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A perceptual Account of Manner Dissimilation in Greek.

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1. Introduction

In this paper, some phonological data from Greek are brought forth, namely a process of optional consonant cluster manner dissimilation found, with some variability, in all Modern Greek dialects (Newton, 1972; B. Joseph and I. Philippaki-Warburton, 1987). Greek consonant clusters consisting of two voiceless stops (e.g. /pt/) or two voiceless fricatives (e.g. /fθ/) can optionally dissimilate into a fricative plus stop [ft], but not into a stop plus fricative *[pθ]. The voiceless fricative /θ/ can change to a stop [t] when it is preceded by another voiceless fricative, so that an /fθ/ cluster can be realized as [ft]. However, when the second fricative in a fricative cluster is the sibilant [s], the cluster optionally dissimilates into stop plus [s]. Thus, the cluster /fs/ can be realized as [ps], the /f/ changing into a [p] in this case leading to an asymmetrical pattern of dissimilation when the sibilant /s/ is a member of such clusters. The introduction of these data is used as a starting point for the formulation of some general hypotheses about the perceptibility of such dissimilated clusters.

Manner dissimilation in Greek can be viewed as the result of what, in traditional phonological terms, would be a classic case of an output rule: two stops or two fricatives in the input are changed to a fricative and stop or a stop and fricative in the output. Why would users of a specific language favor one configuration of continuancy specification over another? To what extent is the resolution towards one particular configuration language specific and to what extent does unbiased, "universal" perceptibility influence the direction of such a resolution? In other words, given a specific phonological system, with a number of contrastive elements and processes, what is the extent to which cross-linguistic perceptual salience shapes and governs local (language specific) processes and contrasts? The bi-directional nature of such considerations is not hard to detect: For a given phonological system to come into existence it has to be subject to specific articulatory constraints (as there is a limit to what a human vocal tract can produce) and auditory constraints (as there is a limit to what the human ear can hear) from the very start. Yet, sound systems are subject to both universal, biologically determined articulatory and perceptual constraints, and at the same time language specific cognitive constraints, that must have evolved along side the observable sound systems. If we want to extract and formalize these constraints in a comprehensive formal theory of phonology, we have to look at existing phonological systems in order to guide and keep our analyses and predictions within the possible universe of natural human languages. The interplay then arises by acknowledging the fact that perception shapes phonology but at the same time phonology can shape speech perception and production.

This interplay of universal perceptual salience and language specific perceptibility is the goal of much recent research (for an overview see Hume and Johnson, 2001 this volume). The goal of this paper is to take a specific phonological process in Greek, namely consonant manner dissimilation and attempt to extract what is idiosyncratic to the particular phonological system that this process is attested in, and what falls under broader salience factors that have to do with independent perceptual considerations in a cross-linguistic framework. Dissimilation as a phonological process is of special interest to a research program that has as one of its goals to understand the role of perception in the evolution and structure of phonological systems across the world's observable languages.

The first part of this paper (sections 2-4) describes the phonological process of dissimilation in Greek in more detail, and the second part (sections 5-8) reports on the results of a discrimination experiment that was designed to gauge the perceptibility of dissimilated consonant clusters (e.g. [ft]) vs. non-dissimilated ones (e.g. [pt]). In order to achieve this, native speakers with two different phonological systems (English and Greek) were asked to evaluate stimuli derived from local contrasts in an alien, for the most part, sound system for the English listeners, and in a familiar, for the most part, sound system for the Greek listeners.

2. Phonotactics, syllable structure and lexical contrasts.

Standard Modern Greek has the consonant inventory given in table 1:

Table 1. Phonemic consonant inventory of Greek.

Place / Manner	Bilabial	Labio-dental	Inter-dental	Alveolar	Velar
stops	p b			t d	k g
fricatives		f v	θ ð	s z	x ɣ
affricates				tˢ dᶻ	
nasals	m			n	
laterals				l	
flap				ɾ	

Voiceless stops in Greek are unaspirated and contrast at three places of articulation: labial, coronal and dorsal. They also have three fricative counterparts at these same places of articulation [f, θ, x]. Voiceless fricatives and stops can combine to form biconsonantal clusters word-initially, word-medially and more rarely word-finally.

In Greek, voiceless bi-consonantal clusters can be found in a large number of words, and they seem to behave as complex syllable onsets since they can be found in absolute word-initial position as in [ktinɔs] 'beast', [xθɛs] 'yesterday' [ksɛnɔs] 'stranger'. Inter-vocalic clusters can be found in words such as [aptos] 'tangible', [efθis] 'straight' and [kɐfsis] 'burning'. Clusters also occur word finally, though they are not frequent in this position and always contain /s/ as in [vlɐks] 'idiot' or [miɔps] 'myopic person'. The possible combinatorics of voiceless C_1C_2 clusters in Greek, found in various positions in the word, are shown in table 2.

Table 2. Possible biconsonantal voiceless clusters attested in the Greek lexicon.

	p	t	k	f	θ	x	s
p		**ptɛriɣɐ** 'wing'		**sapfɔ́** 'Sappho'			**psiçi** 'soul'
t					**atθis** 'Atthis'		**tˢ** (affricate)
k	**ɛkpiisi** 'sale'	**ktinos** 'beast'		**ɛkfilɔs** 'pervert'	**ɛkθɛsi** 'proposition'	**ɛkxɔrɔ** 'assign'	**ksɛnɔs** 'foreigner'
f	**ɛfpɔrɔs** 'affluent'	**ftɛrɔ** 'feather'	**ɛfkɔlɔs** 'easy'		**fθinɔs** 'cheap'	**fxɐristɔ** 'thank'	**rɛfsi** 'flow'
θ							
x	**tˢɐxpinis** 'dapper'	**xtɛnɐ** 'comb'			**xθɛs** 'yesterday'		
s	**spiti** 'house'	**stɛnɔs** 'narrow'	**skɛpsis** 'thought'	**sfirizɔ** 'whistle'	**sθɛnɔs** 'strength'	**sxɐrɐ** 'grid'	

In this consonant matrix some clusters are more common, that is exemplified by more words, than others ([pt] or [kt] for stops and [fθ, xθ] for fricatives especially) and dissimilation is more likely to apply in words with such clusters[1]. Clusters that appear word initially can also appear word medially and more rarely word finally. Clusters that are only given word medially cannot appear word initially. [ts] clusters are best analyzed as affricates in Greek even though they can occur across word boundaries as can some of the clusters that would fill many of the gaps (empty boxes) in the above table (no geminates are allowed in Standard Modern Greek, not even across word boundaries, as indicated by the dark shaded boxes). Clusters in the light shaded boxes are the least frequent. The velar fricative /x/ and the vowel /i/ have a palatal allophone [ç] which can be found after all three voiceless stops as in the word /fotia/ 'fire' pronounced as [fɔ'tçɐ]

[1] Some words are given in their version with a dissimilated cluster (e.g. **xtɛnɐ** 'comb'). These words can also be found more rarely non-dissimilated (ktɛnɐ). Similarly, **ktinos** 'beast' can also be found as **xtinos**. Details about their distribution will be discussed in section 4.

but they are not of immediate interest to this study since, as it will be shown in the next section, are not the result of dissimilation. The same holds for the voiced bi-consantal clusters such as the ones found in words like [ɐvɣɔ] 'egg', or [ɐbdul] 'Abdul' which also seem to pattern differently than voiceless clusters and are not subject to dissimilation in Standard Modern Greek[2].

3. The dissimilation process

In Modern Greek, as noted in the introduction, voiceless consonant clusters of the form Stop+Stop and Fricative+Fricative (when neither of the fricatives is the sibilant /s/) optionally dissimilate to Stop+Fricative. For example, clusters of the form /pt/ (two stops) or /fθ/ (two non-sibilant fricatives) optionally dissimilate to a fricative plus stop, e.g. [ft].

(1) Two consecutive non-sibilant fricatives or stops[3] can change to fricative+stop.

a.	ptero	~	ftero	'feather'
	ktena	~	xtena	'comb'
	epta	~	efta	'seven'
	okto	~	oxto	'eight'
	ekpiisi	~	expiisi	'sale'
b.	xθes	~	xtes	'yesterday'
	fθinos	~	ftinos	'cheap'
	skefθika	~	skeftika	'I thought'
	anixθika	~	anixtika	'I was opened'
	fxaristo	~	fkaristo	'I thank'

When the cluster is formed by two stops the first member of the cluster changes into a fricative, whereas in the case of two fricatives it is the second member that changes. This process is schematized in (2) :

(2) Dissimilation output convergence:

Input Cluster		*Output*		*Input Cluster*	
[**p**t]	------>	[ft]	<------	[f**θ**]	(sounds in **bold** get dissimilated).
[**k**t]	------>	[xt]	<------	[x**θ**]	

epta 'seven' changes to *efta* — *fθinos* 'cheap' changes to *ftinos*

okto 'eight' changes to *oxto* — *xθes* 'yesterday' changes to *xtes*

[2] In other Greek dialects, especially in Cypriot Greek, voiced clusters seem to dissimilate, for example /avɣo/ turning into /afko/ 'egg' where we have both devoicing and dissimilation the /ɣ/ turning to a /k/ after a /v/ and then the /v/ assimilating for voicing to the /g/ turning into a /f/. A detailed description of such clusters in Cypriot Greek is found in Newton, B. 1972.

[3] Notice that almost all clusters have either /t/ or /θ/ as their second member, a tendency in the phonotactics of Greek which is not discussed in this paper.

In (2) we see that there is convergence toward a preferred output of a Fricative+Stop cluster from both directions; that is, both Stop+Stop and Fricative+Fricative clusters, when dissimilation is applied to them, yield an identical output of Stop+Fricative. This process could be analyzed in formal phonology by invoking the Obligatory Contour Principle[4] proposed originally for other dissimilation phenomena (McCarthy 1986, Odden, 1987, Yip, 1988).

(3)	$*C_1$	C_2	OCP Violation
	[-sonorant]	[-sonorant]	
	|	|	
	[αcont]	[αcont]	

As schematized in (3) two adjacent obstruents that share the same value for the feature [continuant] violate the OCP. Thus, the optional dissimilation process in Greek can be viewed as a strategy used to avoid an OCP violation. The question then arises as to which consonant has to change its specification to satisfy the OCP, since based on the schema in (2) a change in the value of [continuant] in either C_1 or C_2 would suffice. And this is exactly what happens in Greek depending on whether the C1C2 cluster is formed by two stops or two fricatives. Recall that if it is formed by two stops, it is C_1 that undergoes dissimilation. But if the cluster is formed by two fricatives, it is C_2 that dissimilates. The differential target of manner dissimilation is shown in (4).

(4)	Target of Dissimilation:	<u>C_1</u>	C_2	C_1	<u>C_2</u>
		p	t	f	θ
		↓			↓
		f			t

This observation then raises the issue of directionality in the dissimilation process in Greek. Why is it that a stop would undergo dissimilation when it is followed by another stop (a /p/ in a /pt/ cluster for example) whereas a fricative would undergo dissimilation only when it is preceded by another fricative (a /θ/ in a /fθ/ cluster)?

To complicate matters even further the sibilant fricative /s/ seems to enjoy a special status when it is found in fricative clusters as seen in the examples in (5).

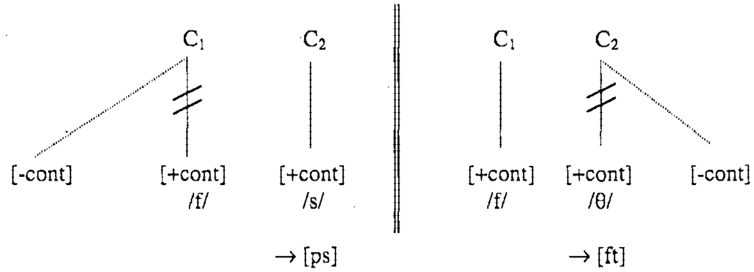
[4] Abbreviated as the OCP this principle is defined (McCarthy, 1986) thus: at the melodic level, adjacent identical elements are prohibited.

(5) Clusters with the sibilant /s/ in first and second position.

a.	sxini	~	skini	'rope'
	pisθika	~	pistika	'I was convinced'
	sfoŋgos	~	spogos[5]	'sponge'
b.	trex-o		e-trek-sa	'I run' (present ~ past)
	kafsimo	~	kapsimo	'burning'
	kaθ-izo		e-kat-sa[6]	'I sit' (present ~ past)

Thus, clusters with /s/ do not follow the generalization in (4). If /s/ is the first member of a cluster as in (5a) then the generalization holds, it is C2 that dissimilates. However, if /s/ is in a C2 position, as in the examples in (5b), it is C1 that dissimilates. This special case that results in a directionality asymmetry in the dissimilation output with regard to clusters with /s/ is schematized in (6).

(6) Sibilant Asymmetry



e.g. *θa γraf + so* [γrɐpsɔ] "I will write"
γraf + θi + ka [γrɐftikɐ] "I wrote myself"

When the second member of the cluster is the sibilant /s/, as is the case on the left in (6), then it is C_1 that dissimilates in a fricative cluster and not C_2 as expected in the non-sibilant fricative cluster to the right. If /s/ were to follow the non-sibilant fricative dissimilation pattern, /s/ might be expected to dissimilate to a homorganic stop [t] but this process is not attested in Greek, further supporting the special status of the sibilant fricative /s/ when it is found in consonant clusters[7].

[5] This particular example is a strictly diachronic one but it completes an otherwise incomplete pattern of dissimilation and it is used for sake of expository completeness.
[6] A /ts/ cluster is probably realized as a [t^s] affricate by most speakers, but its derivation seems to follow the general schema.
[7] Finally, there are clusters that are underlying sequences of stop plus fricative or fricative plus stop (e.g. [ɛkθɛsi] 'essay', [ɛftixɔs] 'fortunately', [ɐftɔs] 'he' [skɛpsi] 'thought' etc.). These contour clusters already satisfy the OCP and show no alternations (except for some rare cases of hypercorrection, for example [skɛpsi] ~ [sxɛfsi] 'thought') and are not the result of dissimilation.

4. Sociolinguistic factors and dissimilation.

As noted above, manner dissimilation in Greek is optional. It is, however, a very robust and active process in the language. Its application is exemplified by L2 phonology patterns of Greeks learning English as a second language such as the pronunciation of the English word *fact* as [fɐxt] or *McDonalds* as [mɐxtɔnɐlts]. This optionality is subject to sociolinguistic influences that stem from a long history of persistent diglossia in Greek speaking communities that have traditionally employed two varieties with unequal status: the high variety called Katharevousa 'purifying' and the low variety called Dhimotiki 'popular' (Ferguson, 1959). In Katherevousa the dissimilation process was resisted, whereas in an "idealized" Dhimotiki phonological system, dissimilation would apply to all candidate clusters. However, the disentanglement of the two phonological systems is problematic since all speakers could code-switch at any given moment and the strong influence of the high variety on the low resulted in the present day situation where the varieties have merged into a highly variable system that exhibits both patterns. One of the most salient differences between the high variety and the low was the realization of voiceless biconsonantal clusters. The pronunciation of words like /ftero/ 'feather', as [pteron] is a sign of usage of the High variety, showing both the retention of a stop cluster, and the adding of a final /n/ in the morphology of the noun that was lost in Dhimotiki. Doublets like [ftero]~[ptero(n)] exhibit some common diachronic developments in Modern Greek, namely the dissimilation of a voiceless stop before another voiceless stop in terms of manner (for example: /p/→/[f]/__[t]) and the loss of word final coronal nasal in nouns (/n/→ Ø/__#). However, these changes, in the case of Modern Greek, cannot be viewed as categorical and non-reversible developments (unlike, for example, the loss of vowel length, or pitch accents, that both Katharevousa and Dhimotiki exhibit) since the high variety never underwent these changes and thus provided speakers with a constant source of variability that was the result of both diachronic sound changes and synchronic sociolinguistic bi-dialectism. This prolonged bi-dialectism can be best viewed as stylistic co-variation piggybacking on the normal development of Dhimotiki dialects alongside of the artificially archaizing Katharevousa style of speech that everybody was sooner or later exposed to (e.g. through the church).

The issues of the diachronic development of dissimilation in Greek are quite complex and beyond the scope of this paper, but dissimilation can also be observed synchronically in alternations that are found even in Katharevousa, in clusters with sibilants. For example, the past tense (aorist) of the ancient Greek verb [grɐp^h-ɔ:] (1st person, singular present), which through regular sound changes, gave Modern Greek [ɣrɐf-ɔ] 'I write", is found in both varieties with a dissimilated /ps/ cluster [ɛɣrɐp-sɐ] (Dhimotiki), [ɛɣrɐp-sɔn] (Katharevousa) 'I wrote', having the /f/ of the stem turning into a [p] before the /s/ found in the past tense morpheme. Here there is no variability, except for paradigm internal alternations in the verb itself, and this is the result of inherited patterns found in ancient Greek that applied de-aspiration in clusters like [p^{h}s] blocking the regular development of [p^h] to [f] in the environment before a sibilant. Indeed the very existence of a cluster such as [fs] in modern Greek can be attributed to the influence of the learned tradition as codified in the high variety that, even though it "carried out" regular sound changes in one level of the phonology, namely the unconditioned change of [p^h] to [f], in another level preserved, or created new phonotactic conventions namely [fs]. Thus Dhimotiki, as it went through regular phonological developments, was never cut off from the conservatism of Katharevousa; at no point were these phonological changes fully realized, or categorical, due to the constant symbiosis of the two varieties (except perhaps in extremely isolated mono-dialectal communities).

The main point of this section is to show the intricate history behind dissimilation in Greek that seems to be the result of complicated diachronic, synchronic and sociolinguistic patterns. Dhimotiki (the low variety) has been declared the official language of Greece since 1974, but the present day language can be best viewed as the fusion of the two varieties more so than a pure form of one or another (Macridge, 1985). In many respects, and especially in the phonotactics found in learned vocabulary, Katharevousa patterns are very common to the point of being obligatory. In others, such as morphological patterns, Dhimotiki patterns are also practically obligatory. However, the main characteristic of this natural merging of the two patterns is the resulting optionality in the application or not of certain phonological processes such as dissimilation. Speakers then can exploit this optionality as a social marker, denotative of stylistic preferences (Kazazis, 1992). It can also be conditioned by other factors such as speech rate, word frequency, and ultimate source (high or low variety) of the lexical item containing such a candidate cluster for dissimilation. An idealized schematization of the different interactions between these factors is given in (7).

(7) Application of Dissimilation

(formal, monitored speech)		(casual, fast speech, informal)
xθεs (0.4139)[8] 'yesterday'		**xt**εs
ktiriɔ (0.1079) 'building'	*dissimilation* →	**xt**iriɔ
εpɔ**pt**is (0.0031) 'inspector'		εpɔ**ft**is
mɔ**xθ**irɔs (0.0012) 'scowler'		mɔ**xt**irɔs
↑ increasing familiarity or frequency		↓ decreasing probability of dissimilation

[8] These are frequencies per thousand words extracted from the Hellenic National Corpus™ (HNC). This 13 million word corpus is developed by the ILSP (Institute of Speech and Language Processing) in Athens, Greece and described in Hatzigeorgiu et. al. (2000).

As shown in (7), speakers would be more likely to dissimilate the very common word for 'yesterday', a traditional Dhimotiki vocabulary item, less likely the Katharevousa, yet very frequent word for 'building', and even less likely the less frequent Katharevousa word for 'inspector'. Finally, the dissimilation of the /xθ/ cluster to [xt] in the word for 'scowler', which is a very infrequent Katharevousa word, would be highly improbable. The decreasing probability in the application of dissimilation is marked by the downward pointing arrow to the right of the dissimilated words and the increasing familiarity/frequency by the upward pointing arrow to the left.

This probabilistic approach in the application of certain phonological processes with sociolingusitic significance is best captured by Guy and Boberg (1997) in their discussion of the Obligatory Contour Principle. By examining the inherent phonological variability found in languages, they propose a new association of the initials OCP as Optional Contour Preference, treating the OCP family of constraints as probabilities rather than violable conditions. In the case of consonant manner dissimilation as found Modern Greek this approach seems to be highly relevant since any formal attempt to describe such a system would fail to capture the multitude of factors that could influence the process at hand. In particular, speech rate seems to be a very important factor in altering the probability of dissimilation. A small pilot study conducted with two native speakers of Greek who were asked to read a text with target clusters, at two different speech rates (one slow and careful, and one fast and casual) showed that speakers are more likely to dissimilate clusters when they read the text faster than slower (Tserdanelis, 2000). Of course, this finding is only relevant to reading style but a tenuous extrapolation to other speech events does not seem very far-fetched. If speakers choose when to apply the OCP on an item-by-item basis then any attempt to constrain this variability and to identify certain patterns in those choices would have to be based also on criteria that have to do with speakers' preferences and attitudes. These attitudes are embedded in a social evaluative context and not solely on an abstract grammar of Modern Greek with an independent set of rules, constraints, or competing rankings of constraints.

To conclude this section, I propose that dissimilation in Greek is then best viewed as the result of various factors interacting and conspiring to induce a certain phonological process. This conspiracy of factors can have a cumulative effect that would tip the balance in favor of triggering a certain process. These factors could be as diverse as the interplay between production and perception as they relate to ease of articulation and acoustic enhancement, social attitudes and contexts, historical developments, rate of speech, frequency of occurrence, lexicalized contrasts, internal borrowing, analogy, etc.

5. Perceptibility as a factor in dissimilation.

Both assimilation and dissimilation can modulate the perceptibility of sound sequences. Assimilation tends to sacrifice syntagmatic perceptibility while accommodating ease of articulation (Steriade, 2001) whereas dissimilation has been interpreted as enhancing perceptibility while demanding more complex articulations than in sequences of non-dissimilated segments (Suzuki, 1998). Gauging and understanding the relevant perceptibility of such segmental sequences then, can prove to be a fertile field of inquiry in order to understand in their totality the mechanics of processes such as manner dissimilation in Modern Greek. By isolating perceptibility, or any other factor that seems to have a bearing on a given phonological pattern, and treating that factor as a potentially independently motivated phenomenon, some interesting generalizations might be arrived at about the structure of sound systems cross-linguistically. Thus, a systematic decomposition of a process affecting a sound system, may lead to a deeper understanding of the phenomenology of the process itself and of possible language sound patterns in general. The interplay and the various interactions between production and perception, or between history (faithfulness) and function (optimization) in the structure and development of languages, are perhaps more important than any one of these factors studied in isolation. But in order to study these interactions, relevant data about some of the interacting components could be very informative. These components can take the form of social, grammatical, phonological and phonetic influences on a given sound system.

In this study, the role of perception in the evolution of dissimilation as a synchronic process in Modern Greek is investigated. Many have noted language preferences for particular sequential contrasts. Greenberg (1978), for example, gives some cross-linguistic generalizations about obstruent consonant clusters summarized in (8). In these implicational universals, a statement "x > y" means that the presence of x in a language implies that y also exists in that language.

(8) Contrast in continuancy is favored over its absence:

a) TTV > FTV, SFV
b) VTT > VFT, VTF
c) FFV > FTV, TFV
d) VFF > VFT, VTF

In (8) T stands for a stop consonant, V for any vowel and F for a fricative consonant. (8a) Then should be read as a stop + stop (TT) consonant cluster before a vowel (V) is less common cross-linguistically than a fricative + stop (FT) or a stop + fricative (TF) before a vowel (V). The same applies for postvocalic stop clusters as well (8b) and clusters with two fricatives (8c-d). According to these cross-linguistic observations, contrast in continuancy between adjacent prevocalic obstruent segments is more common than not. Notice, that Greenberg does not talk about the perceptibility of such clusters, but only about how they pattern quantitatively in the world's languages[9]. Functional models based on salient acoustic modulations in segment sequences have also been proposed to account for the type of generalizations given in (8) (Ohala 1992, Wright 1996). These approaches emphasize both the inherent qualities of segments and their syntagmatic optimization in terms of acoustic salience. For example, [s] is more perceptible than [θ], and a [t] before a vowel is more perceptible than a [t] before another stop. Thus, preference for certain

[9] In formal phonological theory, segmental sequential constraints have been proposed for observed cross-linguistic tendencies in the realization of consonant clusters, such as sonority-based models (Clements, 1988).

sequential contrasts that can result in a modulated acoustic signal such as in Greek dissimilation may have a perceptual basis.

With this as a basis, some general hypotheses about the role of perception in dissimilation in Greek are proposed. First, with regard to the preference for contour clusters, in terms of manner of articulation, the motivation for alternating between stops and fricatives in biconsonantal clusters may be due to perceptual enhancement (increased contrast) at the cost of coordinating two distinct manners of articulation next to each other (Ohala, 1990). In other words, place perception is enhanced in dissimilated clusters in Greek; a manner contrast between fricatives and stops increases the probability that both of the segments in a biconsonantal cluster can be perceived. Second, with regard to the directionality of the dissimilation.

In the case of the dissimilation process in Greek, recall that the preferred outcome of dissimilation is (FTV), fricative + stop before a vowel, unless the (F) is the sibilant [s] in which case the preferred outcome is (TFV), stop + sibilant before a vowel, always preserving [s] even when it is in second position in a fricative cluster. To understand this directionality, we hypothesize that listeners are be better at differentiating between one configuration over another, if indeed there is some degree of difference in the perceptibility of dissimilated clusters depending on what comes first and what comes second (given two choices: fricative or stop) in biconsonantal clusters. Taking into account the cues of different segments in various contexts (Wright, 1996), optimal arrangements can be predicted. For example, since fricatives as opposed to stops have internal cues (Johnson, 1997) by creating a cluster of a fricative followed by a stop an optimization of cues is achieved especially in absolute word initial, prevocalic position: [ftV] is better than [pθV] because both the stop burst and the vowel onset transitions associated with the prevocalic stop are preserved (Fujimura et al. 1978). Some of these cues are realized better in particular contexts, for example a stop burst and aspiration before a vowel rather than before a fricative, where fricative noise can mask them. Similarly, fricatives, even though they lack bursts, have some internal formant structure that can be used by listeners to identify place of articulation, whereas stops rely solely on the preceding and following vowels for place information extracted from formant transitions. As shown in table 3 the optimal configuration, in word initial, prevocalic position when cues are taken into account is for a fricative to precede a stop.

Table 3. Cues for stops and fricatives in clusters after silence.

	#pθV	#ftV	#ptV	#fθV
Burst for C1	NO	N/A	NO	N/A
Burst for C2	N/A	YES	YES	N/A
Formants for C1	NO	YES	NO	YES
Formants for C2	YES	YES	YES	YES

This optimization can be extended to other phonotactic environments as well, having perhaps as a starting point the absolute word initial position where the perceptual gain from the fricative+stop configuration is maximized. For example, both in absolute word initial position and inter-vocalically, a preference for prevocalic stops could also have a perceptual basis because CV formant transitions have been experimentally found to be more perceptible than VC transitions for stop place (Fujimura et al. 1978).

Finally, The sibilant /s/ when it is found in a cluster, never gets altered in Greek no matter what position (C1 or C2) it is found in. Sibilants, unlike other fricatives, are characterized by aperiodic high frequency energy and spectral peaks above 4 kHz, unique acoustic characteristics that perhaps render them more distinct perceptually. This could be a factor in Greek dissimilation where a stop occurs before a fricative (e.g /fsV/→[psV]) , unlike the optimal configuration, in terms of cue preservation, shown in table 3. Thus the inherent acoustic salience of sibilants may be an overriding factor in their syntagmatic perceptibility. Following Kohler 1990, Steriade 2000, we hypothesize that changing the /s/ would lead to a more noticeable change (cf.,) and thus is avoided by speakers. With regard to the dissimilation pattern in Greek then, we hypothesize that listeners will be better at discriminating between clusters that have as one of their members the sibilant /s/ than between clusters that do not. The presence of the salient acoustic cues of the sibilant would enhance the perceptibility of both members of a cluster, preserving the percept of two segments as opposed to one. The distinctiveness of /s/ then can be used by listeners to maintain robust perceptual contrasts with all other segments in the system both syntagmatically and paradigmatically (Hura et al, 1992).

The perceptibility of segment sequences that differ in their specification for continuancy vs. those sequences that do not can be directly tested experimentally, by having listeners discriminate between such clusters and then record the time it took them to arrive at such discriminatory decisions. These results then can be indirectly correlated with the perceptibility of such clusters: the longer it took for listeners to discriminate between two contrastive stimuli the harder those stimuli would be to perceive (Shepard, 1987). We can predict then that Greek listeners should be faster and more accurate at discriminating between contour clusters. Similarly they should also be faster and more accurate at discriminating between (FT) rather than (TF) clusters and between clusters with [s] rather than between clusters with non-sibilant fricatives.

To summarize this section, perceptual salience is introduced as one of the factors that could play a role in the realization of dissimilation. It is posited that a perceptual account might shed light on dissimilation and sequential contrasts in general. In order to test the above hypotheses empirical perceptual data were collected by means of an AX, reaction time discrimination experiment that tests the perceptibility of such clusters by Greek and English listeners, as discussed below.

6. Experimental design and data collection.

6.1 Method

6.1.1 Stimuli

An adult male, phonetically trained native speaker of Modern Greek, recorded nonsense VCCV stimuli containing all possible combinations of the relevant consonants in Greek [p,t,k,f,θ,x,s] that participate in the process of manner dissimilation. The consonants were flanked by the vowel [ɐ], with stress on the first syllable. There were two restrictions in the possible combinations in the consonant clusters constructed: there were no geminates, that is no [tt] or [ff] clusters, and no homorganic clusters such as [kx] or [fp], except in the case of clusters with the sibilant [s] where homorganic clusters such as [st] or [sθ] were constructed and included in the stimuli. The possible stop+stop, fricative+fricative, stop+fricative and fricative+stop, clusters including those with the sibilant [s], are given in (9):

(9) Cluster types (T=Stop, F=Fricative, S=sibilant):

a. TT:	tp, tk, pt, pk, kp, kt	6
b. FF:	θf, θx, xf, xθ, fx, fθ	6
c. FS/SF:	fs, xs, θs / sf, sx, sθ	6
e. TF/FT:	pθ, px, tf, tx, kf, kθ / θp, θk, ft, fk, xt, xp	12
f. TS/ST:	ps, ks, ts[10] / sp, sk, st	6

	Total Number of clusters:	36

The recordings were edited to ensure uniformity of segmental length and recording amplitude. Furthermore, if any of the clusters had a burst in the release of the first stop, in a stop+stop cluster such as in [tp] in ['ɐtpɐ], the burst was deleted and replaced by silence to ensure again the uniformity of the stimuli, since there was some variability in the strength of the burst when a burst was present at all (most stop+stop clusters had very weak bursts or no bursts at all after the first stop[11]). The stimuli were organized into pairs of two nonsense words containing the clusters in (9) of the form [**'ɐtpɐ**] ~ [**'ɐtkɐ**] where the first member of the C_1C_2 cluster is kept constant [t] and the second C_2 was varied [p~k]. The opposite types were also included, that is pairs of the form [**'ɐtpɐ**] ~ [**'ɐkpɐ**] in which C_2 is kept constant [p] and C_1 varies [t~k]. All the pairs constructed in this way are given in appendix 1. Because of this variation in C_1 vs. C_2 constancy, there were a total of (36 x 2) = 72 pairs per block, and every listener was presented with 6 blocks of these pairs randomized, resulting in (72x6) = 432 stimuli pairs per session. The 36 sound files were recorded on analog TEAC cassette tape recorder (normal tape, Dolby NR_ON, mono-Left, recording level 6/10) in a sound booth at OSU phonetics lab

[10] [ts] clusters were constructed by splicing together a final [t] and an initial [s], in order to differentiate the cluster [ts] from the affricate [tˢ].

[11] In *pt/kt* sequences in Greek the first stop can optionally be released both word initially and word medially something that is less likely in English for example in the pronunciation of words like *apt* or *act*. (Pagoni-Tetlow, 1998).

using a HMD head mounted microphone and a SX202 Dual Mic pre-amp (gain 40). The stimuli were read in pairs 4 times by the speaker without a carrier phrase and with a short pause between each stimulus (~500ms) and a longer pause (>2000ms) between each pair. The best tokens were selected and digitized on an IBM PC running PCquirer at 22KHz, and saved in .WAV format.

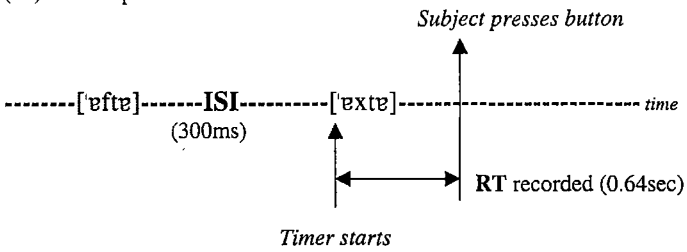
6.1.2 Listeners

The listeners for this experiment were 17 native speakers of Modern Greek (9 males and 8 females), ranging in age from 21 to 63, and 20 native speakers of American English (12 females and 8 males) ranging in age from 18 to 31. Both the Greek and English listeners were from various dialect/accent backgrounds.

6.1.3 Procedure

Pairs were created using MEL® (Microcomputer Experimental Laboratory software) and 6 randomized blocks were generated containing all the pairs found in appendix 1. In each block, the pairs were constructed using the identical .wav sound files to eliminate any production variability. The participants were given an instruction sheet before the experiment informing them about the task and the fact that they were going to be listening to nonsense words and not real words. Listeners were presented the pairs over headphones (Nova 16, 8 ohms, stereo headphones), in a sound attenuated booth, at a comfortable listening level (~70dB) in the fashion schematized in (10):

(10) Stimuli presentation



In (10) the interrupted line represents time (moving from left to right), and the stimuli are presented serially, ['ɐfta] then ['ɐxtɐ] with an inter-stimulus interval (ISI) of 300 ms (note that time measurements are iconic in this diagram) and a Reaction Time (RT) recorded at 640 ms after the start of the second stimulus. Listeners were instructed to listen carefully to the stimuli and decide as accurately and as quickly as possible whether the two nonsense words that they heard were the same or different. They had a choice of two buttons, labeled SAME or DIFFERENT. If they thought that the second word was the same as the first word of the pair presented they pressed SAME. If they thought the first word was different, as is the case in (10), they were supposed to press DIFFERENT. Listeners could only hear the pairs once, and they needed to make their decision within 4 seconds after the presentation of the second word of the stimulus pair. After 4 seconds had passed, the program timed out and the next pair was presented with no reaction time recorded. If the listener identified the pair correctly, feedback was given on a computer screen located in the booth[12]. The feedback had the form: CORRECT ANSWER and the RT was shown in seconds, such as 0.64secs. If the listeners made a mistake, e.g. pressed SAME when the pairs were different, or DIFFERENT when the pairs were the same, a computer message WRONG ANSWER was flashed on the screen, no RT feedback was given and the program proceeded with the next pair.

7. Results.

7.1 RT measurements

Average RTs for the different types of clusters for the Greek listeners are shown in figure 1. These results are calculated over the correct identifications, i.e. when the pairs were different the listeners responded by pressing the DIFFERENT button, and the correct rejections, i.e. when the pairs were the same the SAME button was pressed.

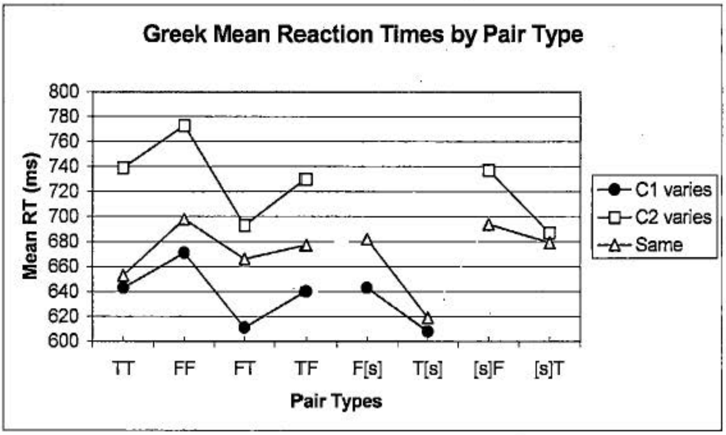


Figure 1. Mean RTs of correct identifications and correct rejections for Greek listeners.

The different cluster types (T=stop, F=fricative, [s] sibilant) are shown on the abscissa, and the average reaction times are shown in the ordinate. Grey triangles represent the "same" trials, for example ['ɐftɐ]~['ɐftɐ], solid circles represent pairs that varied in C_1 having C_2 constant, for example ['ɐftɐ]~['ɐxtɐ], and clear squares represent pairs that varied in C_2 having C_1 constant, for example ['ɐftɐ]~['ɐfpɐ]. Standard deviations and percentages of errors are given in appendix 2. The results for the English listeners are shown in figure 2.

[12] Feedback was given in order to keep the alertness level of the listeners high during a rather long and repetitious discrimination task.

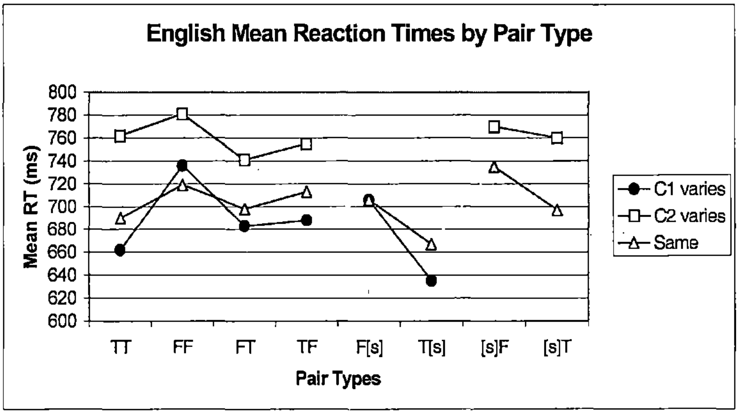


Figure 2. Mean RTs of correct identifications and correct rejections for English listeners.

If we compare the performance between the two groups of listeners within similar cluster types, that is, when C1 varied, as opposed to when C2 varied or when both pairs were the same we get the patterns shown in figures 3 through 5.

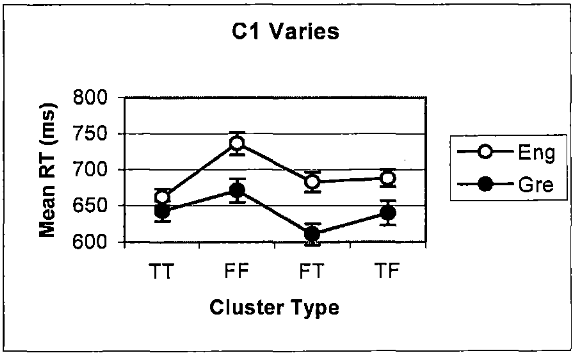


Figure 3. Mean RTs of correct identifications when C1 varied (eg. apta~akta) (T=stop F=Fricative).

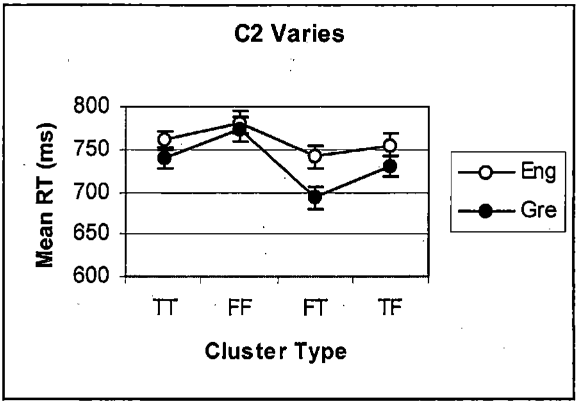


Figure 4. Mean RTs of correct identifications when C2 varied (eg. apta~apka).

In the graphs above we see that both English and Greek listeners pattern similarly showing the slowest reaction times for clusters with two fricatives (FF), for example [ɐfθɐ]~[ɐxθɐ] and the fastest for fricative-stop sequences (FT). However, English listeners showed a preference for (TT) clusters when C1 varied, but when C2 varied, as shown in figure 4, both groups of listeners pattern exactly the same in all pair types[13]. Data for the "same" pairs are shown in figure 5.

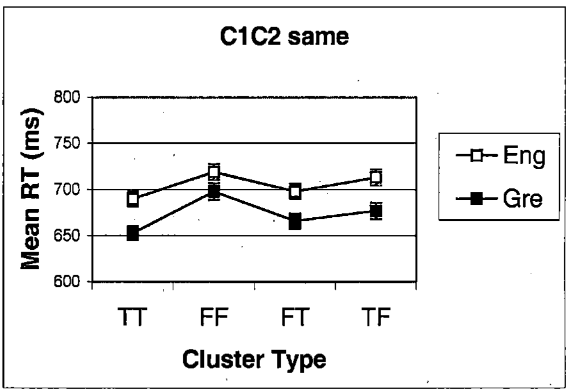


Figure 5. Mean RTs for correct identifications when the clusters were identical (e.g. apta~apta)

[13] Also in figure 4 (when C2 varied), RTs are overall slower than when C1 varied (figure 3) since listeners had to wait for a uniqueness point in the cluster that came later in the signal (C2 position).

Again, we see that both Greek and English listeners pattern similarly. The slowest reaction times are recorded for (FF) clusters and the fastest for (TT) clusters. However, it is interesting that both groups maintained better performance when discriminating between fricative plus stop (FT) clusters rather than stop plus fricative (TF) clusters.

7.2 Error Rates

If we look at the error rates we also see a similar overall pattern, between the two groups of listeners but also some interesting differences:

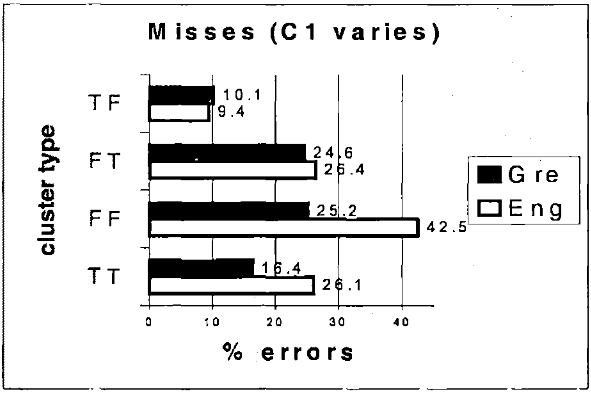


Figure 6. Error rates for incorrect identifications when stimuli were different (varied in C1 position) and listeners thought they were the same (misses).

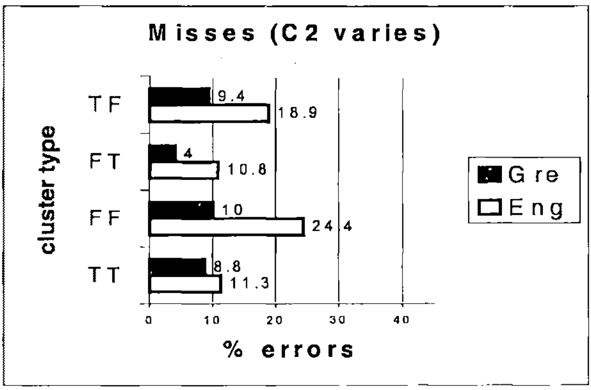


Figure 7. Error rates for incorrect identifications when stimuli were different (varied in C2 position) and listeners thought they were the same (misses).

Both Greek and English listeners made the most mistakes when discriminating between fricative plus fricative clusters. It is also noticeable how error rates decreased overall when it was the second consonant C2 that varied in the cluster. When C1C2 were identical, listeners had the fewest errors as shown in figure 8. Generally, faster reaction times correspond to fewer errors (higher accuracy).

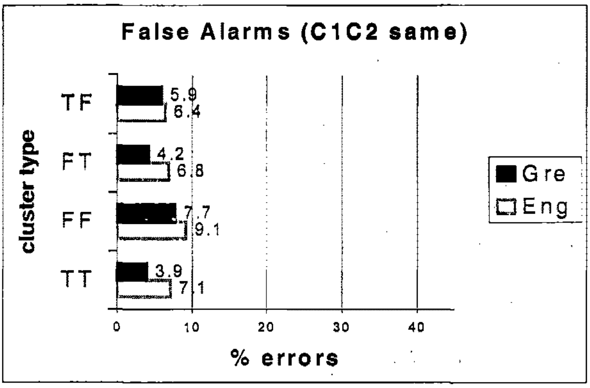
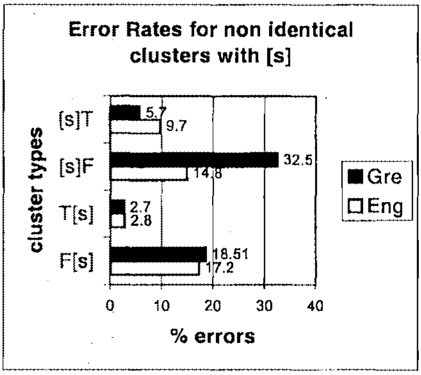


Figure 8. Error rates for incorrect identifications when stimuli were the same but listeners thought they were different (false alarms).

If we turn our attention now to the sibilant [s], we saw in figures 1 and 2 that reaction times were overall faster than in the non sibilant clusters and so the data in figure 9 show that accuracy with sibilant clusters was also better. However, it is interesting to note one exception, that is when [s] was the first member in an [s] plus stop cluster reaction times were not significantly better than in the FT clusters with a non sibilant [s] contrary to the claim that the sibilant [s] is perceptually a more salient sound. (cf. Figures 1, 2 and 9 below).



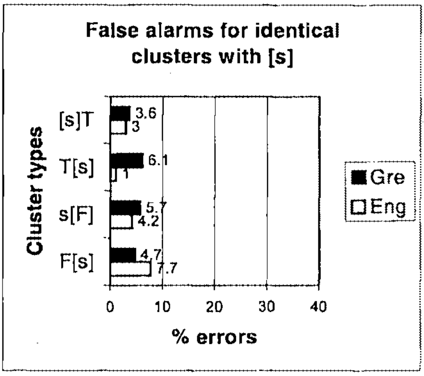


Figure 9. Error rates for clusters with [s]. In the graph to the left F and T varied, either in second C2 or first C1 position (e.g. aspa~asta or apsa~atsa). In the graph on the right the clusters were identical (e.g asta~asta or apsa~apsa).

8. Discussion

The two groups of listeners show similar trends in their average reaction times but also some very interesting differences. Most notably, the Greek listeners were faster in every category [$F=14.1$, $p<.05$], verifying the native language effect. Also, they exhibited their fastest reaction times in discriminating between dissimilated pairs of the form Fricative + Stop for non sibilant clusters (showing a significant effect of cluster type on RT, [$F=32.4$, $p<.05$]) and Stop + Fricative for clusters with the sibilant [s] [$F=6.1$, $p<.05$], exactly as predicted by the directionality preference of the dissimilation process described in section 2, and thus verifying the prediction that fricative plus stop clusters are more perceptible than stop plus fricative. When compared with the results for the English speakers, the Greek results seem to show a very strong preference for dissimilated clusters, something that is not very clear for the English listeners, who seem to be better at discriminating stop+stop clusters when C_1 varies, but show the same pattern with the Greeks (yet not as robust) when C_2 varies. In the case of the clusters with the sibilant [s], both groups of listeners seem to be noticeably better in discriminating stop + [s] clusters than fricative + [s] clusters, but again the pattern is not as robust when C_2 varies in [s]+fricative vs. [s]+stop clusters, even though the trend towards preferring the dissimilated clusters is maintained.

Another unexpected pattern exhibited by both listeners is that of a rather sluggish reaction time average in discriminating between [s]+stop clusters (687ms for the Greeks, 760ms for the Americans) vs. the fricative+stop clusters (693ms for the Greeks, 741ms for the Americans), given the fact that [s]+stop clusters are frequent in both languages. If the directional asymmetry exhibited by clusters containing [s] in Greek as shown in (6) earlier is due to the intrinsic salience of [s] (which as discussed earlier has a distinct high-pitched turbulent noise) resisting modification because of it being more perceptible than [f, θ, x], then this result is problematic for such an account. Perhaps this pattern is due to some masking effect that this high-pitched turbulent noise can have on the cues of the following stop, as in a [st] cluster for example, resulting in loss of perceptibility of the stop, and not because of any internal "weakness" of the sibilant. Interestingly, the fact that stops in English are aspirated except after an [s] might lend some support to this account, but it is still problematic for the Greek listeners who have no aspirated stops in their system.

The results in figures 1 and 2 can be visually schematized to show the relative perceptual distance in contrastiveness between these different types of clusters. In figure 10, this distance is represented by the two divergent arrows, showing the greater perceptibility of contrasts between stop+sibilant clusters on the right end of the scale (longer vertical lines between divergent arrows, indicating maximum perceptibility), vs. contrasts between fricative+fricative clusters on the left end of the scale (adjacent clusters with the shortest distance between them and no vertical line, indicating maximum confusability). The mean reaction times in figure 3 are averaged across the different directionality conditions, to best show the dissimilatory end points, even though in the space in between, some ambiguities, even reversals of the perceptibility rankings were found in the data, espcially TT>FT but not TF for the English listeners.

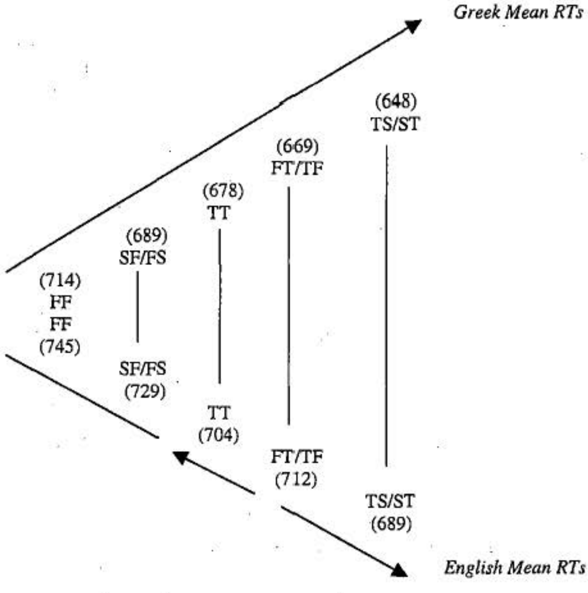


Figure 10. Perceptual salience schematized in terms of abstract distance.

If we were to rank the relevant clusters in terms of perceptibility based on reaction times, and maintain the different directionality data obtained by this experiment, we increase the resolution of the perceptibility hierarchies in (8) provided by Greenberg, so as to reflect the favored segmental sequences in terms of perceptibility by both Greek and English listeners:

(11) revised rankings (T= Stop, F=Fricative, S=Sibilant) – here ">" means "is more easily perceived than".

Greeks:	FT	>	TT	> TF	>	FF	cluster type
	(656)		(678)	(682)		(714)	RT
English:	TT	>	FT	> TF	>	FF	cluster type
	(704)		(707)	(718)		(745)	RT

If we include the special consideration of the clusters containing the sibilant [s] we then get the paired rankings shown in (12):

(12) Sibilant cluster perceptibility rankings:

• Greeks:	TS > TF	ST > FT	FS > FF	SF > FF
	(608) (640)	(687) (693)	(643) (671)	(737) (773)
• English	TS > TF	**ST < FT**	FS > FF	SF > FF
	(635) (640)	**(760) (741)**	(706) (736)	(770) (781)

Notice that the unexpected ranking in ST < FT (bold type) for English listeners is paralleled by the marginal ST > FT for Greek listeners (only 6ms difference in average RT).

In terms of the acoustics of these clusters, the fact that Greek listeners showed a preference for prevocalic stops in the form of FT vs. TF clusters, can be attributed to the fact that a stop before a vowel as in ['ɐftɐ] is acoustically more robust, having more cues before a vowel (burst and vowel transitions in the onset CV of the vowel) than before a fricative, as is the case in ['ɐtfɐ]. The worst position then would be before a stop as in ['ɐtpɐ], when the [t] may lack a burst all together and have offset (VC) transitions in the vowel, something that has been found to be perceptually worse (Fujimura et al, 1978). This phonetic enhancement that takes place by having a voiceless stop prevocalically rather than preconsonantally could also be a factor in the course of development of dissimilatory processes in a language. In addition, the fact that fricatives have internal cues, but stops have bursts could be another factor influencing the formation of sequences such as [ft] where, as discussed earlier in section 5, an optimization takes place, fricative and stops cues maximized, vs. [tf] where a stop cue (burst) is lost in fricative noise. Also the fact that the sibilant [s] seems to pattern differently, resisting dissimilation to a [-continuant] when found in clusters with other fricatives, also lends credence to a claim of better perceptibility of highpitched turbulent noise.

In terms of the phonology of these clusters in Greek and English, we can see the language effect, in the average reaction times. Greek listeners were a lot faster in all categories even in the ones that were preferred by English listeners such as the stop+stop clusters when C_1 varied. The fact that the English phoneme inventory lacks a contrast in the fricative series, namely the velar fricative [x], could also be a relevant factor in hindering the English listeners' ability to discriminate between clusters containing fricatives. This effect was also found in another experiment (Hume et al. 1999) with English listeners that were asked to identify Korean stop bursts, and did worse in the task than Korean listeners, who have an additional manner contrast in the stop series (aspirated, unaspirated and tense) vs. the two way contrast of English stops (unaspirated, and aspirated). Also the fact that both groups of listeners had the slowest RTs for fricative plus fricative clusters, may reflect both the rarity of such clusters in both languages as compared to those of stops and stops plus fricatives, with the Greek speakers actively decreasing their occurrence even more, by dissimilating [fθ] to [ft], and [xs] to [ks] to take two random examples. Furthermore, the finding of a preferred dissimilation output, namely fricative+stop over stop+fricative highlights the necessity of specifying directionality in OCP accounts of dissimilation which would otherwise fail to be informative as to which configuration is more favored cross-linguistically. Also the fact that in Greek these clusters can be found both intervocalically and in absolute word initial positions (complex onsets) as in /ptero/ 'feather' or /xtima/ 'land field' could also be a source of greater ability to discriminate for the Greek listeners as opposed to the English ones who have experience with more restricted phonotactics in their language.

Finally, in terms of the sociolinguistic ramifications of dissimilation, evidence from this experiment suggests that a post-diglossic phonological fusion, and dialect/style mixture in general, can be the source of a great variability in the speech signal. Dissimilation in Greek is an active process only probabilistically and it is severely constrained by as yet formally undefined factors. The perception results obtained from this experiment, can then be used as a starting point for better generalizations in terms of which factors seem to be more relevant in the description and analysis of phonological phenomena as they are paralleled by gross acoustic salience (contextual and inherent), and are manipulated by speakers and perceived by listeners in regular but not monotonic patterns, something that was shown by the limited yet identifiable differences in perception of consonant clusters between these two groups of listeners. Inherent variability in a phonological system, then, can be directly correlated with social attitudes towards such variability, that could sustain it or eliminate it, with perceptibility being just one parameter that can be overridden at any given point, either in historical development as it unfolds over time, or in highly idiosyncratic and evanescent individual speech events.

9. Conclusion

In this paper, the process of manner dissimilation in Greek was investigated, and empirical results from a perception experiment were presented in support of the thesis that perceptual considerations, in addition to other factors, can influence the phonology of a language. Dissimilation can be used as a diagnostic process for understanding the limits and mechanics of the role of perception in phonology. The experimental results in particular showed that listeners belonging to two distinct speech communities exhibited similar, but not identical discriminatory capabilities when presented with an identical number of contrasts. The differential perception of these contrasts as found here, is by no means claimed to be what causes the dissimilation process in Greek, only that it influences it in directions that take overall perceptual salience into consideration; the different parameters and influential factors are weighted and evaluated, resulting only in tendencies that can potentially be verified cross-linguistically. The results presented here constitute such an attempt, and are perhaps a small contribution to some possible answers to the questions generated by trying to understand and describe the complex structure of phonological systems and of language in general. Further laboratory studies of perceptual salience are needed to determine the limits of interaction between universal tendencies and language specific phonological constructs. In particular, future studies varying the linguistic source of contrasts used as stimuli, Greek in this case, and applying the same experimental design to different linguistic populations that possess separate and distinct phonological systems and especially segmental sequencing constraints, are needed. Empirical evidence like this then could help formulate more informed theories and possibly even predictions about the possible avenues of language change and language variation. By investigating the actual language users as they are going into various discriminative states, even in a laboratory setting, I believe is a good way to arrive at some understanding of the interactions between learned habits of varying complexity, and innate, species specific, predispositions.

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APPENDIX 1: Constructed pairs of stimuli.

	TT	*FF*	*FS/SF*	*TF/FT*	*ST/TS*
2nd member constant in pair	pt_kt tk_pk tp_kp	θf_xf fθ_xθ θx_fx	fs_xs θs_xs θs_fs	ft_xt θp_xp θk_fk px_tx kθ_pθ tf_kf	ks_ps ts_ks ts_ps
foils	pt_pt kt_kt tk_tk	θf_θf θx_θx fx_fx	fs_fs xs_xs θs_θs	ft_ft xt_xt xp_xp θp_θp θk_θk fk_fk	ks_ks ps_ps ts_ts
1st member constant in pair	pk_pt tk_tp kp_kt	θx_θf xθ_xf fθ_fx	sf_sx sθ_sf sθ_sx	tf_tx px_pθ kf_kθ θp_θk xt_xp ft_fk	sk_sp st_sp st_sk
foils	pk_pk tp_tp kp_kp	xθ_xθ fθ_fθ xf_xf	sf_sf sx_sx sθ_sθ	tf_tf tx_tx px_px pθ_pθ kθ_kθ kf_kf	sk_sk sp_sp st_st

APPENDIX 2: Mean reaction times, standard deviations and percentages of errors.

NON-DISSIMILATED CLUSTERS

	Stops		
	Tt~Tt	tT~tT	TT~TT
	Greek		
Mean RT	738	643	653
SD	175	220	179
% Errors	8.8	16.4	3.9
	English		
Mean RT	761	662	690
SD	263	193	204
% Errors	11.3	26.1	7.1

	Fricatives		
	Ff~Ff	fF~fF	FF~FF
	Greek		
Mean RT	773	671	698
SD	225	244	232
% Errors	10	25.2	7.7
	English		
Mean RT	**781**	736	719
SD	214	221	223
% Errors	24.4	42.5	9.1

T=Stop, F=Fricative
S=Sibilant

A Capital T indicates that the stop was constant in C_1C_2 cluster. A small case t indicates that the stop varied. for example a pair like Tt~Tt stands for a pair of actual stimuli: ['ɐptɐ]~['ɐpkɐ].

DISSIMILATED CLUSTERS

	Fricative + Stop		
	Ft~Ft	fT~fT	FT~FT
	Greek		
Mean RT	693	611	666
SD	219	220	195
% Errors	4.0	24.6	4.2
	English		
Mean RT	741	683	698
SD	220	222	205
% Errors	10.8	26.4	6.8

	Stop + Fricative		
	Tf~Tf	tF~tF	TF~TF
	Greek		
Mean RT	730	640	677
SD	205	253	211
% Errors	9.4	10.1	5.9
	English		
Mean RT	755	688	713
SD	219	214	224
% Errors	18.9	9.4	6.4

SIBILANT CLUSTERS

	Fricative + /s/	
	fS~fS	FS~FS
	Greek	
Mean RT	643	682
SD	220	196
% Errors	18.51	4.7
	English	
Mean RT	706	706
SD	222	209
% Errors	17.2	7.7

	/s/ + Fricative	
	Sf~Sf	SF~SF
	Greek	
Mean RT	737	694
SD	185	241
% Errors	14.8	5.7
	English	
Mean RT	770	735
SD	174	239
% Errors	32.5	4.2

	Stop+ /s/	
	tS~tS	TS~TS
	Greek	
Mean RT	608	619
SD	198	179
% Errors	2.7	1
	English	
Mean RT	635	667
SD	199	200
% Errors	2.8	6.1

	/s/ + Stop	
	St~St	ST~ST
	Greek	
Mean RT	687	679
SD	164	236
% Errors	5.7	3
	English	
Mean RT	760	697
SD	203	258
% Errors	9.7	3.6