block displays the occurrences in the Hungarian National Corpus (MNSZ1), followed by the frequencies in our Experiment 1, in the fast speech (quiz) and normal (typing) conditions, separately. Finally, we also present the number of subjects (repeated measure pairs) producing the back allomorph in both conditions (BB), the back allomorph in fast speech, but the front allomorph in the normal condition (BF), etc.

			Corpus		**fast**		**normal**		***(fast, normal) pairs***			
	allomorph chosen:		B	F	B	F	B	F	BB	BF	FB	FF
hamburger	'hamburger'	.Iness	1	11	1	24	0	25	0	1	0	23
sláger	'hit'	.Dat	1	127	0	21	1	24	0	0	1	19
dzsungel	'jungle'	.Iness	30	569	0	25	1	25	0	0	1	24
hotel	'hotel'	.Iness	236	1419	6	19	1	24	1	5	0	18
farmer	'jeans'	.Dat	4	4	7	17	5	17	3	2	2	14
farmer	'farmer'	.Dat	13	30	10	15	6	17	6	4	0	12
fotel	'armchair'	.Dat	12	3	6	19	4	21	3	3	1	17
férfi	'[male] man'	.Dat	3908	928	12	2	16	7	9	2	1	1
Athén	'Athens'	.Iness	2717	359	22	4	23	2	20	1	3	1
balhé	'roughhouse'	.Iness	24	0	24	0	26	0	24	0	0	0

between regular morphology and historically motivated irregularity. None of them behaved in our experiment in a peculiar way.

Most interesting are the four "really" vacillating words ('hotel', 'jeans', 'farmer' and 'armchair'). Based on their phonological appearance, their corpus frequencies and overall behaviour in our experiment, they clearly represent a single pattern. So while analysing their respective figures separately does not yield any statistically significant result, we may justifiably collapse them.

Our null hypothesis presumes that there is no difference between the backnesses (the probability of producing the back allomorph) in the two experimental conditions. If it is so, there will be no significant difference between the BF and the FB columns: switching from back to front is as likely as switching from front to back, even if the responses in the two parts of the experiment are correlated. Applying McNemar's *Chi-squared test* with continuity correction (Edwards 1948; McNemar 1947), we can reject this null hypothesis with the collapsed data of these four vacillating words ($\chi^2 = 5.8824$, df = 1, $p = .0153$). Hence, Experiment 1 brings us to the preliminary conclusion that "classic" vacillating stems might be more likely to be affixed with a back suffix in fast speech than in normal conditions.

In the second experiment, ten target words required the dative case, and eight target words the inessive case. Some of them were those already used in the first experiment, sometimes with the same case, and sometimes with a different one (Table 2).

Table 2: Frequencies of back (B) and front (F) allomorphs in Experiment 2. (For details, refer to Table 1. Here, corpus frequencies from MNSZ2 are provided. Words are ordered according to increasing backness, as calculated from the average backness in the two modalities.)

			Corpus		**fast**		**normal**		***(fast, normal) pairs***			
	allomorph chosen:		B	F	B	F	B	F	BB	BF	FB	FF
hamburger	'hamburger'	.Iness	1	14	2	58	1	56	0	1	1	53
sólet	'cholent'	.Dat	3	4	4	51	5	51	1	3	4	44
dzsungel	'jungle'	.Dat	2	37	6	50	4	55	0	5	3	45
rubel	'ruble'	.Iness	2	129	5	53	6	54	4	1	1	50
roller	'scooter'	.Dat	0	5	9	47	5	54	2	6	3	43
hotel	'hotel'	.Dat	9	122	10	51	6	53	3	7	2	46
stopper	'stop-watch'	.Dat	4	6	9	50	9	51	2	5	5	45
makett	'model'	.Dat	2	8	12	44	12	44	6	6	5	37
suszter	'shoemaker'	.Dat	22	36	16	45	11	50	5	11	6	38
amper	'ampere'	.Dat	0	1	9	35	15	42	2	5	7	27
koffer	'suitcase'	.Iness	25	44	13	46	16	46	7	6	9	37
bunker	'bunker'	.Iness	84	316	14	48	19	43	10	4	9	39
notesz	'notebook'	.Iness	28	48	16	40	18	43	11	5	5	35
fotel	'armchair'	.Iness	588	476	19	39	17	44	11	8	5	34
balett	'ballet'	.Iness	17	56	13	26	15	27	7	5	4	19
pancser	'bungler'	.Dat	9	12	22	38	22	39	14	7	7	31
bakter	'track-watchman'	.Dat	12	9	24	33	23	39	15	9	6	27
panel	'concrete building'	.Iness	193	207	30	28	30	32	20	10	8	20
farmer	'jeans'	.Iness	222	266	33	28	30	32	23	10	6	22
Athén	'Athens'	.Iness	5274	547	54	7	55	6	50	3	4	3

The tendency was again that fast speech forms included more frequently [+back] suffixes than normal speech forms. Again, more subjects replaced their back suffix in the oral quiz with a front suffix in the typing modality (BF) than vice versa (FB). This tendency was, however, not significant any more at the 5% significance level. The aggregation of the words *hotel*, *farmer* and *fotel*—taken over from the previous experiment, but inflected in different cases—failed to reject the null hypothesis (McNemar's Chi-squared test with continuity correction: $\chi^2 = 3.1842$, df = 1, $p = .0744$), and so did other aggregates.

However, a more detailed analysis revealed that the participants—displaying a spectrum of social-educational background broader than in Experiment 1—employed various strategies during the experiment. Some speakers were unnaturally stressing the suffix, and indeed, their allophone choices displayed a reversed effect. Some of them might have been uneasy in a scientific experiment, consider-

Table 3: Consistent production and allomorph switches between the two conditions among "real fast speakers" in Experiment 2.

	(fast, normal) pairs			
	BB	BF	FB	FF
hamburger	0	1	1	42
sólet	0	3	3	37
rubel	4	1	0	41
dzsungel	0	5	2	35
roller	2	5	3	34
hotel	3	7	1	35
stopper	2	4	4	35
makett	5	6	3	28
amper	1	5	5	19
suszter	5	11	4	28

	(fast, normal) pairs			
	BB	BF	FB	FF
koffer	7	6	7	28
bunker	8	4	9	28
notesz	10	4	3	28
fotel	10	8	4	25
pancser	12	7	4	24
balett	7	5	3	15
bakter	14	9	5	16
panel	17	10	7	13
farmer	21	10	4	14
Athén	42	3	2	1

ing even the first (quiz, fast speech) condition a formal situation, which prompted them to speak in an unnatural, hyper-correct way. Others were hesitating too much, or found the quiz too difficult, and so did not focus on speed. Yet another group of people, despite the prize promised, did not take the time pressure in the quiz seriously, and so did not produce fast speech. Therefore, we have decided to discard 13 subjects, and the results of the remaining 49 appear in Table 3.

This admittedly subjective *post hoc* selection of data should only be regarded as a pilot to future work, in which non-fast speaking subjects will be filtered out according to *a priori* criteria. And yet, McNemar's Chi-squared test with continuity correction yields a highly significant result ($\chi^2 = 8.0904$, df = 1, $p = .0045$). Hence, we conjecture that those participants who presumably really acted in the first part of the experiment as if they were in a quiz situation had some preference for "backing" the vacillating stems in fast speech.

A further observation supporting this conjecture can be made if we calculate McNemar's Chi-squared test separately for each participant. Only five of the 62 participants in Experiment 2 yield a χ^2 test statistic with continuity correction that is larger than 3.84, which would correspond to the 5% significance level. (None of them would be significant with Bonferroni correction being taken into account.) In accordance with our hypothesis, four out of these five subjects had a strong tendency to use a back suffix in fast speech for alternating stems that they would produce with a front suffix in the second part of the experiment. Whereas there was only a single subject behaving contrariwise, producing six words with front suffixes in fast speech, but with back suffixes in the written modality. Based on the recordings of the first part, this latter subject strikingly hesitated before the

suffixes, and might be suspected of hyper-correction, whereas the former ones were at ease during the quiz.

5 Conclusion

In conclusion we propose, based on a restricted set of words, that vacillating Hungarian stems—consisting of back vowels followed by front vowels—"primarily" prefer front suffixes. Hence, they obey *local* harmony. The back suffixes occurring in alternative forms are the results of additional factors promoting the harmonising influence of a distant back vowel. The stronger these additional factors, the more frequent the alternative (back suffixed) forms. Our two experiments present the first evidence for either time pressure, faster production rate or, more generally, cognitive load being exactly such a factor. Certainly much more work is required to conclusively establish this assertion, based on a larger set of stems and suffixes, and with a higher statistical significance.

In an Optimality Theoretic framework—as the one hinted at in Tableau 1—we could argue that the adequate analysis of Hungarian vowel harmony should rank constraint LocalHarmony[**F**] higher than DistantHarmony[**B**], turning the forms with the front allomorphs of the suffixes grammatical. Alternative forms with back suffixes would nevertheless be produced, and produced more often in fast speech. As discussed in section 2, this can occur for a number of reasons, depending on one's assumptions and theories.

It is intuitive to think that from a phonetic perspective local harmony captures ease of articulation, and so its demotion in fast speech would be unexpected. A more plausible proposal would offer reasons for a slight promotion of distant harmony. Does it become "less distant", at least as measured in milliseconds elapsed between the prime (the back vowel in the stem) and the primed (the vowel in the suffix)?

Another explanation might be related to word stress, always on the first syllable in Hungarian. With the sole exception of the word *férfi*, stressed vowels were always [+back] in our experiments. If the unstressed front vowel in the subsequent syllable were slightly more reduced in fast speech than in normal language production, but this were not the case for the stressed back vowel, then we could explain why the harmonising influence of the front vowel—but not the influence of the back vowel—becomes slightly weaker in fast speech. Such an explanation, however, postulating that a vowel's effect is fine-tuned by its phonetic realisation, presupposes gradient representations (Smolensky 2016) and gradient constraint interactions.

In the spirit of Stochastic Optimality Theory (Boersma & Hayes 2001), we would suppose that constraint LocalHarmony[**F**] is ranked higher than DistantHarmony[**B**], and some (e.g., Gaussian or uniform) noise is added to their ranks at

evaluation time. Most speakers have these two constraints ranked close enough to each other (equivalently, noise is large enough), so that noise has a non-negligible chance to reverse the two constraints: this probability might even be in the order of magnitude of 30 – 40%. For fast speech (or time pressure, or increased cognitive load), we could postulate either the higher ranked constraint's rank to be slightly reduced, or the lower ranked constraint's rank to be increased, or—as a reviewer suggested—noise to be increased. In either case, this Stochastic OT model will predict a small increment in the proportion of the back suffixed forms. More powerful experiments exactly measuring each form's distribution are required to distinguish between these options. Namely, increasing noise can never push up a back form's proportion beyond 50%. But shifting constraint rank values might theoretically reverse the relative order of the two constraints, yielding measurably reversed frequency relations.

Another way to distinguish between these approaches is by focusing on the subjects who produce more back forms than front forms. If they indeed do so consistently, and not only in a small random sample, then we should postulate a reversed ranking of the above mentioned two constraints in their mental grammar. If the quiz situation demoted LocalHarmony[**F**] or promoted DistantHarmony[**B**] (for whatever reason discussed earlier), then they would produce even more back suffixes in the first part of the experiment. But if the quiz situation increased noise, then these subjects should display a reversed pattern.

Certain words—*férfi*, *Athén* and *balhé* in our experiments, and many more in Hungarian—have a backness index significantly higher than 50%. Increased noise—or, as the above mentioned reviewer put it, "increased randomness"—would mean these words would be slightly more likely to get a front suffix in fast speech.[8] If, however, fast speech prefers back suffixes as a rule, these words should occur even more frequently with a back suffix. While we included some of these words in our experiment in order to test these options, the effect seems to be much smaller than expected. Therefore, only a much more powerful experiment in the future will be able to come to a definitive conclusion.

Yet, the presence of these words in the language already point toward a more complex picture, with more than two constraints in the game. These words should be analysed by invoking further constraints, which, for instance, are sensitive to the quality of the vowel in the last syllable of the stem. The more constraints in an OT model, the more complex their interactions. Therefore, it would be premature to draw conclusions regarding the proper treatment of fast speech in Stochastic Optimality Theory.

[8] The behaviour of *Athén* might support this hypothesis: although to a statistically non-significant extent, it seems to display a reversed phenomenon. This high backness word receives slightly more front suffixes in the first experimental condition. Much more data would be needed to establish this observation on a statistically significant level.

Finally, an alternative explanation was to refer to imperfect mental computation. How would such a framework look like? For each input (at least, among the "standard" vacillating stems: *hotel*, *fotel*, *farmer*. . .), the front suffix form should be the global optimum ('grammatical form'). Such a model would include, in a first approximation, two constraints: LocalHarmony[**F**] ranked higher than DistantHarmony[**B**]. Yet, the back suffix form would also be made locally optimal by including further candidates intervening between these two (cf. Fig. 1). Our model of mental computation, running an algorithm such as *simulated annealing*, aims at finding the global optimum, but is prone to be stuck in this second local optimum. How frequently this happens determines the frequency of the back-suffixed forms, that is, the backness. Importantly, a faster mental computation—which may be due to time pressure or to reduced cognitive resources—will be more likely to be stuck in the globally not optimal local optimum. In short, more forms with the back allomorph, more "errors" are made in fast speech.

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