Optionality and Gradience in Persian Phonology: An Optimality Treatment

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Abstract

The distribution of the allophones of glottal stop /ʔ/ in certain contexts involves free variation and gradient preferences. An organized survey was conducted to elicit the judgments of 37 native Persian speakers concerning the well-formedness of /ʔ/ allophonic behavior in five different phonological positions. The results showed that the differences in judgment between the various categories are not just the result of random variations, but are an authentic reflection of the underlying structural differences. Following Boersma and Hayes (1999) and Hayes (2000), a stochastic model is proposed within optimality theory to account for the gradient judgments involved. The model assumes that constraints are arranged along a continuum of constraint strictness, with a band of strictness value assigned to each. When the strictness bands of two constraints overlap, then both rankings of the two constraints are equally available for the generation of outputs, yielding free variant forms. However, when a particular form can be generated only by assigning a constraint a strictness value (/?/ or /??/) within a designated "fringe" of the strictness band, the model generates the form marked with an intermediate degree of well-formedness.

Keywords: Free Variation, Gradience, Well-Formedness, Allophonic Behavior, Strictness Band

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1. Introduction

The phonological status of glottal stop in Persian has caused considerable discussion among phonologists. One question concerns the phonemic status of glottal stop. Some argue for the optionality of glottal stop due to its predictability in onset position, suggesting a (C)V(C)(C) syllable structure for Persian of which only three emerge phonetically (CV, CVC and CVCC), given a phonotactic constraint that bans onsetless syllables (Lazard, 1957; Samareh, 1977). Others assign a phonemic status for /ʔ/, mainly through minimal pair contrast, holding that Persian syllable structure consists only of CV, CVC and CVCC (Pisowicz, 1985).

Another question, which is of most concern in this paper, addresses the phonetic interpretation of glottal stop. Often, glottal stop is not satisfied to reach the intended target i.e., complete glottal gesture ([ʔ] and is realized in speech with different magnitude of glottal gesture variation from a weak through complete deletion of glottal stop (Lazard, 1957; Samareh, 1977; Windfur, 1979). This is most evident in syllable coda position, where glottal stop arises as an allophonic non-modal phonation on a portion of the preceding vowel (or creaky vowel, shown by [']) or complete deletion accompanied by lengthening of the preceding vowel, which is known as compensatory lengthening (CL), shown by [:]. The glottal gesture reduction is, also common in intervocalic position, where glottal stop is deleted without being compensated by lengthening of the preceding vowel, possibly to avoid changes in syllable weight (shown by [Ø]).

It is commonly held that the pattern of /ʔ/ allophony in certain contexts involves free variation and gradient preferences (Lazard, 1957; Samareh, 1977). Free variation is indeed reported for intervocalic position, where either of the allophones [ʔ] or [Ø] sound acceptable, and syllable coda position which yields free variation between [ʔ], ['] and [:]. However, no theoretical model has been developed so far to account for /ʔ/ allophonic optionality. In addition, many phonologists hold that the distribution of /ʔ/ allophones in some contexts produces a gradient, rather than categorical, effect, finding well-formedness judgments difficult to make. The analysis, however, developed so far to pattern gradient judgments on glottal stop results in categorical outcomes, as assumed by generative grammar.

Many scholars, however, maintain that much of the patterning of gradient judgments is based on authentic structural aspects of the linguistic material being judged. What is lacking, in their views, is the right theoretical tools to model grammars that can generate outputs with varying degrees of well-formedness (see Schütze 1996, 63-64; and below).

Recently, it has been suggested that within Optimality Theory (Prince & Smolensky 1993), it is possible to account for optionality and gradience in linguistic materials. The modification in the theory that is needed to devise optional and gradient forms is strikingly minor, and is quite independent of the choice of formal representations and constraints used in the grammar (Hayes, 2000).

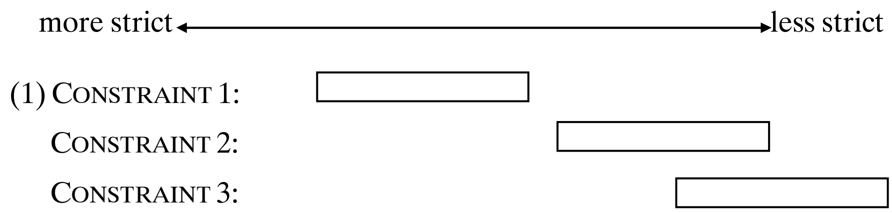
This paper studies the pattern of /ʔ/ allophony using Farsi speakers' judgments and explores the question whether their judgments for the phonological behavior of glottal stop is categorical or gradient. The hypothesis made in this research is that Farsi speakers' judgements for words involving /ʔ/ allophony are categorical. This hypothesis holds that the words involved are either acceptable or unacceptable, and if there is some degree of gradience in the speakers' judgments, it may well be attributed to performance factors rather than the linguistic knowledge of Farsi speakers.

2. An Optimality Treatment of Gradient Well-formedness

Optimality theory is a linguistic model that proposes that the observed forms of language arise from the interaction between conflicting constraints (Karger, 1999; Prince & Smolensky, 1993). There are two basic types of constraints in optimality theory. Faithfulness constraints require identity between input and output forms. Markedness constraints impose requirements on the structural well-formedness of the output. Each plays a crucial role in the theory. These constraints often stand in direct disagreement with one another over the quality of a given input-output relation. Given the range of alternative outputs for an input, the model defines the optimal output by hypothesizing that constraints are ranked with respect to each other on a language-specific basis. Given two candidates, A and B, A is better than B on a constraint if A incurs fewer violations of the highest-ranked constraint distinguishing A and B. A is optimal in its candidate set if it is better on the constraint hierarchy than all other candidates.

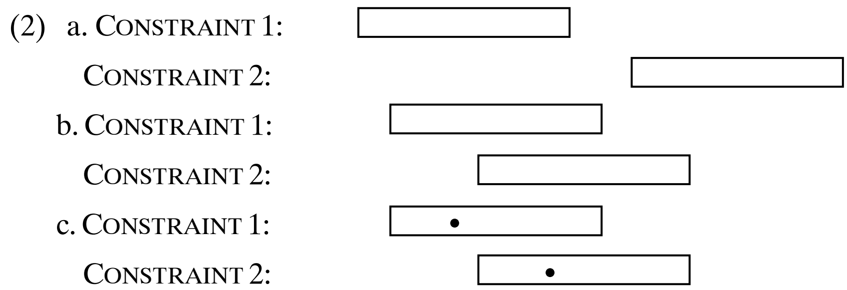
Boersma and Hayes (1999) and Hayes (2000) propose a model in optimality theory to account for carefully elicited gradient judgments which do reflect the internalized knowledge of the native speaker. The model developed by Hayes makes two important assumptions: First, constraint ranking is continuous and second, the evaluation of candidates is stochastic.

The model presupposes a linear scale of constraint strictness in which higher values correspond to higher-ranked constraints. The scale is arranged in arbitrary units, and in principle has no upper or lower bands. The scale depicted graphically in (1) shows the ranking of the three constraints C1, C2 and C3:



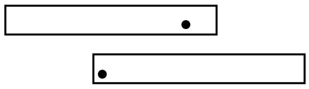
According to (1), outputs will be generated by respecting C1> C2> C3. This scale shows that the differences in distance between constraint pairs are not equal. These differences have observable consequences (Boersma & Hayes, 1999). The shorter difference between C2 and C3 is interpreted as indicating that the ranking is less fixed than that of C1 and C2. Now, the question is how the model yields multiple outputs or produces forms with intermediate well-formedness.

Boersma and Hayes (1999) suggest that each constraint is associated with a range of values, instead of a single one, each corresponding with a value of strictness taken on by that constrain in a given speaking situation. The value obtained by a constraint at an evaluation time is called a selection point. The value more permanently associated with a constraint, which usually falls on the center of the range is called the ranking value. This means that in the process of speaking, the position of each constraint is temporarily perturbed by a random positive or negative value. Here, there are two possibilities: if the ranges covered by the selection points do not overlap, the result is categorical ranking (2a.). But if the ranges overlap, there will be free ranking (2b.).



d. CONSTRAINT 1:

CONSTRAINT 2:

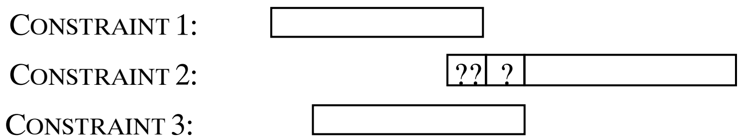


Free ranking in (2b.) is due to the fact that at evaluation time the selection points may fall anywhere within the ranges of the two constraints. C1 will outrank C2 in most of the cases (speaking situations). In 2.c, for example, the selection points are such that on the particular speaking occasion involved, outputs will be generated that respect a ranking of C1 over C2, but if, at a given situation, the selection point for C2 occurs on the upper part of its range and the selection point for C1, on the lower part of its range, then, C2 will outrank C1 (2d.). So, the overlapping ranges produce an observable effect: For forms in which C1>C2 yields a different output than C2>C1, one will observe free variation, i.e., multiple outputs from a single underlying form.

Here, one point is in order: As we know optionality is gradient in character. It is not necessarily the case that if two constraints are in conflict, both of them can win with the probability of %50, e.g., one form may occur in %80 and the other in %20 of the cases. This means that we should interpret constraint ranges as probability distributions (Boersma & Hayes, 1999; Hayes, 2000). Using probability distributions, one can handle any degree of optionality by making predictions about the relative frequencies of free variants.

But how can we handle gradient well-formedness in the model just sketched? Hayes suggests that the problem of gradience can well be treated by further amplifying the strictness band idea. He assumes that the range of a constraint is not firmly limited. He formally models this idea by permitting parts of each band to be designated as fringes. Fringes are special blocks at the edges of a constraint' strictness band with diacritics such as"/?/"and"/??/". Selection points may fall within the fringes, but only at the cost of the degree of ill-formedness indicated. Consider the following diagram:

(3)



This sample diagram can be interpreted as follows: (a) ordinarily, Constraint 2 is outranked by constraints 1 and 3. (b) However, it is somewhat possible for 2 to outrank 3. This will occur if the selection point for C2 occurs quite close to the left edge of its "?" fringe, and that for C quite close to the right edge of its strictness band as a whole. Forms that can be generated only with this ranking are intuited to be mildly ill-formed ("?"). (c) It is only marginally possible for B to outrank A. This will occur if the selection point for B occurs close to the left edge of its "??" fringe, and that for A close to the right edge of its strictness band. Forms that can be generated only with this ranking are intuited to be considerably ill-formed, though not completely excluded ("??").

Hayes tests the proposal against data involving light and dark /l/ in American English, using a set of gradient intuitions obtained from ten native speaker consultants. Showing that the differences in judgment between various categories are an authentic effect of underlying structural differences, he attributes the variations in /l/ to conflicting principles based on articulation and perception, and account for the variations involved in terms of the model just sketched.

3. Well-formedness Judgments on Glottal Stop Allophony

To explore the pattern of /ʔ/ allophony using Farsi speakers' judgments, I conducted an organized survey of the judgments of 37 native Farsi speakers. All of the participants were educated, and none of them had any linguistic background. Each participant was presented with ten words, each placed in a particular phrase or sentence to make the meaning clear. The words involved five different phonological positions. The positions were word-initial, syllable-initial post-consonantal, intervocalic, syllable-coda post-vocalic and coda post-consonantal positions. Each word contained a /ʔ/ and was pronounced by the author with four different allophones; namely, [ʔ], [Ø], ['] and [:]. [ʔ] indicates a complete glottal closure, [Ø] complete deletion of glottal stop, ['] week glottal gesture, and [:] indicating compensatory lengthening of the vowel preceding /ʔ/. Examples (4) provide sample sentences from the data, with the test words underlined:

(4) a. kodɑm ʔarteʃ piruz ʃod. (word-initial position)
which army winner be -past-3SG.
"Which army won the battle."

b. be sanʔat tavadʒdʒohi nemiʃe (syllable-initial post consonantal position)
to industry attention not-be-present-3SG.
"No attention is paid to industry."

c. ʔu ʃɑʔer nist. (intervocalic position)
he poet not-be-present-3SG.
"He is not a poet."

d. darde meʔde dɑre. (syllable coda position)
ache stomach have-present3SG.
"He suffers from stomachache."

The participants were asked to rate the pronunciations on an integer scale ranging from 1 to 7, with 1 indicating "sounds just right, perfectly normal in Farsi" and 7 indicating "sounds awful, I would never say it that way." The judgments were measured by carefully computing the values given to each phonetic string of words by the participants. To examine the effect of /ʔ/ allophonic behavior on well-formedness judgments, a two-way ANOVA test was run with allophones (having four levels, namely [ʔ], [Ø], ['] and [:]) and phonological positions (having five levels, namely word-initial, syllable- initial post-consonantal, intervocalic, syllable-coda post-vocalic and coda post-consonantal) as the fixed factors and well-formedness value as the dependent factor.

3.1. Data Pattern

On the whole, the judgments made were subject to some random variation. However, when averaged over all the participants, the results formed a coherent pattern. The results of the survey come below along with a general and structural description of the facts:

(1) Word-initial position: The results of the survey for /ʔ/ in word-initial position which included the words /ʔamal/ and /ʔarteʃ/ are as follows:

Table 1. ***Mean and Standard Deviation Well-Formedness Values for /ʔ/ allophones in Word-Initial Position and Results of Two-Tailed T-Tests***

Allophones	mean	St. dev	Effect of /ʔ/ allophony on well-formedness for each comparison
[ʔ]	2.11	0.92	All comparisons were significant at $\varrho<0.05$
[Ø]	5.42	0.94	
[']	4.73	0.98	
[:]	6.34	0.72	

Given the large difference in mean between [ʔ] and the remaining allophones, it seems utterly obligatory to produce [ʔ] in word-initial position such that the substitution of [ʔ] with any of the remaining allophones would lead to the unacceptability of the forms involved. Table 1 also shows that the differences of the means obtained for [Ø], ['] and [:] are statistically significant. Among the forms produced, those with [Ø] and [:] are the most awkward, indicating that complete deletion of /ʔ/ cannot be tolerated. The forms with a weak glottal stricture, ['], make a less awkward effect, but still they are excluded.

This finding is in line with the results from previous studies on glottal stop in Farsi. Samareh (1977) treats glottal consonants in word-initial position as strong allophones which resist glottal deletion or vowel lengthening. Windfur (1979) claims that glottal stop in word-initial position is realized in careful speech with a noticeable stricture, arguing that its realization as a weak variant would be highly unlikely in this position. He also excludes the possibility of glottal deletion or compensatory lengthening in word-initial position.

Syllable initial post-consonantal position: The results for /ʔ/ in syllable initial post-consonantal position which included the words /sanʔat/ and /maʃʔal/ are presented in Table 2. As can be seen, all comparisons came out as significant but one between [Ø] and [']. Here, too, the forms produced with [ʔ] are the most preferred. The forms with weak glottal stricture are slightly ill-formed. A question mark,"/?/", will be used in this study to designate slightly ill-formed variants. The results also indicate that the forms in which glottal stop is deleted without being recovered are considerably ill-formed, though they are not excluded completely. These forms will be marked with a double question mark, "/??/". Further, as it can be seen, the forms undergoing compensatory lengthening are excluded, as they achieve a high well-formedness value in the ranking scale.

Table 2. *Mean and Standard Deviation Well-Formedness Values For /ʔ/ allophones in Syllable Initial Post-Consonantal Position and Results of Two-Tailed T-Tests*

Allophones	Mean	St. dev	Effect of /ʔ/ allophony on well-formedness for each comparison
[ʔ]	2.27	1.03	All comparisons were significant at ϱ<0.05 but [Ø] and ['] (ϱ= 0.09)
[Ø]	4.11	1.26	
[']	3.76	1.32	
[:]	5.92	0.98	

This finding is supported by previous research on the phonological behavior of glottal stop. It is commonly maintained that like word-initial position, glottal stop in syllable initial post-consonantal position is realized as a strong allophone, and that if it undergoes deletion or vowel lengthening, or realized as a weak variant, the results will sound awkward (Samareh, 1977).

(2) Intervocalic position: The results for /ʔ/ in intervocalic position which included the words /ʃɑʔer/ and /dɑʔem/ come below in Table 3:

Table 3. ***Mean and Standard Deviation Well-Formedness Values for /ʔ/ allophones in Intervocalic Position and Results of Two-Tailed T-Tests***

Allophones	mean	St. dev	Effect of /ʔ/ allophony on well-formedness for each comparison
[ʔ]	2.54	0.99	All comparisons were significant at ϱ<0.05 but [ʔ] ≈ [Ø] (ϱ= 0.08)
[Ø]	2.19	1.02	
[']	3.55	1.12	
[:]	4.97	1.06	

The table shows that glottal stop in this position yields free variation between [ʔ] and [Ø]. The participants found the forms with either of these two variants fairly acceptable, with [Ø] being slightly preferred. The forms undergoing compensatory lengthening are completely ill-formed while those with weak glottal stricture produce a less awkward effect.

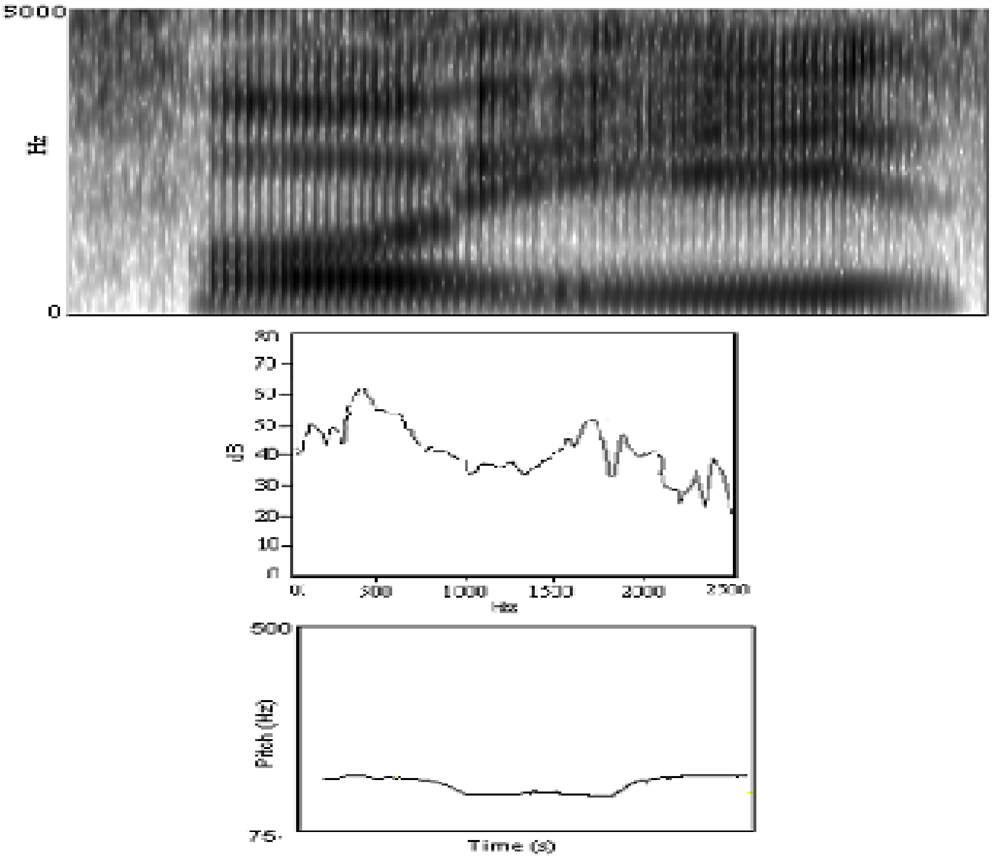


Figure 1. *The Spectrogram, FFT Spectrum and F0 Contour for the Word /saʔeb/ "Competent". The Spectrum, Taken Over A 25 Ms Window, Was Centered at 20th of The Vowel*

This finding is supported by previous studies in the literature. The analysis developed so far by Persian linguists for /ʔ/ in intervocalic position suggests that words pronounced with either [ʔ] or [Ø] sound fairly acceptable. Samareh (1977) considers intervocalic glottal stops as strong variants which do not trigger vowel lengthening. However, he does not exclude the possibility of glottal deletion in this position. In a moraic account of compensatory lengthening in Persian, Darzi (1991) argues that glottal consonants /ʔ/ and /h/

in intervocalic position may be deleted, adding that this deletion dose not trigger lengthening since consonants occupying syllable-initial positions are not moraic in Persian.

One possible phonetic interpretation for the deletion of glottal stop in intervocalic position is that /ʔ/ is completely deleted such that it shows normal voicing that is continuous throughout the glottal constriction gesture. Under such assumption, glottal gesture is realized with similar measurements of voice quality variation throughout VʔV sequences. In other words, it is assumed that there is no interval of non-modal phonation type corresponding to the entire length of the glottal consonant.

More recently, however, it has been suggested that VʔV sequences cannot simply be viewed as involving complete deletion of glottal stop; rather, as the glottal stop closure is not reached as the target point, a laxer laryngeal setting is adopted and the glottal consonant /ʔ/ arises as an allophonic variant of the following vowel which is known as creaky or laryngealized phonation (Sadeghi, 2011). Fig. 1 shows the spectrogram, FFT spectrum and F0 contour for the word /sɑʔeb/ "competent". The spectrum, taken over a 25 ms window, was centered at 20th of the vowel [e]. The spectrogram shows a creaky laryngealized vowel visually reflected in increased distance between the vertical striations reflecting pitch pulses before modal voicing commences on the latter portion of the vowel [e]. In addition, the drop in F0 value, and a steeply positive spectral slope in the FFT spectrum due to a fall off in energy at H1 all signal the sequencing of phonation differences, characterized as modal-creaky-modal phonations.

Both of these interpretations, however, are consistent with the results given in table. One can assume that any degree of reduction in glottal gesture in intervocalic position from a lax laryngeal setting through complete loss of glottals is perceived as instances of glottal deletion, which participants find fairly acceptable, along with [ʔ] which is mostly common in careful speech.

Syllable-coda position: The results for /ʔ/ in syllable-coda position which included the words /meʔde/ and /ʃamʔ/ come below in Table 4.

Table 4 shows that glottal stop in this position yields free variation for three allophones, namely [ʔ], ['] and [:]. As can be seen, the values resulted for each of these three variants are considerably low, indicating that the resultant forms are fairly acceptable. The table also shows that the forms undergoing glottal deletion in syllable-coda position are unacceptable.

Table 4. *Mean and Standard Deviation Well-Formedness Values for /ʔ/ allophones in Syllable-Coda Position and Results of Two-Tailed T-Tests*

<table>
<tr><th>Allophones</th><th>mean</th><th>St. dev</th><th>Effect of /ʔ/ allophony on well-formedness for each comparison</th></tr>
<tr><td>[ʔ]</td><td>3.06</td><td>1.10</td><td rowspan="4">significant comparisons all at $\varrho<0.05$: [Ø] ≈[ʔ]
[Ø] ≈ ['];
[Ø] ≈ [:]
non-significant comparisons: [ʔ]≈ ['] ($\varrho= 0.07$);
[ʔ]≈ [:] ($\varrho= 0.23$);
['] ≈ [:] ($\varrho= 0.25$)</td></tr>
<tr><td>[Ø]</td><td>5.11</td><td>0.88</td></tr>
<tr><td>[']</td><td>2.65</td><td>1.40</td></tr>
<tr><td>[:]</td><td>2.86</td><td>1.10</td></tr>
</table>

This finding is in line with the results of previous studies on glottal stop behavior in coda position. It is commonly held that Persian glottal consonants in syllable coda undergo vowel lengthening. Some questions have arisen, though, concerning the phonological operations involved in CL. One view suggests that glottal allophonic weakening is compensated by vowel lengthening (Samareh, 1977). Thus, /ʔ/ (and /h/) in coda changes to, or realizes as, a weak allophone, followed by lengthening of the preceding vowel. Another view holds CL involves the deletion of a coda glottal consonant followed by the lengthening of the adjacent nucleus vowel (Darzi, 1991). Both views, however, hold that coda glottals may be persevered in slow and formal speech. More recent studies, however, suggest that CL is a gradient process in which different magnitude of glottal gesture is realized in speech from a weak through complete deletion of glottal (Shademan, 2003; Sadeghi, 2007, 2008). In addition, allophonic reduction of glottal gesture is accompanied by lengthening of the preceding vowel as glottals attain a gesture much similar to a vowel. This third interpretation seems to provide a better account of the results given in table 4 as it encompasses all the resultant acceptable forms by positing a continuum of laryngeal gesture from a weak through complete deletion of glottal stop.

On the whole, the results show that word-initial position involves categorical judgment: [ʔ] is the only allophone allowed to be realized in this position. The results also reveal that intervocalic and coda positions yield free variation between allophones: [ʔ] and [Ø] are freely distributed in intervocalic position and [ʔ], ['] and [:] are freely distributed in coda position. The results follow a universal tendency in phonology according to which word-initial position exhibits much less phonological variation than word final or syllable coda positions (Kohler, 1990; Lindblom, 1990; Steriade, 1993; 1997). A closer examination of the variable cases in forms involving free variation reveals that the variants are hardly ever on an equal footing. Typically, one sounds better than the other although both are possible. Given that the difference in well-formedness values for the variable cases is not statistically significant, each variant is assigned the same well-formedness category, namely, "ok"; but this quantitative effect, will be accounted for later on in the research. In addition, based on the statistical results, we have used two linguistic categories, namely "/?/" and "/??/" to represent the gradient preferences. On the whole, we have reduced the numerical data of the survey to the traditional categories "ok", "/?/", "/??/" and "*".

3.2. Data Analysis

Given that phonology influences the distribution of optional and gradient forms, the question remained to be answered is what theoretical model can handle optionality and gradient well-formedness in grammar. Hayes and Boersma (1999) and Hayes (2000) devise a specific model within optimality theory, suggesting that this modified version of OT can generate free variants and outputs with varying degrees of well-formedness. In this paper we will try to provide an account of free variation and gradience in the participants' survey in terms of Hayes's model. A sketch of Hayes's model is provided below.

3.2.1. Constraints

The constraints needed to account for the phonological behavior of glottal stop are as follows:

A) Faithfulness constraints:

1- Ident-IO (str.): Correspondent consonants in the input and output must have identical values for the degree of stricture.

2- Max-IO: Input segments must have output correspondents. Any deletion of segments in the input will violate Max-IO.

3-WT-IO: Correspondent segments in the input and output must have identical quantity. This constraint militates against both vowel shortening and vowel lengthening in the input.

4- Syllabification: Syllable boundaries in the input segments must not be altered. Any change in the syllabicity of input segments will lead to the violation of this constraint.

B) Well-formedness constraints

1- *[ʔ]: /ʔ/ must not be realized as a complete glottal stop. This constraint is, in fact, grounded in speech production. The loss or weakening of articulatory closure in the glottis seems fairly to be a case of lenition. This sound pattern is effectively arranged to facilitate ease of articulation.

2- Word initial:[ʔ]: This constraint requires that /ʔ/ be realized with complete glottal closure. The constraint is grounded in perceptual system. Ohala (1990) asserts that positions such as word initial and prevocalic are perceptually salient; and so, they call for allophones which are essentially salient acoustically to render maximal distinctness of contrasting forms in perception.

3- ['] in coda: This constraint requires that glottal stop not be realized as a weak allophone except in coda position. In fact, this constraint limits the weak allophone, ['], to coda position. "['] in coda" is grounded in speech perception. Prevocalic position is perceptually salient and hence, perceptual cues of consonants must be present in this position to provoke a full phonological contrast. In contrast, codaposition is not perceptually salient, and thus, consonants in this position tend to be unrealized or poorly realized, lacking perceptual cues that are needed for their maximal distinction (Kirchner, 2000).

For the purpose of presentation only, let us assume that constraint ranking is categorical in character. The grammar with this effect generates an invariant set of outcomes, with no free variation and no gradient well-formedness. If we adopt such a grammar, then our problem simply is to rank the constraints listed such that the following forms emerge as the optimal outcomes:

To generate these outcomes, we assume that Word initial:[ʔ], WT-IO, Syllabification and ['] in coda dominate *[ʔ], and that Max-IO and Ident-IO (str.) are outranked by *[ʔ]. We further assume that Complex coda dominates Max-IO. Consider Table 5. This table is imperfect and to some degree tricky, since some of the rankings turn out to be important only when we take into account free variation and gradient well-formedness. However, by examining the table, the following generalizations emerge:

- In word-initial position, [ʔ] is forced by the dominance of Word initial: over the lenition constraint *[ʔ]. Here, the violation of a high-ranked constraint, Word initial: [ʔ], suffices to rule out forms pronounced with [Ø], ['] and [:] variants.
- In syllable-initial post-consonantal position, again forms with [ʔ] come out as the optimal candidates. This effect is followed by the fact that the lenition constraint *[ʔ] is outranked by the higher-ranked constraints WT-IO, Syllabification and ['] in coda.
- In intervocalic position, [Ø] comes out as the winner. This follows directly from the dominance of Max-IO by the higher-ranked constraints, namely *[ʔ], WT-IO and ['] in coda. Here, [Ø] candidates have incurred a violation of Max-IO but they have satisfied the higher-ranked constraints, while forms with [ʔ], ['] and [:] have violated *[ʔ], ['] in coda and WT-IO respectively, and as such; have lost their chance of being selected as the winner.
- In syllable coda position, forms with ['] are selected as the winner as the faithfulness constraint Ident-IO (str.) is outranked by the higher-ranked constraints WT-IO, Max-IO, and *[ʔ].

Table 5. *An Optimality Account of /ʔ/ Allophonic Behavior Based on Categorical Constraint Ranking*

(4)		Word initial: [ʔ]	WT-IO	Syllabification	['] in coda	*[ʔ]	Max-IO	Ident-IO (str.)
/ʔamal/	[ʔamal]							
	[Øamal]	*!					*	
	[’amal]	*!			*			*
	[a:mal]	*!	*				*	
/sanʔat/	[sanʔat]							
	[sanØat]			*!			*	
	[san’at]				*!			*
	[sa:nat]		*!				*	
/ʃɑʔer/	[ʃɑʔer]							
	[ʃɑØer]						*	
	[ʃɑ’er]				*!			*
	[ʃɑ:er]		* !				*	
/meʔde/	[meʔde]							
	[meØde]		* !					
	[me’de]							*
	[me:de]						*	

[ʔ] in word initial position ([ʔamal] and [ʔarteʃ]) and syllable-initial post-consonantal position ([sanʔat] and [maʃʔal]),
[Ø] in intervocalic position [ʃɑØer] and [dɑØem]),
['] in coda position ([me'de] and [ba'd]).

3.2.2. Accounting for Free Variation

As the result of the survey indicated, forms with intervocalic and coda /ʔ/ involve free variation. In intervocalic position, forms with either [Ø] or

[ʔ] sound fairly acceptable, with [Ø] slightly preferred. In coda position, participants found fair acceptability for [ʔ], ['] and [:] variants, with ['] one showing slight preference. To account for the observed free variation, we need a more accurate model, one that can readily generate multiple outputs for a single input. To do this, I follow Hayes' proposal of constraints ranking scales. As was explained in 2, Hayes assigns a strictness band to each constraint and asserts that free variation results from overlapping strictness bands. It seems that by translating the analysis developed so far into a strictness band approach, we can account for optionality in our linguistic data.

Let's begin with intervocalic position. To yield both [Ø] and [ʔ] variants, one needs simply to assign the two constraints Max-IO and *[ʔ] to overlapping bands at the bottom of the scale, with Word initial: [ʔ] and WT-IO ranked on the top of the scale:

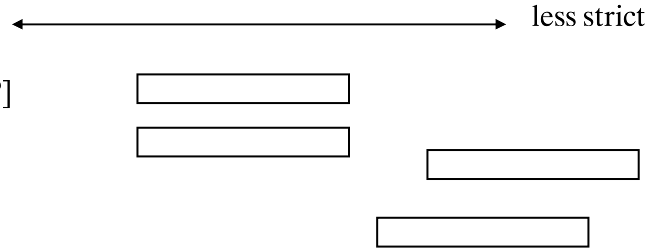
more strict ⟷ less strict

(5) Word initial: [ʔ]

WT-IO

Max-IO

*[ʔ]



Here, the overlapping of Max-IO and *[ʔ] bands allows for [Ø] and [ʔ] candidates to emerge as two perfect outputs. But, as it happens, there is a rather small difference in the ranking values of Max-IO and *[ʔ]. This difference, indeed, corresponds to a slight preference in the participants' judgments for forms produced by [Ø]. Here, one point is in order: The overlap in the strictness bands of Word initial: [ʔ] and WT-IO is non-crucial since their ranking is irrelevant as having no empirical consequences.

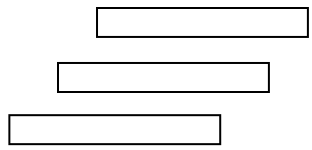
For free variation in coda position, it suffices to place the constraint Ident-IO (str.) within the ranges of the continuous scale covered by Max-IO and *[ʔ]. More specifically, we need only to rank Ident-IO (str.) to a small degree lower than Max-IO and *[ʔ]. The result is that though all [ʔ], ['] and [:] are possible, forms with ['] sound better:

more strict ⟵⟶ less strict

(6) Ident-IO (str.)

Max-IO

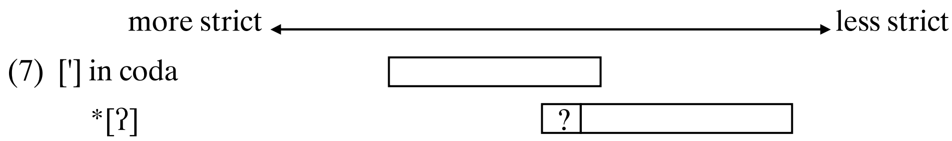
*[ʔ]



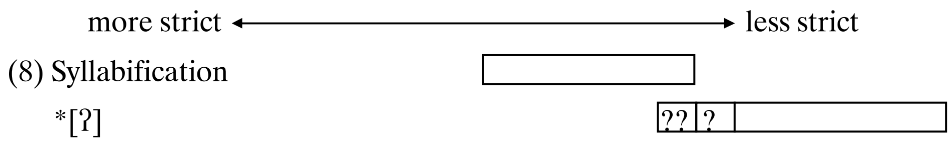
3.2.3. Accounting for Gradient Well-formedness

Our final step is to develop a formal analysis of the linguistic data in which speakers' judgments involve intermediate well-formedness. The cases that yielded intermediate well-formedness in the participants' survey were (1) Forms produced with a weak glottal stricture in syllable-initial post-consonantal position were somewhat ill-formed, producing a /?/ effect (?[san'at]; (2) Forms produced with ['] in intervocalic position produced a /?/ effect (?[ʃɑ'er]; and (3) in syllable-initial post-consonantal position, forms with [Ø] were considerably ill-formed; yet were not excluded (??[saØnat].
Following Hayes (2000) we can account for the gradience in our linguistic data by making use /?/ and /??/ class fringes in the strictness bands of constraints. Beginning with /ʔ/ in syllable-initial post-consonantal or intervocalic positions (cases 1 and 2 above), we, first, assume that the two constraints which derive the appearance of such forms (as ? [san'at] and ʔ[ʃɑ'er) are *[ʔ] and ['] in coda. Further, we may assume that the upper /?/ fringe of *[ʔ], and not its central region, extends upward into the region occupied by ['] in coda (7). This means that it is indeed possible to generate a set of outcomes with *[ʔ] outranking [']

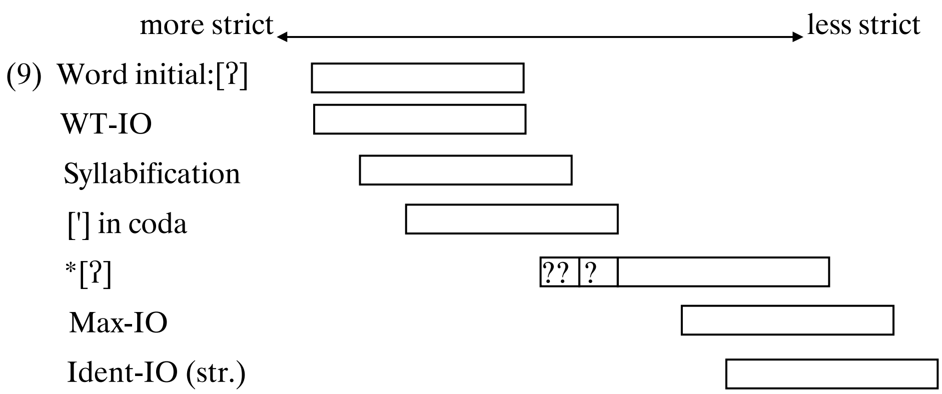
in coda (*[ʔ]>['] in coda). But this comes at the cost: Forms produced with such ranking receive /?/ mark.



Let's consider, next, forms produced with [Ø] in syllable initial position. Assuming that the two constraints which enforce the appearance of [Ø] and [ʔ] forms in this position are Syllabification and *[ʔ], we may claim that Syllabification is placed almost in the upper region of the continuous scale, while *[ʔ] appears in the lower one. We, further, assume that Syllabification is not strong enough to override the *[ʔ] constraint. To put it another way, we assume that the upper /??/ fringe of *[ʔ], not its /?/ or central region, extends high enough to pervert rankings in which *[ʔ] dominates Syllabification (8). Forms resulted from this ranking deserve a /??/ mark.



Taking all the above continuous rankings together, the grammar of glottal stop allophonic behavior can be graphically depicted as (9):



The kinds of rankings posited here under (9) can generate not only free variants (resulting from overlap in constrains' bands) and gradient data (resulting from overlap only in constraints' fringes), but it can also account for invariant data in our survey. The participants' judgments in word-initial position involved categorical well-formedness where all forms except those with /ʔ/ were found completely ill-formed. This can be accounted for by the invariant non-overlapping ranking of the two constraints Word initial: [ʔ] and *[ʔ]. The complete ungrammaticality of forms with [:] in syllable-initial post-consonantal position can also be accounted for by the fact that the bands of the relevant constraints, namely WT-IO and *[ʔ], fail to overlap even in their fringes.

4. Conclusion and Discussion

In the present paper, I studied the pattern of glottal stop allophonic behavior using the judgments of 37 native Farsi speakers. Several Persian natural words were chosen that included glottal stop /ʔ/ in one of five different phonological positions, namely, word-initial, syllable- initial post-consonantal, intervocalic, syllable-coda post-vocalic and coda post-consonantal (there were two words for each phonological position). The glottal stop /ʔ/ in each word was pronounced by the author in four different ways, namely, with a complete glottal closure ([ʔ]) with complete deletion of glottal stop ([Ø]), with a week glottal gesture ([']), and with compensatory lengthening of the vowel preceding the glottal stop ([:]). The manipulated tokens were embedded in appropriate sentences and given to the participants to judge on a scale ranging from 1 to 7, with 1 indicating "perfectly normal in Farsi" and 7 "totally ill-formed, I would". The participants' judgments were measured by carefully computing the values given to each phonetic string of words. Results of statistical analyses revealed that the judgments made by the participants were not completely categorical, as assumed by the generative grammar. For example, intervocalic and coda positions yielded free variation between the two allophones [ʔ] and [Ø], and syllable-initial post-consonantal position produced gradient well-formedness judgments as between the allophones ['] and [:]. While in some cases the participants produced categorical judgments (like word-initial position in which [ʔ] was the only allophone allowed to be realized in this position).

Following Hayes (2000), a minor modification in the framework of Optimality Theory (Prince & Smolensky, 1993) was suggested that enabled the model to accommodate phenomena where Persian speakers' intuitions on the glottal stop allophonic behavior involved free variation, or were gradient, falling somewhere between complete well-formedness and complete ill-formedness. The proposal consisted of assigning to certain constraints *bands of values* along a reified continuum of constraint strictness. As long as the strictness bands of two constraints overlap, then both rankings of the two constraints will be available for the generation of outputs, yielding free variant forms. However, when a particular form can be generated only by assigning a constraint a strictness value within a designated "fringe" of the strictness band, the grammar generates the form marked with an intermediate degree of well-formedness.

The proposal is rather conservative since all previous forms of constraint ranking in the current OT literature are compatible with what has been suggested here. Indeed, the kinds of rankings posited in earlier Optimality-theoretic work may be seen as a subset (indeed, a very important subset) of the rankings countenanced here.

A further advantage that could be asserted for the present approach is that it deals with gradient well-formedness in a completely general way, one intimately tied up with the structure of the theory itself; rather than involving *post hoc* additions to the theory in particular areas. The pervasiveness of gradient well-formedness judgments in language suggests that a fully general approach is likely to be the correct one.

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