

Paradigm Uniformity and Analogy:
The *Capitalistic* versus *Militaristic* Debate¹

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Abstract

In American English, /t/ in *capitalistic* is generally flapped while in *militaristic* it is not due to the influence of *capi[r]al* and *mili[t^h]ary*. This is called Paradigm Uniformity or PU (Steriade, 2000). Riehl (2003) presents evidence to refute PU which when reanalyzed supports PU.

PU is thought to work in tandem with a rule of allophonic distribution, the nature of which is debated. An approach is suggested that eliminates the need for the rule versus PU dichotomy; allophonic distribution is carried out by analogy to stored items in the mental lexicon. Therefore, the influence of the pronunciation of *capital* on *capitalistic* is determined in the same way as the pronunciation of /t/ in monomorphemic words such as *Mediterranean* is. A number of analogical computer simulations provide evidence to support this notion.

key words: analogy, flapping, tapping, American English, phoneme /t/, Analogical Modeling of Language, allophonic distribution, Paradigm Uniformity.

I. INTRODUCTION. In traditional approaches to phonology, all surface forms are generated from abstract underlying forms. However, the pre-generative idea that surface forms can influence other surface forms, (e.g. paradigmatic analogy in historical linguistics) has reemerged in a number of formal models (Benua, 1995; Burzio, 1996; Kenstowicz, 1996; McCarthy, 1995; McCarthy & Prince 1994a, b; Steriade, 1997, 1999, 2000). The differences in the American English pronunciation of the medial /t/ in *capitalistic* and *militaristic* (*mili[t^h]aristic* versus *capi[r]alistic*) has received a great deal of attention in this regard beginning with Withgott (1982). Since /t/ appears in the same phonetic environment in both words, it should be given the same pronunciation. The fact that it is generally flapped² in *capitalistic* but aspirated in *militaristic* is thought to be due to the pronunciation of the base words *mili[t^h]ary* and *capi[r]al*.

Steriade (2000) accounts for these words by appealing to the notion of Paradigm Uniformity. For Steriade, there are two competing processes; regular phonological distribution is the default that is occasionally interrupted by the effects of Paradigm Uniformity (henceforth PU). In the present paper, two criticisms of her analysis of *capitalistic* and *militaristic* are discussed. The discussion is couched in terms of an explicit model of linguistic analogy that holds that allophonic distribution is based on analogy to stored memory tokens of past linguistic experience. In contrast to Steriade's notion of regular distribution plus PU, analogy is a unitary process that predicts all instances of phonological distribution, not just the exceptional cases that appear to be due to the influence of other members of a paradigm.

II. PARADIGM UNIFORMITY. According to Paradigm Uniformity (Steriade, 1997, 1999, 2000) if a base has a particular non-contrastive phonetic feature, derivatives of that base will tend to keep that feature. Since *military* contains a medial [t^h] while the /t/ in *capital* is generally flapped, these features carry over into the derivatives *mili*[t^h]*jaristic* and *capi*[r]*alistic* in spite of the fact that /t/ appears in a similar phonetic context in both of the derived words. Steriade (2000) tested the idea of PU by having subjects read a list of ten words, some of which are generally flapped (e.g. *rotary*) and others that are not (e.g. *voluntary*), and then having them read a list of neologisms ending in *-istic* based on the ten words (e.g. *voluntaristic*, *rotaristic*). She found that 11 of the 12 subjects pronounced the derived forms with the same phone (i.e. either [t^h] or [r]) as they did the base forms, which she presents as evidence in favor of PU.

However, Riehl (2003) takes issue with Steriade's neologism study. She replicated Steriade's experiment with the modification that the test subjects repeated each of the four base and four derived forms (*negative/istic*, *positive/istic*, *primitive/istic*, *relative/istic*) twelve times rather than once. According to Riehl, PU would only be supported if all 12 repetitions of a base and its derived form are produced with [r] or if none of the 12 are pronounced with a flap. In her study, some variability was encountered within a single subject's responses (e.g. *primi*[t^h]*ivistic* vs. *primi*[r]*ivistic*) which Riehl takes as a prima facie refutation of PU.

Riehl is correct in pointing out that Steriade does not clarify how

variation in pronunciation would fit into PU. However, Riehl's data may actually support PU if statistical tendencies, rather than an all or nothing interpretation, are considered. To this end, a correlation was performed using Riehl's experimental results; the number of times each speaker used a flap in the base form was correlated with the number of times a flap was used in the derived form. The analysis comprised the data for all four test items and was highly significant ($r(14) = .748, p < .0005$, two-tailed).³ This demonstrates that the more often a speaker flapped the /t/ in the base form, the more often he or she flapped the /t/ in the derived word, and vice-versa. However, the one-to-one correspondence that Riehl seemed to expect was not present. Riehl's findings are easily accounted for in terms of analogy, but an introduction to the particular model of analogy espoused in the present paper is in order before proceeding any further.

III. ANALOGY. In traditional approaches, analogy has been used to patch up the cases that the operation of supposedly regular processes fails to account for. According to the model employed in the present paper (i.e. Analogical Modeling; Skousen, 1989, 1992, 1995, 1998), linguistic processing, including phonological distribution, is the result of analogy. The distribution of the allophones of /t/ is generally thought to be a matter of finding which context each allophone occurs in, storing the generalizations gleaned from the input, and then applying them in subsequent linguistic processing. Formal accounts differ most in terms of what factors and mechanisms they allow in deriving the

correct allophone in the correct context (Davis, 2005; Giegerich, 1992; Harris, 1994; Jensen, 1993; Kahn, 1980; Kiparsky, 1979; Nespors & Vogel, 1986; Rhodes, 1994; Selkirk, 1992). Analogy, on the other hand, assumes that speakers store their linguistic experience in all of its redundant glory, a notion that is supported by a great deal of empirical evidence (Alegre & Gordon, 1999; Baayen, Dijkstra, & Schreuder, 1997; Bod, 1998; Brown & McNeill, 1966; Bybee, 1994, 1995, 1998; Goldinger, 1997; Manelis & Tharp, 1977; Palmeri, Goldinger & Pisoni, 1993; Pawley & Syder, 1983; Pisoni, 1997; Sereno & Jongman, 1997). The idea that behavior is influenced by analogy to past experience has been demonstrated with both linguistic and non-linguistic data (e.g. Bybee & Slobin, 1982; Chandler, 1995, 2002; Hintzman, 1986, 1988; Hintzman & Ludlam, 1980; Stemberger & MacWhinney, 1988).

According to analogy, exactly which stored instances will influence the choice of allophone depends on similarity.⁴ The choice of which phone to use in a word such as *capitalistic* is influenced by analogy from a number of different sources, the largest one being the word *capital* because it has so many orthographic, semantic, and phonetic characteristics in common with *capitalistic*. It is safe to assume that most instances of *capital* in an American English speaker's mental lexicon contain a flap but some also may contain [t^h].⁵ This in and of itself accounts for some of the variability registered by Riehl. Although *capital* is arguably the most prominent analog for *capitalistic*, any stored instance of a word that has characteristics in common with *capitalistic* can exert some influence. The more the two have in common, the greater the chances of

influence. In all likelihood, some of the analogs would point to a [t^h] pronunciation and others to a [r] pronunciation.

If the sum influence from all relevant stored tokens pointed to 90% [r] and 10% [t^h] in *capitalistic* then there are at least two ways of using this stochastic knowledge (Skousen, 1989: 82). The first, called selection by plurality, is to consider the flap the “winner” and apply it in each case. The second, called random selection, is to consider the probabilities and apply them to the task at hand which would essentially result in pronouncing [r] in 90% of the cases and [t^h] in 10%. Using either random selection, selection by plurality, or both strategies, as children in non-linguistic experiments appear to do (Messick & Solley, 1957), would account for the sort of variability that occurs in actual language usage and that is hard to account for in formal approaches that predict one and only one outcome in a particular environment.

The question naturally arises regarding how closely this algorithm or any computer program models the mental mechanisms speakers employ in the course of language production. Analogy is based on the uncontroversial idea that linguistic information is stored in the mind and retrieved as necessary. That groups of similar words can effect the behavior of other words with similar characteristics is well-attested in the psycholinguistic literature (e.g. Bybee & Slobin, 1982; Stemberger & MacWhinney, 1988). There is also ample evidence that human behavior is based on stored exemplars (Eddington, 2000; Hall 2005; Medin & Schaffer, 1978; Murphy, 2002; Nosofsky, 1988; Schweitzer & Möbius, 2004; Solé, 2003). Computer algorithms of analogy are designed to

model these effects. Therefore, what the brain and analogical models have in common is the ability to use a database of past experience to predict behavior. However, too little is known about the exact functioning of the brain to even begin to explain exactly how instances are stored, accessed, or categorized on the neural level. For this reason, it is impossible to conjecture about how faithfully any computer algorithm mirrors actual brain processes beyond the ability of both to analogize.

III.1. A simulation of derived *-istic* words. Rather than speculating about how analogy can account for the relationship between the phonetic shape of a base word and its *-istic* derivative, a concrete simulation was carried out in which the pronunciation of /t/ was predicted in a number of computer simulations.

III.1.1. Test words. Test words included those used by Riehl and Steriade: *capitalistic, negativistic, positivistic, primitivistic, and relativistic*. All of these may be pronounced either with a flap or [t^h] in American English. In addition, six other words with the same phonological structure have been included that are not part of the discussion in the extant literature on the topic: *habitability, irritability, immutability, dissatisfaction, concatenation*. *Concatenation* is interesting because rather than a flap, the base *concatenate* generally has a glottal stop ([k^hɛnk^hæʔnejt]).

III.1.2. The database. In order to carry out a simulation of these ten test words, a database is needed that represents past linguistic experience with /t/. A total of 3,719 instances of /t/ allophones were taken from the TIMIT corpus (Garofolo, Lamel, Fisher, Fiscus, Pallett, & Dahlgren, 1993; Zue & Seneff, 1996). TIMIT was originally designed for use in natural language processing tasks, and consists of 6,300 utterances resulting from having 630 speakers read 10 sentences each. There were 2,342 different sentences, some of which contained no instances of /t/ and others contained multiple instances. Past experience with analogical simulations shows that robust predictions are made on a database of a few thousand instances. For this reason, the TIMIT corpus was “mined” for the first 3,719 instances encountered. The phonetic transcription which was used in the simulations was carried out via acoustic analysis by the TIMIT researchers, however, they did not distinguish between released and aspirated allophones of /t/; instead, they indicated the voice onset time. For the purposes of the present paper, phones with a VOT of 60ms or higher were considered aspirated and those with a VOT of 59ms or lower as released unaspirated stops.

The resulting database used for the simulations contained 564 instances of [r], 234 [ʔ], 284 [∅], 760 [t], 860 [t⁻], and 969 [t^h]. In addition, 48 instances of /t/ were voiced and much longer than a flap and were therefore transcribed as [d] in TIMIT (e.g. *carpenter*, *congratulate*). For each of the 3,719 instances of /t/, the particular allophone was identified. In instance (1) it appears as variable 1. The phonological and morphological context surrounding /t/ were converted

into variables as well: the three phones or boundaries to the right of /t/ (variables 2-4) and the three phones or boundaries to the left of the /t/ (variable 5-7). The boundary values that could occupy one of the variable slots were either a phrase internal word boundary, a phrase internal pause, or a utterance initial or final pause/word boundary. The stress of the syllable preceding and following /t/ was also included (variables 8-9). For example, the flap pronunciation of /t/ in *meet* in the sentence *I know I didn't meet her . . .* yields this entry in the database:

- (1) 1) [ɾ], 2) word boundary, 3) [m], 4) [i], 5) word boundary, 6) [ə̆], 7) pause, 8) primary stress, 9) unstressed

The simulation could have included semantic or orthographic variables as well; however, these variables proved sufficient for the purposes of the study.

III.1.3. Algorithm. The simulations were carried out using the algorithm in Analogical Modeling of Language (AM; Skousen, 1989, 1992, 1995, 1998). AM makes its predictions on the basis of a test item, which is a vector of variables that represents linguistic information about the entity whose behavior is being predicted (see Skousen, 1989, 1992 for a detailed treatment of the algorithm). A variable vector, such as in (1) above, contains information about the context in which /t/ occurs. If the goal is to predict the pronunciation of /t/ in (1), for example, the algorithm would search the database for items that share variables

with (1), excluding of course the first variable which is the one that is being predicted. The algorithm then creates groups of database items with shared similarities called subcontexts. For example, one subcontext would contain all database items with [i] before /t/, another with [mi] preceding /t/, another with [i] preceding and a word boundary following /t/, and so on until all single variables and combinations of variables are considered.

Variable vectors that have more in common with the test item will appear in more subcontexts. Subcontexts are further combined into more comprehensive groups called supracontexts. Some supracontexts will be homogenous in that members will “agree” and exhibit the same allophone of /t/ or the same variable vector. Other supracontexts will have disagreements in that they contain members with different allophones. Such supracontexts are heterogeneous and in some cases their members are eliminated from consideration as analogs (see Skousen, 1989). Minimizing disagreements by eliminating members of heterogeneous supracontexts results in the analogical set, which can be conceived of as containing those database items that belong to the most clear-cut and unambiguous areas of contextual space.

AM uses the members of the analogical set to calculate the probability that the test item will be assigned one of the allophones of /t/ found in the database. Essentially, what AM calculates is that the allophone in the database items that are most similar to the test item will predict the behavior of the test item, although the allophones of /t/ that appear in less similar database items have a small chance of applying as well, provided that they appear in

homogenous supracontexts. Allophony is always calculated in terms of a particular test item and as a result, no global characterization of the data is made as is the case for rules of allophony. This implies that the variables which may be important in determining the allophone of /t/ for one test item may be not be important in determining the allophone in a different one (Skousen, 1995: 223-226).

III.1.4. Method. In a previous study that used this algorithm and database (Eddington, forthcoming) analogy was able to correctly predict the pronunciation of /t/ in many of the database items. In addition, the rate of correct predictions remained high when analogs were drawn from only a small fraction of the database. Predictions also remained robust when supposedly critical variables such as stress were eliminated from consideration. In the present study, the model was used to predict the probability that each of the allophones of /t/ would apply to the test words. Two sets of simulations were performed. Before carrying out the simulations, the base words (e.g. *capital*, *relative*, *immutable*) were deleted from the database along with other derivatives such as *capitalize* and *relatively*. In the flap simulations, one instance of the base word was then added to the database in which the pronunciation was a flap. In the aspiration simulations, the pronunciation was given as [t^h] to each base word. For *concatenation*, one simulation was performed with [k^hənk^hæʔnejt] in the database and another with [k^hənk^hæt^hənejt].

Insert Table one here

III.1.5. Results of the simulations. The predicted probability of each allophone appears in Table 1. It should be clear that the simulations support the notion of PU; the pronunciation of the base word affects the pronunciation of the derived word. However, even when there is only one base form in the database with one outcome, and hence no variability, analogy predicts some slippage toward the other possible pronunciations. For example, when the base form is *negatʃive*, *negatʃivistic* is predicted at a rate of 98%, *negat^hivistic* at 1%, and *negat^hivistic* at 1%. This was the sort of behavior that Riehl's subjects demonstrated. Another important point to mention is that the base word does not account for all of the analogical influence by itself. For example, when *capital* is included with the aspirate pronunciation, *capitalistic* is predicted to be aspirated at a rate of 90%. Inspection of the analogical set reveals that *capital* only accounts for 30% of that total. Eight other database items (e.g. *appetite*, *hepatitis*, and *particular*) account for the other 60% of the aspirated members of the analogical set. The remaining 10% is split between a deleted /t/ in *cent* and a glottal stop in one instance of *not*, and an unreleased pronunciation in the final /t/ of *participate*.

III.2. Simulation with morphologically simple words. According to Steriade (2000), the phonetic context in which /t/ appears in words such as *militaristic* and *capitalistic* favors a flap pronunciation, hence, the aspirate in *milit^haristic*

goes against the general trend due to PU. Davis (2005) argues that Steriade is wrong about the context of the flapping rule. In his analysis, aspirated stops reflect the general pattern. Therefore, *mili[t^h]aristic* follows the regular distribution, and it is the flap in *capi[r]alistic* that is unexpected and must be explained as due to the influence of the base *capi[r]al*. To prove his point, David discusses a number of monomorphemic words that are phonologically similar to *militaristic* and *capitalistic* (e.g. *lollapalooza*, *abracadabra*). Two of these, *Mediterranean* and *Navratilova* contain medial /t/ and are directly relevant to the present discussion. Since these are pronounced with aspirates rather than flaps, the general tendency for words of this sort must be [t^h], and PU cannot play a role in their pronunciation because the words are monomorphemic.

III.2.1. Test words, database, algorithm, and method. *Mediterranean* and *Navratilova* were the test cases and the same database and algorithm described in sections III.1.2 through III.1.3 were used. No morphological relatives of the test words needed to be removed from the database prior to running the simulations, however.

Insert Table 2 here

III.2.2. Results of the simulations. The results appear in Table 2. Both words were predicted to have [t^h] rather than [r]. Does this mean that Davis'

characterization is to be preferred over Steriade's since his default rules predict [t^h]? Davis and Steriade both assume a framework in which generalizations about linguistic data are formulated and used in the course of language processing. Analogy to a paradigmatic relative is thought to override the generalization in certain cases. For Steriade, it overrides what should be a flap in *militaristic*. For Davis, it overrides what should be an aspirated stop in *capitalistic*. In other words, both researchers subscribe to the idea that analogy only plays a role in explaining exceptional cases not covered by the global generalization. In contrast to this view of analogy, the assumption underlying the present simulations is that no global generalizations about allophonic distribution are made, nor are they necessary. Instead, all predictions are made on a case-by-case basis. Analogy does not merely perform the task of accounting for exceptional outcomes due to paradigmatic similarity; it is used to predict all outcomes. Therefore, from an analogical perspective Davis is only correct as far as *Mediterranean* and *Navratilova* are concerned. Whether his characterization is valid for other words with medial /t/, or for words containing medial stops other than /t/ would have to be determined separately.

IV. CONCLUSIONS. Riehl's study was designed to test whether PU could account for the discrepancy in the pronunciation of /t/ in words such as *capitalistic* and *militaristic*. Her test subjects did not behave in accordance with PU in 100% of the cases. However, a statistical analysis of those results reveals that the subjects' responses correlated highly with the predictions of PU,

which actually argues in favor of Steriade's formulation of PU. A simulation of the words in question was performed using a computationally explicit model of analogy. The model predicts the sort of variability demonstrated by Reihl's subjects, and shows that analogical effects along the lines of PU are tenable but not void of variation.

Davis' critique of Steriade's analysis of *capitalistic* and *militaristic* concerns what allophone of /t/ should occur in the absence of PU. This would occur in monomorphemic words such as *Navratilova* and *Mediterranean*. Contra Steriade, he argues that [t^h] is the default rather than [r]. A simulation of the two monomorphemic words favors Davis' analysis; however, analogy works on a case-by-case basis and utilizes no global predictions, therefore, it can only verify Davis' analysis for these particular words. Both Davis and Steriade assume that an analogical process only applies when one surface form is a morphemic relative of another. In the rest of the instances, a more general process is thought to apply. The model of analogy described above, on the other hand, calculates all cases of allophony on the basis of stored memory traces. Accordingly, PU occurs because derived forms and their bases share many traits. Because analogy works on the basis of similarity, a base usually appears in the analogical set that is extracted from the mental lexicon when predicting the pronunciation of one of its derived forms. As a result, the base's pronunciation influences the pronunciation of the derived form.

There is a major advantage to the idea that allophonic distribution is carried out by analogy. Psychological evidence demonstrates that analogy plays

an important role in human cognition. In contrast, much of the machinery required in rule analyses has been called into question on formal grounds (Burzio, 1996; Cole, 1995; Cole & Hualde, 1998; Steriade, 1995). More importantly, the psychological reality of rules and constraints is highly questionable on empirical grounds as well (Derwing, 1973; Eddington, 1996; Lamb, 2000).

How could children subconsciously and effortlessly intuit the kinds of generalizations about allophony (which are often complex and abstract) that many intelligent graduate students of phonology have a difficult time formulating? If linguistic processing is analogical no such generalizations need to be made. If people formulate such generalizations, why are they not able to express them overtly? According to those who consider them psychologically real, it is because they learned and manipulated subconsciously. From an analogical viewpoint, speakers cannot describe the rule they use to determine that *plooty* would contain a flap because no rule exists. If pressed for an answer speakers will rarely give a rule-type response, but more often will state that *plooty* “sounds right” with a flap, or that it is similar to words such as *duty* and *booty*. Clearly, the search for psychologically plausible models of phonological processing must incorporate analogy.

Notes

1. I express my thanks to Royal Skousen, José Antonio Mompeán, Dirk Elzinga, Andy Wedel, and Steve Chandler for their input on this paper.
2. According to very precise phonetic descriptions taps and flaps involve different articulations (Ladefoged 2006: 170-171). In the present paper, the term flap is used to describe a non-retroflex, non-r-colored rapid stop gesture. This should cause no confusion since taps and flaps are not distinguished.
3. In some instances there is no data for a particular response. For example, one subject pronounced *positive* with a flap ten times and without a flap only once, and one response is missing. For the purposes of the correlation, 10.5 flap responses to *positive* were counted because the missing response would most likely have been another flap and that puts the figure halfway between the actual and probable number if all 12 responses had been given.
4. Exactly which characteristics are used to determine similarity is a question that needs to be explored in more depth. In this vein of research Eddington (2002) compared similarity based on phonemes versus similarity based on phonetic features and found no significant difference.
5. The fact that the word is written with a *t* surely plays a part as well beyond that of analogy.

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Test Word	Simulation Type	t ^h	r	t	∅	ʔ	t [̄]	d
capitalistic	Flapping Simulation	12	78	0	3	3	4	0
	Aspiration Simulation	90	0	0	3	3	4	0
negativistic	Flapping Simulation	1	98	0	0	0	1	0
	Aspiration Simulation	93	6	0	0	0	1	0
positivistic	Flapping Simulation	0	99	0	0	1	0	0
	Aspiration Simulation	96	3	0	0	1	0	0
primitivistic	Flapping Simulation	0	96	1	1	0	1	0
	Aspiration Simulation	94	2	1	1	0	1	0
relativistic	Flapping Simulation	10	90	0	0	0	0	0
	Aspiration Simulation	86	14	0	0	0	0	0
habitability	Flapping Simulation	8	80	0	0	0	14	0
	Aspiration Simulation	80	0	0	0	0	20	0
irritability	Flapping Simulation	3	95	0	0	0	2	0
	Aspiration Simulation	96	3	0	0	0	1	0
immutability	Flapping Simulation	4	93	0	1	0	3	0
	Aspiration Simulation	83	12	0	1	0	4	0
dissatisfaction	Flapping Simulation	0	100	0	0	0	0	0
	Aspiration Simulation	100	0	0	0	0	0	0
concatenation	Glottal Stop Simulation	0	0	0	0	100	0	0
	Aspiration Simulation	100	0	0	0	0	0	0

Table 1. Predicted Probability of Each Allophone for Simulations with [r], [t^h], or [ʔ] in the Base Form.

Test Word	t^h	r	t	∅	?	t[̄]	d
Mediterranean	68	21	5	1	0	4	1
Navratilova	47	27	19	2	1	4	0

Table 2. Predicted Probability of Each Allophone for Monomophemic Words.

Paradigm Uniformity and Analogy

Table 1. Predicted Probability of Each Allophone for Simulations with [r], [t^h], or [ʔ] in the Base Form.

Table 2. Predicted Probability of Each Allophone for Monomorphemic Words.