FAUXPACITY: AN ANALOGICAL REFRAMING OF SYNCHRONIC PHONOLOGICAL OPACITY AND PSYCHOLINGUISTIC EVIDENCE IN FAVOUR

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Declarations

I declare that this thesis, including footnotes, quotations and the data in the original language, does not surpass 30.000 words.

This thesis is the result of my own work and includes nothing which is the outcome of work done in collaboration except where specially indicated in the text.

Acknowledgements

Writing the acknowedgement section of this thesis is probably the closest I'll ever get to making an Oscar speech, so please imagine the following read in front of a cheering crowd by a very emotional individual.

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Lights out as I exit the stage.

Abstract

This thesis aims to examine the concept of phonological opacity and reconceptualise it. A large part of the discourse on the subject is focused on theory-specific issues and how to best model opaque data within a particular framework, with little to no literature on metatheoretical questions surrounding the phenomenon. Phonological opacity has posed one of the biggest challenges for modern phonological theories such as Optimality Theory. Its modeling, however, is straightforward in rule-based frameworks. This thesis aims to provide a somewhat less theory-bound analysis of the concept (and related ideas) and examine what features seem to be required for successful modeling of opaque data. It will be proposed that an acknowledgement of the diachronic dimension is key to make sense of the phenomenon. Moreover it will be suggested that thinking of opacity as a subset of exceptionality, as is done in historical linguistics, is a fruitful line of inquiry, one that was largely foreclosed by the radical separation of synchrony and diachrony in the Post-Bloomfieldian tradition. Case studies will be presented that provide an empirical basis for the evaluation of these assertions. This leads into a discussion of the kind of evidence that might be regarded as equally valid across framework, followed by a pilot study that illustrates the type of external evidence that could be brought to bear on theoretical debates.

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Introduction

Phonological opacity is a concept that was first formulated by Kiparsky (1971). In its early conception (Kiparsky, 1971; 1973), and therefore in a rule-based framework, opacity is defined as:

> A phonological rule P, A -> B / C_D is opaque if the surface structure presents one of the following:
> 1) A in environment C_D
> 2a) B generated by process P in an environment other than C_D
> 2b) B generated by process other than P in environment other than C_D

An oft-cited example of phonological opacity is Canadian Raising (CR - Chambers, 1973). CR consists of raising of /aʊ, aɪ/diphthongs to [ʌʊ, ʌɪ] when they immediately precede a voiceless obstruent, producing outputs such as [prʌɪs] "price", [nʌɪf] "knife" and the famous [əbʌʊt] "about", contrasting with words where the diphthong precedes a voiced obstruent, therefore staying unraised: [praɪz] "prize", [naɪvz] "knives", and [laʊd] "loud".

In Rule Based Phonology (RBP), in which generalisations are formulated as rules and are serially ordered, opacity is thought of as an interaction of rules, rather than as a property of a single rule. Single rules are conceived of as applying blindly when their turn comes in the serial derivation, and it is their interplay that produces opacity. CR is in an opaque configuration with flapping (a rule which neutralises the voicing of alveolar stops, reducing them to a tap) when the input of a derivation

is the relevant diphthong followed by an alveolar stop as illustrated below:

Canadian Raising		
UR	/raider/ *rider*	/raiter/ *writer*
CR	-	rʌɪter
Flapping	raɪɾer	rʌɪɾer
SR	raɪɾer	rʌɪɾer

CR is opaque: surface forms to which it applies illustrate Kiparsky's criterion 2a - raising appears to occur outside its expected environment, as in *writer*, where it precedes a segment voiced on the surface.

Theoretical Approaches - Strengths and Limitations

The modelling of opacity is straightforward in RBP because of its multistratal architecture, determined by the serial derivation: an intermediate level is necessary in accounting for most kinds of opacity. Since RBP is no longer the dominant phonological framework, the solutions developed within RBP are not available and the issue of opacity has cropped up again as arguably one of the greatest descriptive challenges for Optimality Theory. Instantiations of OT have a broad commitment to monostratality and parallel, simultaneous derivations, properties which in many cases have hindered the theory's ability to model opaque data (for a more in-depth discussion of this, see Vaux, 2008; for an overview of what exactly the challenges are for different types of OT see Idsardi 1997, 1998; Odden, 2008; Kager, 1999; Kiparsky, 2000; McCarthy, 1997, 2002, 2003a, 2003b, 2005; Bermudez-Otero, 2003; Ito and Mester, 1997, 2003; amongst others).

The serial definition of opacity given above is not applicable to OT, which has

instead worked with the closely related but not entirely overlapping concepts of surface-truth and surface-appearance (McCarthy, 1999). Generalisations are not surface-true when "some generalisation G appears to play an active role in some language L, but there are surface forms of L (apart from lexical exceptions) that violate G". They are not surface-apparent when "some generalisation G shapes the surface form F, but the conditions that make G applicable are not visible in F". The two concepts roughly correspond to Kiparsky's conditions 1 and 2 (both a and b) respectively, with the focus of the definitions having become surface-oriented and no longer involving levels.

When compared with RBP, Classical OT (Prince & Smolensky, 1993) with its single-level architecture can't directly model the majority of opaque interactions. Many extensions have been proposed, all of which have in practice resulted in introducing levels of derivation into OT, or mimicking the effect of levels. The level-based extensions include Stratal OT (introducing levels within which constraints are independently ranked) and Serial OT (in which constraints can make reference to a position specified at a previous step during the derivation), while the effects of levels are expressed less overtly by Sympathy Theory (the choice of the optimal candidate is influenced by the phonology of one of the failed candidates, selected by a special constraint), Local Constraint Conjunction (a complex constraint created by combining two simple constraints through a limited series of operations exists alongside the two simple constraints individually) and OT with Candidate Chains (a candidate is a series of forms, each form in the chain effectively representing a derivational step), amongst others such as Turbidity (Goldrick, 2001) and PC theory (Lubowicz, 2003).

These revisions all change the basic architecture of OT in fundamental ways that

subvert its original appeal: one type of change involves the a priori apparently unmotivated linking of constraints (the potentially unprincipled conjunction in LCC-OT, where the linking constraint is ranked freely without reference to the independent member constraints), others change the nature of the generation function GEN and forsake ROTB (Richness of the Base is part of an effort to make the theory as universal as possible, by making it so that all inputs are available in all languages, and it is seen as the role of the phonology to filter out infelicitous forms (Smolensky, 1996) - ROTB is also in line with psycholinguistic findings that motivated cohort models and competition between forms), while others require EVAL not to operate in a blind fashion (blind operation of the phonological component is attractive as a phonological computation that does not operate blindly often involves problems of the "look-back" type, and may be unfalsifiable). These radical changes are often not motivated empirically by anything other than the goal of modeling opaque phenomena. Moreover, none of these strategies have so far been able to model all attested cases of opacity.

Before going forward it should be noted that RBP's approach has arguably not been entirely free from criticism when it comes to modeling opacity, contrary to what is often assumed:

> "[T]he [rule-based serialism] treatment of opacity is significantly more elegant than its OT counterparts: it *predicts exactly the attested types of opacity effects and deals with them straightforwardly and in a unified way [...]*. Since opacity is one of the most fundamental phenomena in human language, we must prefer a theory that accounts for it straightforwardly ([rule-based serialism]) over one that seems unable

to deal with it (OT)." (Vaux, 2008; emphasis added)

Critics of RBP might argue that, while it can model attested types of opacity, it can also model a large number of unattested phenomena, because of the sheer power of a rule-based framework, and therefore even if the modeling is successful, it's not necessarily particularly insightful; and that giving a unified account of opaque phenomena is undesirable, given how different the phenomena under the opacity umbrella can be in terms of cause, purpose and shape. Let us illustrate examples of the above criticisms.

There are a number of cases that can be insightfully analysed by invoking comparisons between outputs and parallel derivations, generally available in OT but not in RBP. One such case is crossderivational feeding (Bakovic, 2005, 2006, 2007, 2010). Consider for example the alternation in the shape of the English past tense desinence. It involves two rules: Epenthesis (defined in the standard analysis as inserting a vowel between two consonants which differ at most in voicing) and Assimilation (which involves assimilating the second consonant in an adjacent pair to the first one's voicing). Below is the standard bleeding analysis:

	a. /paet+d/	b. /paed+d/	c. /paek+d/
Epenthesis:			
ø →ə / C_1_C_2	ə	ə	
Assimilation:			
$[-son]$ → [αvoi] / [αvoi] _#			t
	/paet+əd/	/paed+əd/	/paek+t/
	Glosses: "patted"	"padded"	"packed"

While the above does give the correct description of the phenomenon, it is requiring Epenthesis to arbitrarily ignore the difference in voicing between the two

consonants, precisely the difference which would be neutralized by Assimilation if it were to apply to the inputs. A different analysis which avoids this arbitrariness involves imposing a strict identity requirement on Epenthesis (thereby waiving the unmotivated discounting of voicing features in establishing identity) relying on assimilation to indicate the correct context of application. Assimilation doesn't actually apply - it only potentially does - but this seems to be enough to "feed" the application of epenthesis with strict identity. Epenthesis only applies if its structural description is met by the potential output of Assimilation. An intuitive way to model this is through parallel derivations which interact:

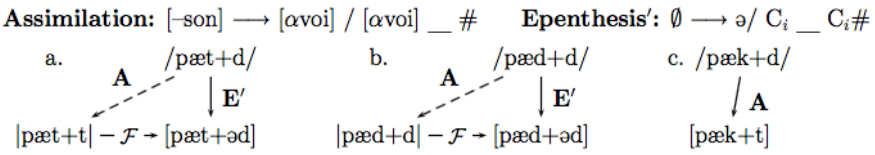

Figure 1: Crossderivational Feeding (Baković, 2009)

As epenthesis here overapplies if motivated by the potential application of Assimilation, this is in fact technically a case of opacity under this analysis. Further benefits of the analysis involve linking this particular fact about the grammar of English with the more general fact that the language doesn't allow two identical stops next to each other[1] (but tolerates a consonant cluster with members differing only in voicing), adding motivation to the model, unifying a set of phenomena. Interestingly, it has been argued (Fruehwald Gorman, 2011) that crossderiva-

[1]This is the wording of Baković. To my knowledge English does allow adjacent stops across morpheme boundaries (as would potentially be the case here) in words such as un-natural. Perhaps the statement should be restricted to oral stops, but words like boo[k:]eeper, ste[p:]arent, pos[t:]reatment (in many pronunciations) would falsify this statement too. It's harder to find a similar environment with inflectional morphemes, but this is not synonymous with the illegality of homorganic stop clusters straddling morpheme boundaries. As this fact about English is one of the main motivators behind the analysis, Baković's argument might not hold up. More broadly, lack of a theleological component is often held against RBP.

tional feeding is in fact an epiphenomenon of the history of the language and other extragrammatical factors, and therefore not to be accounted for in a synchronic grammar. This is exactly what will be suggested as the optimal treatment of all kinds of opacity and exceptionality in this thesis.

A further proposed empirical issue with RBP's modeling of opacity is evidenced by mutual bleeding phenomena. Take the case of the interaction of /l/ and /n/ in Korean (Um, 2002): in general, the coronal /n/ assimilates to /l/ when it is followed or preceded by it.

When /n/ is followed by /l/:		
a. /sən.lo/	[səllo]	"railway" (cf. to:.lo [to:ro] "road")
b./wən.lon/	[wəllon]	"principle" (cf. sə.lon [səron] 'introduction'
c. /tʃiː.ljək/	[tʃiːlljək]	"endeavor" (cf. no.ljək [norjək] 'effort')
When /n/ is preceded by /l/:		
a. /mal.njən/	[malljən]	"old age" (cf. soː.njən [soːnjən] 'boy')
b. /pul.nɨn/	[pullɨn]	"incapability" (cf. juː.nɨn [juːnɨn] 'ability')
c. sil.nae	[sillae]	'indoor' (cf. sa.nae [sanae] 'within the company')

However in some cases /l/ assimilates to /n/ when adjacent to it:

When /n/ is followed by /l/:

a. /k^{h}ɨn/ /latio/	[kɨnnadio]	"big radio" (cf. /sae/ /latio/ [saeradio] "new radio"; /latio/ [radio])
b./sin/ /lamjən/	[sinnamjən]	"an instant noodle" (cf. /tʃ^{h}a/ /lamjən/ [tʃ^{h}a ramjen] "tea noodle"; /lamjən/ [ramjən])
c. /tehelan/ /-lo/	[teheranno]	"Teheran street, a street in Seoul" (cf. /ɨl.tʃi/ /-lo/ [ɨldʒiro] "a street in Seoul")
d. /ɨm.un/ /-lon/	[ɨmmunnon]	"phonology" (cf. /tʃa.ju/ /-lon/ [tʃajuron] "J.S. Mill's *On Liberty*")
e./tʃ^{h}u.tʃin/ /-ljək/	[tʃ^{h}udʒinnjek]	(cf. /ɨj.tʃi/ /-ljək/ [ɨjdʒirjək] "will power")
e. /mjən/ /-lju/	[mjənnju]	"kind of noodles"

When /n/ is preceded by /l/:

a. /səːl/ /nal/	[səːllal]	"New Year's Day"
b. /tal/ /nala/	[tallara]	"moon (as a country)"
c. /sul/ /nolae/	[sullorae]	"wine song"
d. /pul/ /napi/	[pullabi]	"fire moth"
e. /kwail/ /noŋ.sa/	[kwailloŋsa]	"fruit farming" (cf. /pu.noŋ/ [punoŋ] 'rich farmer')

It is intuitively possible to characterize the environments guiding the direction of the assimilation: the difference depends on the prosodic word boundaries at which the sequence is found. However from a rule based perspective, this must be characterized by at least four distinct rules (l-assimilation and n-assimilation,

in a direction which is determined by the position of a prosodic boundary on a continuum), which are intrinsically ordered differently in different environments[2]. It is therefore worth keeping in mind that RBP and its serialist architecture face at least some minor criticisms, suggesting that serialism might not be all there is to the phenomenon, and it merits further investigation.

On the other hand, RBP is not the only theory able to model opacity: for example, an analogical, word-based framework (which develops a diametrically different intuition than RBP) can also model the data equally well by very different means. Within this approach, opaque generalisations have a status equivalent to any other kind of generalisation, and levels are not necessary in the model. It appears then that levels per se are not necessary for an account of opaque generalisations, but rather their function is. In a word-based theory, the lexicon is the locus of opacity: it is as if the end product of RBP-style derivations (which therefore can fulfill the same functions as the derivation itself - from an RBP perspective, words are effectively flattened derivations) was taken as the basic unit of the theory.

The two frameworks carry out the same function by different means: the importance of the mechanism is secondary to that of the function it performs. Comparing the assumptions and mechanisms of these two frameworks to those of OT, OT occupies a middle ground in many respects. It could be argued that this position along the various continua should allow it to combine the best aspects of the more extreme frameworks. If this were true, OT would be expected to perform better, or at least just as well, as its competitors on opaque data - however, OT notoriously

[2]A potential soultion would be establishing two simultaneously applying rules, with each specifying the environments in which /l/ assimilates to /n/ and viceversa. RBP doesn't normally allow rules to apply simultaneously or to be unordered with respect to each other if the rules in question interact - simultaneous application would provide a technical solution which however goes against principles of RBP and subverts part of its appeal.

struggles with opacity. What is the function performed by RBP and word-based analogy which is so elusive to OT? Comparing OT to RBP, the issue appears its lack of levels, as it is RBP's use of intermediate representations that allow it to model opacity. The reverse appears true when comparing OT to word-based analogy: OT relies excessively on processes as opposed to a more realisational approach[3]. Relying on metatheoretical comparisons, this thesis wishes to identify the functions that are crucial to accounting for opacity, abstracting away from their mechanisms.

Abstracting away from theoretical implementation

It is important to note from the beginning that opacity is not a pseudoproblem resulting from its original formulation in derivational terms. It is descriptively accurate to say that languages undoubtedly present generalisations that are often eschewed by a number of items with different degrees of systematicity. Whether the most appropriate way to model these involves derivations or other mechanisms is a separate issue. The discussion on opacity has focused on the phenomenon in relation to various theories ever since its original formulation, with little to no literature existing on the phenomenon itself. As the aim of this thesis is in part to examine the phenomenon of opacity on its own merit, a theory-neutral definition of opacity (or at least as close as possible to neutral) should be formulated as a starting point.

[3]Note how formulations of OT that go a little further towards the extremes (such as Stratal/Serial OT on one side and O-O correspondence OT on the other) perform better than their Classical counterpart.

> A generalisation is opaque if it dissociates an alternation from the environment(s) in which the alternation characteristically occurs.

From now on, the term "opacity" will only be used to refer to the phenomenon within a derivational framework - the theory-neutral concept will be referred to as AED (Alternation-Environment Dissociation). The definition above effectively puts opacity back into the context of exceptionality - opaque generalisations in the sense of Kiparsky can be interpreted as special cases of exceptionality, ones that operate above a certain threshold of systematicity. The CR case described above can de easily characterised in these terms: a generalisation, CR - /aɪ, aʊ/ raise before a voiceless obstruent - must be independently postulated as it is pervasive in the language, and so must flapping. There are however forms which present raising in an environment different from one defined by a voiceless obstruent - these forms feature a dissociation between the environment (preceding a voiced obstruent) and the alternation (the raising itself), as one is present when the other one is not. The existence of patterns of this kind is not in question - what is to be debated is what type of framework provides the best tools to model it.

Two types of AED are attested:

> Overincidence - forms in which the pattern is not expected, but present;
>
> Underincidence - forms in which the pattern is expected but not present.

The two types of AED defined above exhibit overlap (not complete, but partial) with the categories of counterfeeding and counterbleeding opacity (Kiparsky's con-

ditions 1 and 2 respectively). As the focus of the definition of AED is more surface-oriented compared to that of opacity, the imperfect overlap is inevitable.

It may be however auspicable to carve the phenomenon up even further. RBP proponents often present it as an advantage of their theory that the two opaque orderings that they define (as well as the two transparent orderings) can be modeled by the same mechanism - the interaction of serially ordered rules. It is however not universally agreed that this is advantageous, as the two AED subtypes (and their further subdivisions) seem to have a variety of causes and mechanisms of diffusion (discussed at length in Bakovic, 2007, 2011). For example, it is not clear that a derived environment effect (a generalisation restricted to desinence[4] junctures) and a phenomenon like cross-derivational feeding of the type above should be treated identically, as while they both can technically be modeled by a serial derivation they have very different characteristics. Derived Environment Effects only apply to specific morphological environments, often have little phonetic motivation, and they appear to serve the function of reducing uncertainty (see section 2.1.2), while crossderivational feeding is taken to exist as part of a conspiracy to avoid geminates. The same rationale could be applied to the difference between AED which neutralizes a contrast, compared to AED which maintains contrast at word level: the question of whether these at times very different phenomena should have a unified representation is yet to be answered. Despite arguments relying on simplicity and Occam's razor against the need for multiple mechanisms to account for AED when rule interaction can successfully model it as a unified phenomenon (Vaux, 2008), this is not necessarily advantageous or accurate - especially for theories with a commitment to teleology or functionalism, or an interest in giving a

[4]Because of the theoretical implications of the term "morpheme/affix" I will use "desinence" to refer to a subset of a word string.

diachronic explanation to the synchronic facts. Questions concerning whether a unified representation for the various patterns is necessary or desirable, whether these patterns are diachronically different but synchronically similar enough to warrant a unified representations and related issues are still open, and have so far only been explored theoretically, but not cognitively.

Taking AED as the primary object of inquiry, let us discuss the scope and purpose of this thesis. Much of the recent literature on opacity has focused on lower-level problems - there is considerable discussion about what modifications need to be made to the architecture of OT to allow it to accommodate the data (Smolensky, 1993, 1995; Green, 1993; McCarthy, 1995, 1999, 2006a, 2006b; McCarthy Prince, 1995; Kiparsky, 2008), and surveys of attested patterns (Bakovic, 2007, 2011; Idsardi, 2000). Research of this kind has improved our understanding of the range of opaque phenomena and consolidated the perception of patterns of this kind as recalcitrant to a variety of extensions of OT, but hasn't been as successful as hoped in providing a solution to the problem of modeling opacity without compromising core principles of OT. It might be said that recent research on the matter has paid excessive attention to the trees, losing awareness of the forest.

The present thesis aims to provide an overview of this forest by taking a step back from details concerning theory implementation and considering higher-level factors that seem to contribute to an ability to model AED phenomena.

Outline

The first section will investigate which metatheoretical factors have proven advantageous in modeling opacity, the role that each of these factors serves in the

modeling (and consequently how can the function fulfilled by each of these factors be replicated, if at all, in different theories), and what are the assumptions made by each model that may be hindering it from successful modeling. It will be argued that the key is the differing capacities of the models to telescope the language's history in their mechanisms: AED patterns often originate when a generalisation active at one point in the history of the language disrupts the effects of an earlier applying generalisation. This temporal dimension is implicitly present in RBP's serialist derivation: rules that apply earlier are generally those which have their origins earlier in the history of the language. The older a generalisation is, the more exceptions it is likely to have - as more changes will have had a chance to occur between the inception of the rule's application and the present day - and the more likely it is to have been morphologised, or affected by non-phonological factors - as more generations will have had to acquire the language, therefore increasing the chance for a reanalysis of its environment or target, and creating more opportunities for processes to disrupt the original environment. RBP's architecture allows the indirect incorporation of time depth as an implicit factor thanks to its serialism. Classical OT's monostratal architecture cannot incorporate the chronology of the language in the same way, which severely restricts its ability to model AED effects. The implementations of OT that are most successful in modeling AED effects all try to mimic the presence of an intermediate form[5], and therefore of the chronology of the language. However, the parallelism of constraint application (and the synchronic orientation of the framework) is largely maintained, which is likely why no single implementation of OT has yet been able to achieve complete coverage of AED effects.

[5]A potential exception is Output-Output Correspondence OT, which is more similar to an analogical account in that it establishes a correspondence relationship (in the form of faithfulness constraints) between two morphologically related outputs.

Representing diachrony is key to AED modeling, but it doesn't have to take the shape of serialism. Placing the burden of the work of history elsewhere in the language faculty is not only feasible but also potentially advantageous: a serial derivation is effectively collapsing the diachronic dimension with the synchronic, implying that when a word's surface representation is derived, the word relives its history. The optimal representation of the chronological dimension is one where its effects are acknowledged, but so is its non-synchronic status - the adequacy of this solution is, of course, contingent on equivalent empirical coverage. The lexicon, for example, would then be an ideal locus for the placement of chronology, as it fulfills both conditions above: the effects of history are fossilized in the words themselves, removing the need to derive these synchronically but still allowing their reflexes to be present and accessible.

Once the temporal depth dimension is encoded in this way, the issue of the shape of the synchronic grammar crops up again. As the main purpose of levels is that of telescoping history, if this function is expleted elsewhere the reduction of levels may be seen as desirable, given equal empirical coverage. In a word-based lexicon, the function of the synchronic stratum would be that of supporting interactions and relations between existing words and the formation of new ones, which wouldn't a priori necessitate more than one stratum, and could operate similarly to OT.

Section 3 discusses interim conclusions: a number of approaches can model AED data in an internally satisfactory way, as long as they present the desiderata discussed in Section 1. As traditions behind the various approaches have claimed cognitive relevance, the question is not how is AED best modeled (as the answer is contingent on beliefs about evidence and theoretical commitments), but which model resembles most closely the cognitive reality of AED phenomena.

Section 4 outlines existing evidence bearing on the cognitive status of AED. There is surprisingly little work of this kind, and most of it centers around language acquisition. However, any acquisition evidence will have to be looked at through the lens of our beliefs about the competence-performance divide, beliefs which are particularly relevant when looking at acquisition data: as different frameworks have substantially different views of this divide, this type of data cannot, at present, be meaningfully employed to elucidate the processing of AED.

An experimental design on adult subjects offers the best chance for evidence that would be less dependent on theoretical beliefs, as this source allows for control over the most factors. Section 5 identifies word comprehension as an area where the analogical model makes different predictions to RBP and OT - as the analogical model is word-based, it predicts no significant difference between the processing of an opaque and a transparent word once other factors have been taken into account. Conversely, RBP and OT predict that a transparent word should be impose a lower processing load than an otherwise equivalent opaque word, as processing of opaque words involves considering multiple possible derivations that must be explored to ascertain the UR. The experimental setup, the data, the results and their discussion are then outlined. An auditory lexical decision task is performed, the results of which point to no significant difference in the processing costs of opaque and transparent words, be these real words or non-words, confirming the expectations of the analogical model.

More research on the topic, especially of the experimental type, is still needed. Section 6 will address potential areas of investigation that stem from this thesis, and discuss the implications of the findings for linguistic theory.

1 The Theory

The following section aims to explore and compare the properties of previous approaches to AED phenomena and how these have contributed to the success or perceived failings of the framework in modeling this kind of data. The goal of this exercise is to identify the set of properties that are necessary to account for AED.

1.1 Telescoping History

The history of a generalisation often sheds light on its synchronic distribution. AED patterns do not tend to originate spontaneously[6] but rather develop over the course of generations. IIt is often the case that an originally regular pattern may have its regularity removed by a second generalisation that started applying later in the history of the language, or that the generalisation's scope might restrict or widen with time under the influence of factors different from those of its original state.

An example of disrupted surface regularity is British English /e/ lowering before /r/ in codas, which entered the language in the 1500s (Hickey, 2007). This pattern underwent AED with the advent of /r/-deletion, a change which was completed by the 1700s, and destroyed the environment of e-lowering, which appears unexpectedly present in words which used to have /r/. Consider as an example words such as *heart, sergeant, Berkshire/Hertfordshire*, which preserve the <er> cluster

[6]There have been arguments proposing that there are spontaneous opacity effects in language acquisition, but that is not necessarily the same phenomenon. For further discussion on this see Section 3.

in the spelling as a testament to their origin. An example of the change in scope is German Umlaut (detailed in Section 2), originally a phonological vowel harmony process, which restricted its application to certain morphological environments. In both cases, the time depth dimension is crucial in understanding the synchronic distribution of the pattern: linguistic event A occurs, then later in the chronology a linguistic event B occurs, causing AED in at least some of the words featuring linguistic event A.

1.1.1 Representing time within a model

It is the ability to include chronology within a model that has made RBP so successful in modeling AED. An RBP architecture can neatly model the role of chronological developments, re-encoding them in a model of synchronic competence: event A (modeled by rule A) applies earlier in the serial derivation than a chronologically posterior event B (modeled by rule B). This is why levels appear to be crucial: they can act as a surrogate for the chronology of language change.

Classical OT fares poorly on most AED phenomena as, while having the same goal as RBP - modeling synchronic competence - its monostratal architecture is less well adapted to mimicking the workings of history, as these happen sequentially along the dimension of time. The reason why Stratal OT and Serial OT provide such an improvement in the modeling of opacity is that they introduce the possibility of mirroring chronological stages. Current versions of the models above have a comparatively small number of levels/strata (stages), next to the almost infinite number in RBP. Imposing a general bound on the number of stages has sometimes got in the way of a successful analysis of linguistic data, as more levels than were available seemed to be required, as described earlier in the discussion of OT's

approach to opacity[7]. RBP's edge in this respect seems once again to be due to its similarity to the way linguistic change works: the language is in constant flux, so its trajectory is better modeled the more stages are defined. It seems therefore that a successful model needs to be able to express the effects of history on the origin and development of AED patterns, without collapsing chronological stages or imposing arbitrary numerical bounds on the number of interacting sound changes that can occur.

1.1.2 The Idealisation of Chronology and its Perils

There are other arguments for acknowledging the effects of history in the most direct way possible rather than attempting to telescope it: even models such as RBP that are able to incorporate an implicit diachronic dimension in their model necessarily do so in an idealised way, which may yield unsatisfactory results when the attested facts are more complex than the particular idealization.

There is an often direct relation between the point when a generalisation emerges in the history of the language, its productivity and the locus of its conditioning factors in the grammar (whether low-level e.g. phonetic or high level e.g. morphological). Generally speaking, the older a generalisation is, the less productive it tends to be, and the more it will tend to be conditioned by higher-order factors such as morphology, at least in part. This has often been discussed as the life cycle of generalisations (Osthoff & Brugmann, 1878; Bermudez-Otero Trousdale (2012); Bermudez-Otero (2015) for a discussion in more modern terms), and the idealised

[7]Specifically in the modelling of phenomena like the Duke of York Gambit (Pullum, 1976), which requires at least 3 levels. Many OT implementations involving strata have tried to cap their number at 2 as any more is perceived as an undesired incipient return to RBP (Bermudez-Otero, forthcoming).

pathway has been moulded into RPBP's architecture.

Generalizations start as phonetically motivated patterns which by their very nature have maximal productivity (Osthoff & Brugmann, ibid.; Ohala, 1993), they then undergo phonologisation (Hyman, 1976), which occurs when a phonetic epiphenomenon is reinterpreted and systematized in a way which is crucially under cognitive control - it turns from a gradient process into a discrete one. At this stage the generalisation is likely to still have very high productivity, but may begin to restrict the phonological environments in which it applies compared to its phonetic equivalent.

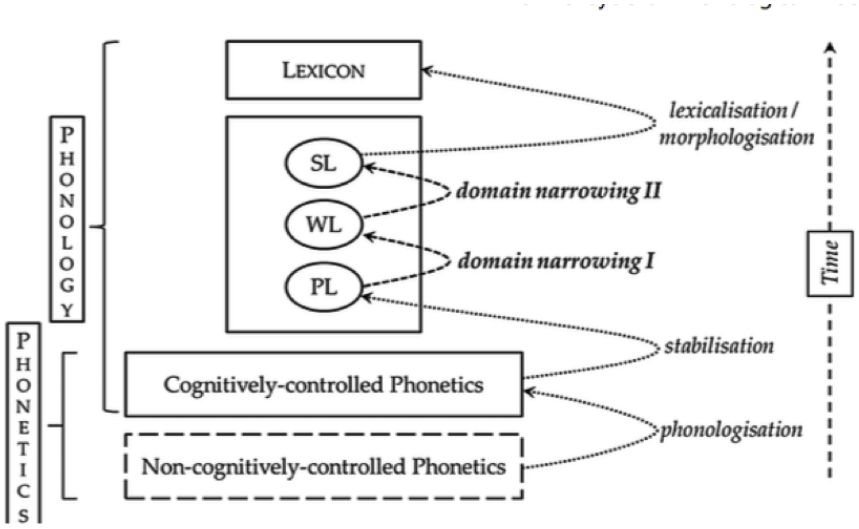

Figure 2: PL: phrase level; WL: word level; SL: stem level (Ramsammy, 2015)

With time, the generalisation will restrict its environment and incorporate conditioning factors which are not strictly phonological, such as sensitivity to word or desinence boundaries, which will automatically reduce its productivity across all possible environments (although the rule is likely to still have quite high, although not necessarily exceptionless, productivity in the narrowed environment). Later, a generalisation will tend to become heavily reliant on morphological or syntactic

factors, and even become lexicalized, at which point its status as a productive process is open to question.

These are highly idealised conceptions of the lifespan of a generalisation - while many cases can be described in these terms, many others deviate from the model in various ways. The idealised direct relationship present between productivity, area of the grammar and age of a generalisation is entrenched in serialist models: morphological and morphophonological rules apply earlier in the derivation (correlating with their earlier historical origin) but also have many more exceptions[8]. This conception of the factors correlating with an earlier position in the derivation, while expressing a valuable and in many cases accurate intuition, can hinder the model when generalisations don't quite behave as expected.

Consider for example instances when a generalisation is revitalized, such as Osthoff's law (OstL) in Latin. OstL describes the shortening of long vowels preceding a resonant followed by another consonant (V:RC sequences). Weiss (2009) notes that the law seems to apply at three distinct points in the history of the language. Round A applies earlier, as it feeds the weakening of *a to /e/ in medial unstressed syllables such as in *parentēs 'parents'* and *calendae 'calends'*. Round B is fed by archaic parsing syncope and alignment syncope, and itself feed raising of *e, *o to /i/ /u/ before velar nasal, such as in *nuncupāre* and *sinciput*. Round C applies relatively late, after monophthongisation, such as in *undecim*. Because of the different relations of each round to other generalisations in the language, a serialist account would have to posit this as three separate rules applying at different points in the derivation so that the correct output can be achieved. The

[8]See for example the use of readjustment rules in Distributed Morphology (Embick Halle 2005) or earlier morpheme structure constraints (Stanley 1967)

separate rule approach misses the generalisation that it is actually the same rule at work. An account that was able to connect the different rounds would provide a more insightful analysis: an analogical account would be able to capture this fact and explain the three rounds of application as spikes in the activity of the generalisation (for a detailed analysis see Sayeed, 2017). A very similar situation is that of o-raising in Polish (detailed in Section 2) - a very old process which has effectively reached the stage of lexicalization while remaining highly active.

Data like OsthL in Latin cannot be well modeled by serial derivation alone. The mechanism usually employed by derivational theories to allow a generalisation to apply more than once at different stages of the derivation is the cycle (Lexical Phonology and Morphology - Booij, 1981; Kiparsky, 1982 - and derived approaches such as LPM-OT - Booij 1996; 1997; Orgun 1996; Bermudez-Otero 1999). If the intuition that levels and cycles are a proxy for historical time is correct, it is necessary to abstract from their theory-specific implementation and isolate their function in light of this.

Cyclicity in a rule-based formalism permits generalisations to apply iteratively at different stages and to domains of different sizes (Chomsky et al., 1956; Chomsky Halle, 1960), from smallest to largest. The ordering of application to domain sizes is highly reminiscent of the life cycle of a generalisation described earlier in this section: as a generalisation gets older, it tends to restrict itself from phrase level, to word level, to stem level. The two tendencies, for older generalisations to be earlier in the derivation and to be closer to (or only active at) stem level, are likely to have related origins: complex morphology tends to form outwards, from the stem to the edges of the word. The further a desinence is from the stem, the more recent its origin is likely to be.

This is because of how grammaticalisation works (Givon, 1979): words that become phonologically dependent on their referent (clitics) will with time increase their closeness to the word by losing their independence and becoming a desinence of the referent. Desinences will get stacked in this way, with newer desinences necessarily being closer to the edges[9]. If we maintain the assumption that processes apply only once in the history of the language (but that they may then extend analogically to later forms, such as Osthoff's law), it is readily explained why older generalisations will tend to apply to more internal domains: at the time the generalisation applied, the outer desinences were not part of the word. This conversely also explains why newer generalisations will apply to the largest domain possible, and why language change will overwhelmingly operate in the direction of domain restriction. The cycle is therefore a mechanism necessary in RBP and OT to allow for successful telescoping of history into the synchronic grammar.

As for the interleaving of morphology and phonology within each cycle, if the premise that a derivation is mirroring time depth is accepted, it is sensible that a model involving screenshots of the grammar at different points in the history (therefore involving both the morphology and the phonology) would perform better than a non-cyclic rule based approach, within which all the morphology will tend to be dealt with before the phonology.

However, even with the inclusion of the cycle, RBP still has a hard time accounting for certain patterns in a way that presents the intuitive relationship between the different instances of the same generalisation without recurring to analogy.

[9] An exception to this is productive infixation and metathesis processes, which have the form they do because of pressures related to the nature of spoken language, which then phonologise and/or morphologise. See Garrett and Blevins (1998, 2009) on metathesis and pseudometathesis; and Yu (2006) on the pathways to infixation and pseudoinfixation.

A salient example is that of intrusive /r/ in non-rhotic Englishes, as in "Pizza[r] Express": the generalisation originated as an overextension of linking /r/ (an etymological /r/ is pronounced at desinence boundaries intervocalically)[10] to words where no etymological /r/ was present desinence-finally in the triggering environment described. This is historically demonstrably analogical (Hartmann Zerbian, 2009; Hock, 2009) and it is highly likely to synchronically still be so (see Soskuthy (2009) for an overview of the arguments). RBP has to model this with more than one generalisation, and in a way that does not express the intuitive analogical relationship that is commonly acknowledged between the two.

If the intuition that strata are a proxy for a historical time dimension is correct, it is worth reframing the use of cycles and the interleaving of phonology and morphology (and their relative success compared to earlier non-cyclic models) in this light.

The tools that RBP has at its disposal have inherent characteristics and connections with parts of the grammar, e.g., post-lexical rules are highly productive and phonetically motivated, whereas morphophonological rules are less productive, and the phonetic motivation is obscured. These tools and characteristics do not always match attested patterns and behavior. Hence while RBP mimics well the intuitions and idealised conceptions about what the lifespan of a generalisation looks like, and captures well the general patterns in the data, having these built into the model can prove a disadvantage for modeling the smaller subpatterns and the relation between them.

[10]Restrictions on vowels that allow either linking or intrusive /r/ exist in many varieties and differ between lects.

1.1.3 Diachronic AED - similar or the same?

Synchronic AED has been at the centre of the debate on opacity, but it is not the only type of AED on which there is data: diachronic AED has got much less attention from phonological theory, as it is usually thought to be within the remits of Historical linguistics. But it is not clear a priori that the two are so different after all. This subsection will look at the treatment of diachronic AED and whether any aspect of it can inform a synchronic account.

The Neogrammarian Hypothesis (first stated explicitly in Leskien, 1876) states that all sound change is regular - when an exception to sound change (i.e. an AED) is found, analogy is most often[11] deemed the cause. Consider the case of Latin intervocalic rhotacism, and how this has extended analogically to the nominative singular:

[11]Exceptions to analogical explanations consist of cases in which a subgeneralisation (or refinement of a generalisation) is used as the explanation, such as with Grimm's law (Grimm, 1822), whose exceptions (mostly) conform to Verner's law (Verner, 1875). The other option is that the word in question be a borrowing or loan, explaining its exceptional behaviour - it is usually unproblematic to tell whether analogy or loanword phonology is at play.

Stage 1: Latin before 400BC

honōs "honour"	labōs "labour"	nominative singular
honōsem	labōsem	accusative singular
honōsis	labōsis	genitive singular

Stage 2: rhotacism: s > r/V_V

honōs "honour"	labōs "labour"	nominative singular
honōrem	labōrem	accusative singular
honōris	labōris	genitive singular

Stage 3: after 200BC, analogical reformation of nominative singular

honōr "honour"	labōr "labour"	nominative singular
honōrem	labōrem	accusative singular
honōris	labōris	genitive singular

A regular sound change occurs (stage 2), and it is extended analogically to the nominative singular (stage 3) because of paradigmatic leveling pressures (for a more detailed analysis see Saussure, 1916; Foley, 1965; Matthews 1972; Kiparsky 1982; Kenstowicz 1996). The pattern now features overincident AED. Given that an analogical approach has almost universally been adopted in accounting for AED in historical linguistics, it is worth asking why a comparable analogical process would not be expected to play a role in synchronic cases of AED. If possible, an extension of an analogical account to the synchronic domain would provide a unifying analysis of both synchronic and diachronic instances of AED.

1.1.3.1 Analogy as Mechanism and Similarity as Trigger An analogical model makes a testable prediction: analogical change spreads from item to item, it is not an immediate change across the board - there are paradigms which maintain

the unlevelled situation such as the monosyllabic *flos, floris* and textitmos, moris, and polysyllabic nouns which were not similar enough in shape to be attracted into the pattern, such as *opus, operis* or *corpus, corporis*. It is hypothesized that the data comprising the attested AED pattern will present irregularities and exceptions based on similarity metrics from various parts of the grammar. It will be illustrated in Section 2 that phenomena of this form do occur - some role will need to be accorded to analogy

The question of how similarity is defined is crucial to any work involving analogy, and one which still lacks universal consensus. Let similarity be operationalized below as the edit distance between two strings: the number of operations required to turn a string into another is the edit distance between the two (Levenshtein 1966). The concept of edit distance is commonly employed at the segment level (e.g. the edit distance between /kat/ and /fat/ is k=1), but can also be applied at other levels such as syllabic (at which level the edit distance between the two tokens above would be k=0), and subphonemic (e.g. in a theory with phonological features, the edit distance between /pa/ and /ta/ would be k=1, as the two strings differ in place of articulation of the first consonant, while the edit distance between /pa/ and /θa/ is k=2, as the two strings differ not only in place of articulation of the initial consonant but also in manner).

Metrics of this sort don't have to rely solely on the form's shape: they can also be semantic (a little harder to quantify without computational aid, but nevertheless possible, using methods such as the Semantic Edit Distance metric (Rios Gelbukh, 2012)) or paradigmatic (such as Lee, 2015) which would involve a combination of previously described metrics used to compare whether, given two sets of comparable words such as the nominatives and genitives of two lexemes, an equiv-

alent relationship is present between the members of the two sets. According to this hypothetical metric, *honor, honoris* and *arbor, arboris* would have a paradigmatic edit distance of k=0, while honor, honoris and *corpus, corporis* would have a paradigmatic distance of k≥1, amongst others. So the idea of two items being similar enough to undergo analogy can be formalised as fulfilling the condition of k≤x, where x is a variable dependent on factors such as the number of items already undergoing the pattern, the token frequency of individual members of the pattern, the token and type frequency of the word being attracted, and more.This conception of similarity and analogy will be invoked in the case studies in section 2.

1.1.3.2 The Synchronic-Diachronic Dichotomy There are advantages to acknowledging history directly, as represented by outputs of different generations of sound changes, rather than attempt to incorporate it into a synchronic grammar. A model like RBP, which incorporates a proxy for the chronology of the language into its architecture, requires a word to "relive" all its history as it is processed synchronically, which is not strictly necessary given that these processes have already applied in historical time[12].

Moreover, separating synchronic and diachronic AED doesn't necessarily have sound theoretical motivation, but instead it is likely an indirect result of the spheres of influence of linguistic subdisciplines.

Most generalisations, if not all, have both a synchronic and a diachronic facet[13],

[12] "Those who ignore the past are doomed to repeat it (inside the synchronic grammar)." - O. Sayeed (p.c.).

[13] Every linguistic generalisation has an origin and a trajectory, so necessarily a diachronic aspect to it. Moreover, even generalisations which are no longer productive will often play some role in the synchronic grammar, e.g. the ablaut pattern of English praeterites is no longer

and linguists can choose to prioritise either in their analysis. Modern phonological theories have had a tendency to neglect the diachronic aspect of generalisations (arguably sensibly, as the aim of RBP, OT etc. is to model synchronic competence) and thus to account for them in the synchronic grammar, often considering the alternative mostly when mechanisms of the grammar appeared not optimally suited to handle the phenomenon.

There is little reason to propose that speakers have direct access to the various stages of their language, and that every utterance is the result of running an underlying form through the various historical changes in real time. This was in a way what was proposed in Chomsky & Halle's Sound Patterns of English (1968) by positing underlying segments that were never attested in surface forms, but which thanks to a series of rules which mirror chronologically the stages of the language would turn the segment into its expected surface form. This approach did make largely accurate predictions about attested forms (the consequence of modeling history as closely as possible) and justified the extreme abstraction as a way to indicate underlying relatedness between forms. This was progressively deemed an inappropriate solution because of its excessive focus on the diachronic aspect of language and not enough on its synchronic cognitive status for a theoretical framework that was increasingly focused on achieving cognitive relevance (Vachek, 1976). While a majority of more modern implementations of multistratal theories reject this mode and level of abstraction for the reasons above, the presence of levels is still effectively carrying out that same function: making a form re-live its history every time it is uttered.

It can be often be tricky to diagnose the synchronicity or lack thereof of a pattern:

productive (is lexically specified) but can still recruit new forms

the obvious candidate diagnostic is whether the process applies to nonce words or loanwords. If a generalisation does not apply to these two classes, it can safely be said that its presence in the language is a historical fossil. However, even if it appears to have a synchronic element, it doesn't necessarily entail it is part of the synchronic grammar. Two possibilities should be considered: a) the generalisation is part of the synchronic grammar and it will apply whenever its environment is met or b) the generalisation, while not synchronically productive, is synchronically active, as it may recruit new items if they are similar enough to existing ones. These two possibilities can be hard to tease apart, as generalisations that are highly active may resemble fully productive ones in their behaviour. The number and type of exceptions to a generalisation could help disambiguating between the possibilities: if the exceptions are rare and/or all have a common factor, it is likely that the generalisation in question is productive rather than active). However, as will be discussed at length in this work, this process is theory-dependant and potentially challenging, so conclusions about productivity and activity will likely be made on a case-by-case basis and will depend on the theorist, yielding no single conclusion.

The usefulness of a synchronic/diachronic divide and its exact placement are open questions, the answers to which are informed by both theoretical and empirical factors. Consider vowel shifts: the literature generally maintains that they are of two types, diachronic (such as the Great English Vowel Shift (GEVS) or the New Zealand Vowel Shift) and synchronic (Njebi (Guthrie, 1968); Xiamen Tone Sandhi (Chen, 1987)). Putatively synchronic chain shifts are dealt with within the synchronic grammar, with rules arranged in a counterfeeding order to prevent the neutralization that would otherwise ensue. Below is exemplary data from the

supposedly synchronic vowel shift in Bedouin Hijazi Arabic (Al-Mozainy, 1981), in which a rule 1) /i/ $\rightarrow\emptyset$ / _ σ needs to precede a rule 2) /a/ $\rightarrow i/\_\sigma$. If the order of the rules were reversed, all instances of /i/ and /a/ would be deleted, which is not the case in the attested data:

i $\rightarrow\emptyset$	/?arif/-/at/	?arfat	"she knew"
	/kitil/	ktil	"he was killed"
	/kitil/-/at/	kitlat	"she was killed"
	/kitil/-/na/	ktilna	"they were killed"
	/yaskin/-/uun/	yasknuun	"they (m.) dwell"
	/yaskin/-/in/	yasknin	"they (f.) dwell"
a $\rightarrow i$	/katab/	kitab	"he wrote"
	/sami?/	simi?	"he heard"
	/rafaagah/	rifaagah	"companions"

This shift is apparently pervasive in the language[14]. A similar thing could however be said for the GEVS, a putatively diachronic shift: iits consequences are likely just as pervasive in the language, and the pattern created by it can still recruit nonce words (Eddington, 2001), giving a synchronic dimension to the pattern. Why then is one type of chain shift treated as synchronic and the other as diachronic (and therefore relegated to the lexicon) when the two have relatively similar shape and degree of productivity/activity? One point of interest is that shifts classified as diachronic often have in common a relatively good attestation of their chronology, development and exceptions, while putatively synchronic shifts have been overwhelmingly identified in less well-studied language families.

It is therefore worth entertaining the hypothesis that the true difference between

[14]Its triggers are certain aspect and tense combinations (Al-Mozainy, 1981)

the two classes of chain shifts might be the depth of our knowledge. When phonological theory first started looking systematically at the GEVS, in Chomsky Halle (1968), it was effectively incorporated into the synchronic grammar. It is only with time, the progressive rejection of excessive abstraction and a closer look at the data that it was agreed to relegate the effects of the GEVS to the lexicon.

There are issues and difficulties (both theoretical and empirical) when it comes to deciding on the boundary between the synchronic and the diachronic, as patterns will usually have both facets and the validity of arguments for one prevailing over the other is often subjective and theory-dependent. Before addressing the question of the placement of the divide, it should be considered whether the divide is necessary at all - acknowledging the chronologically dualistic nature of patterns has its advantages as it can explain both its idiosynchrasies and its productivity or activity level. Moreover, imposing a dichotomy by force compounds the issues stemming from idealization identified in the previous sections, for the treatment of AED in particular.

1.2 The Synchronic Grammar

The previous section has outlined the necessity to include as directly as possible the chronology of a generalisation in a model to successfully account for AED data, and that establishing the division of labour between the diachronic and the synchronic is not straightforward. This section will deal with the shape of a synchronic grammar in which this dualistic nature is acknowledged, and how labour can be optimally assigned to the relevant parts of the grammar.

If the effect of history is acknowledged more directly rather than telescoped into

the synchronic grammar, a key motivation for levels is removed. In fact, a priori, the synchronic grammar shouldn't necessitate more than a single stratum (which would bring with it all the advantages outlined in the manifesto of Classic OT): if the function of levels was mirroring chronology, that function is expleted outside the synchronic component. There are a number of possibilities for the shape of the synchronic grammar: a word-based lexicon, for example, wouldn't duplicate the work of the chronology (as the output of the chronology is the minimal unit of the theory) but would still allow its output to be synchronically available, acknowedging the amphichronic nature (in the words of Bermudez-Otero, 2012) of the pattern.

More direct acknowledgement of diachrony outside of the synchronic realm, and a monostratal view of the synchronic grammar would imply two important positive features for the treatment of AED in particular. AED patterns are often influenced by more than one part of the grammar in an apparently simultaneous manner from a synchronic point of view (the Latin example above is influenced by phonology - the right phonological environment must be present - but also morphology - the extension to the nominative) and a monostratal grammar can describe simultaneous conditioning environments that refer to different properties. In addition, a monostratal word-based model is incorporated in psycholinguistically plausible models that have been developed in branches of cognitive linguistics, which offer a body of evidence supporting this architectural choice, such as connectionist models (a tradition the early form of which is subsumed in Rumelhart et al., 1986).

Let us exemplify the consequences for AED of a monostratal synchronic grammar, for the sake of argument consisting word-based lexicon: it is generally assumed that morphologically simple words have to be stored in the lexicon - storage of

the minimal units of language (form+meaning combinations) is the purpose of the lexicon, at least for models of lexical knowledge that operate in terms of form repositories. Whole-word storage for morphologically complex words with at least one idiosyncratic property has been famously argued for by Pinker (1991) and Pinker and Prince (1991), there is also evidence that non-idiosynchratic morphologically complex words with a high enough token frequency (Bybee, 2001) are processed in the same way. Moreover, the presence of neighbourhood effects for both simple and complex words (Schreuder Baayen, 1997; Baayen et al., 2006; Kuperman et al., 2010; Baayen et al., 2011) suggests that there is interaction between whole words during processing, pointing to whole word storage of all forms in a speaker's 'mental lexicon'[15]. Words with AED would be stored in their full form, as they are idiosynchratic (pretheoretically, AED is exceptionality), which would resolve the issue of having to derive them, which has proved so problematic for OT, and allow for influence on each other and similar words which, as will be illustrated in section 2, is at the base of the diffusion of the AED patterns considered.

An objection to the picture presented above may come from the extensive literature advocating some amount of internal structure in morphologically complex words, a category in which AED is highly represented, often attracted by morphological boundaries (discussed in section 1.2.1 and 2.1.2). The literature often describes the findings in terms of decomposition (Rastle et al., 2004; Longtin Meunier, 2005; McKinnon et al., 2003; Buchanan, 2003; amongst others), which is taken to imply that not all words are stored as wholes. These studies however rarely differentiate between the decomposition hypothesis and the weaker hypothesis that

[15]The exact implementation of the storage is not within the scope of this thesis, but it could take a number of forms, from full storage of all tokens (Full Listing Hypothesis - Butterworth, 1983 and derived models) to more abstract representations involving schemas or paradigms.

the behaviour attributed to decomposition is a reflex of the presence of internal structure (which would be compatible with whole word storage). Before stronger conclusions can be drawn about morphologically complex non-idiosyncratic words with internal structure, reliable techniques and methodologies that differentiate between the two possible interpretations of the results are needed. Recent work by Loo (2018a, 2018b) aims to distinguish between the two conclusions, and preliminary results seem to suggest that the decompositional account is less likely to be correct: a number of reaction time tasks on inflected words were performed with speakers of Estonian, and whole word-frequency, inflectional paradigm size and morphological family size appear to be more important predictive factors than lemma frequency. These results fit well with non-decompositional theories, in which systems are shaped by predictability and discriminability of forms (Blevins et al., 2017).

A monostratal synchronic grammar has a number of auspicable implications for the modelling of AED, which appears to involve interactions between parts of the grammar, and between the forms themselves; and a realisational synchronic grammar in particular would dispose of the difficulties involved in deriving AED words.

1.2.1 The Minimal Unit in AED Effects

A word-based lexicon was suggested earlier as a possible locus of AED phenomena that would escape the duplication problem as, because forms with AED are effectively exceptional, they'd count as idiosynchratic and would have to be stored in their full form, making a derived account superfluous.

Exceptionality of patterning is not the only reason to hypothesise that words as minimal units play a large role in AED effects. Historical changes (and AED in particular) are often taken to have the word as their unit of application and diffusion. The Latin rhotacism case shows that it is not all instances of /s/ intervocalically that rhotacise, but other conditions about the word need to be taken into account. Rhotacism largely does not apply outside desinence boundaries (eg *causa, miser*) - but also in some cases does unexpectedly not apply at desinence boundaries (*vas, vasis/*varis*) - therefore referencing properties of the internal structure of the word. There is a reason why desinence boundaries tend to attract AED: boundaries between desinences have high entropy. The uncertainty for the hearer about what might come after is high when desinence boundaries are encountered. This explains why desinence boundaries (and entropy peaks in general) attract AED effects or marked configurations: these serve to signify that there is more material to follow, and can give clues to its nature (a more detailed and exemplified account of this will be given in section 2.1.2). As AED is sensitive to relationships between desinences, properties of the whole word appear to play a role.

The Latin rhotacism example also provides envidence for words being the basic unit of AED effects in the extension to the nominative. Rhotacism doesn't extend to forms which do not have the correct shape (*honor, honoris* but *corpus/*corpur/*corpor, corporis*), in which the nominative is presumably not seen as similar enough to the rest of the paradigm to justify leveling, a comparison that can most accurately be described as between word forms), or an adequate number of syllables (monosyllables like *flos, floris* don't undergo leveling), thereby referencing properties of the whole word. In addition, such changes spread on an

item-by-item basis even synchronically, as will be illustrated in section 2.

It is then not only the word that plays an important role in AED phenomena, but the relationships between them. A number of mechanisms have been used to encode relationships between forms: Chomsky and Halle (1968) and the more abstracting traditions of underlying representations allowed underlying forms to feature phonemes that would never surface with the purpose of representing relations between forms and mirroring an earlier stage of history. Underlying representations serve a function: that of relating forms which are distinct on the surface - e.g. electric /ɪ'lɛktrɪk/- electricity /ɛlɪk'trɪsɪtiː/ are evidently related, but it's challenging to express their relationship with rules that would be relevant to more than a small subset of the lexicon. An underlying form such as //ɛlɛktrɪʁ//-/ɪtiː/, in which the nature of the vowels is shaped by stress and the realisation of the morphophoneme //K// is dependent on the presence and nature of a suffix, expresses a connection between the two forms that is not readily apparent on the surface.

If the function of a serial derivation is indeed that of mimicking sound changes that have occurred, their input can be interpreted as an ancestor to the current one. This is not as evident in more modern derivational approaches, but an oft cited example is Chomsky and Halle's use of the phoneme /x/ in /rixt/, /nixt/ → [rait], [nait], which exactly models the historical evolution of Old English /x/ in these words. Under the assumption that history shouldn't be telescoped in the synchronic grammar, underlying representations lose their function as ancestor forms, but retain that of expressing relatedness. The relationship between the forms can be characterized by schemas or networks, which set up relations between items and identify items that pattern together in a number of respects - forms that

are opaquely related on the surface can be related by a construct (similar in shape and purpose to Proto-Indo-European reconstructed forms) equivalent in function to the underlying form, characterisable in terms of edit distance: the constructed form is the "least common ancestor" between the two, the form that is reached by performing the least edits on the related forms, akin to what is done when reconstructing a form in a protolanguage. The form derived in this manner will often mirror the last historical form that the two items had in common and are derived from, and the edits will often retrace the steps of sound changes.

The previous paragraph has described how words that are in some way idiosynchratic in their form or meaning would benefit from being listed in the lexicon when encountered. The forms which could potentially be accounted for by regular derivation remain as a result in a relative minority, as some degree of idiosyncrasy is quite common. There is however reason to propose that even at least some completely nonidiosynchratic forms should be listed in the lexicon when encountered: AED patterns (such as the Latin example discussed above) show that interaction can occur between forms of a paradigm or extension by similarity to unrelated forms, so there seems to be a need for attested complex words (especially the more frequently attested, Bybee (2001)) to be represented as wholes in the lexicon rather than distributed across sub-lexicons and assembled in real time, even for regularly derivable forms. The exact shape of lexical knowledge is irrelevant to this work, but schemas and paradigm relations, networks or simply whole word storage (full listing hypothesis, Butterworth (1983) and derived models) with or without a degree of abstraction are potential candidates for an implementation of these conclusions.

1.2.2 The Role of Analogy in Synchronic AED

It has been repeatedly said above that history shapes the lexicon (an idea dating as far back as Paul (1880) and the Neogrammarians). The mechanisms by which it does, and those by which the items within the lexicon interact with each other, are analogical. This is demonstrably the case for the influence of history, as hinted at above and as will be detailed in more depth in section 2.1 - it is often the case, especially for AED effects, that a feature spreads or is restricted analogically within a certain domain (cases of paradigm leveling, or restriction to certain environments such as morphologically derived ones), and also that these patterns spread lexeme by lexeme based on similarity.

An analogical mechanism for both synchronic and diachronic residue effects would provide a series of benefits. It would yield a unifying analysis of diachronic and synchronic AED by extending the established mode of handling exceptionality within historical linguistics to the synchronic domain. In addition, a primarily analogical model in conjunction with the cumulative reflexes of history represented in words can explain well the correlation found between productivity, phonetic motivation, and recency of origin of a pattern while still allowing this to be a strong trend rather than an exceptionless rule[16]. Exceptions to it can be motivated by referencing the relatively high strength of certain attractors in parts of the grammar where such strength is less usual.

An analogical model is successful in modeling and motivating these departures from the general trend of the productivity-age-scope correlation: in an analogical model, it is inevitable for patterns with different levels of generality to form at

[16]Stratal and serial theories also acknowledge the trend (discussed in 1.1.1), but can less readily model exceptionality to it, due to the high degree of idealisation of a language's history.

all levels of the grammar. Factors that influence this are to do with the position of attractors, the closeness of their neighbourhoods and the current size of the pattern[17]. This is in fact what we find: different parts of the grammar have several patterns and subpatterns some more or less productive. Consider the English past tense formation, which aside from the regular -ed formation also has several islands of regularity of different sizes such as the set of irregulars SPRING-SPRUNG, SWING-SWUNG, FLING-FLUNG, CLING-CLUNG etc, all at a small edit distance from each other, which follow the same ablaut pattern. Wug testing (Berko, 1958) shows that nonce verbs at close edit distances to this set have a high chance of analogizing to the ablaut pattern instead of taking the regular desinence, (Bybee Moder, 1983; Prasada Pinker, 1993).

The use of analogical processes also avoids the problem of having to predetermine environments. While allowing phonetically motivated changes, analogy can also model patterns corresponding to crazy rules (Bach Harms, 1972)[18] which are captured less neatly in theories relying on features[19] such as RBP and feature instantiations of OT. Similarly, the number of strata or their interactions need not be predetermined. Analogy allows for attraction between elements in various parts of the grammar, with empirical success. This type of mechanism appears particularly useful for AED phenomena, which do seem to work by attraction,

[17]Analogy doesn't work completely unrestrictedly, it just allows surface forms to influence one another in more ways than RBP, in a fashion closer to OT.

[18]Features and natural classes explete the function of describing classes of sounds that tend to pattern together. This is especially helpful when accounting for new and/or synchronically productive patterns, as phonetic motivation tends to be important at this stage. However, when theories telescope history into the synchronic grammar, they are forced to use synchronically oriented mechanisms to account for the diachronic. As is the case with crazy rules, this can be problematic in principle and in practice.

[19]A potential exception to this is Mielke's emergentist view of features - which, however, arguably diminishes the role for features in the first place. "A more compelling case for innate feature organization could be made on the basis of features which pattern in a certain way in spite of their phonetic definitions." (Mielke, 2008:27).

involve elements in different parts of the grammar, are often lexicalized, and are often not phonetically motivated (section 2) .

An analogical model, combined with a lexicon in which history is effectively "flattened", is not only able to model the phenomena in a way that is coherent with the newly found assumptions worked out in this section, but also to better convey some of the intuitions that were present in previous frameworks.

1.3 The Data

Different treatment of data can lead to different verdicts about a phenomenon, the treatment of AED providing a prime example of this. This is a problem particularly prevalent in phonology, as in this academic subculture interest in data itself is secondary to its theoretical significance. In morphology, for example, there is generally an underlying understanding that a theory should cover the whole system, and not just subsets of it. Moreover, morphological traditions generally value description of data in its own right, and do not see theory construction as the primary goal of analysis. This has profound implications for the nature of conclusions in phonological theory, which bear on the debate about the ontology of AED.

1.3.1 Exceptionality and how to approach it

Language is highly structured: plenty of generalisations can easily be identified in all areas. The statement is also heavily motivated by considerations about

acquisition: a relatively high degree of regularity is imposed by learners[20] when they generalize patterns, in an effort to minimize uncertainty in predicting forms. This yields a high amount of structure (however, not necessarily of regularity in the narrow sense) in language. Once the belief that language is highly, or even completely, regular is accepted as an assumption, the issue is what to do with (possibly apparent) exceptions to regularities.

This dilemma is well illustrated in generative theories which, in contrast with more descriptively-oriented traditions (exemplified in the works of Filmore (eg, 1987)), are particularly reluctant to recognize exceptions to generalisations, especially when the exceptionality is itself systematic rather than sporadic. Holding on to a commitment to regularity has paid dividends at times, as further probing of apparent exceptions has revealed these weren't exceptions after all. One notable success case is precisely the treatment of phonological opacity for Rule Based Phonology: Kiparsky (1971) proposes that systematic exceptions to a phonological generalisation could not only be modeled through rule ordering, but were in fact predicted by the theory ("In that sense, opacity has no status in a rule-based grammar. Opacity is just a point of logic, a possible result of applying rules in some order." - Hale Reiss, 2008), thereby accounting for perceived exceptionality seamlessly within the theory.

What is less often noted in discussions of opacity is that opacity, a pattern of surface exceptionality, may have plenty of its own exceptions (section 2 provides many such examples). AED data is much less neat than what can be gleaned from

[20]There is however high internal competition within a regular pattern, so if this competition exceeds a threshold, the pattern may be harder to acquire (but not to generalise) than an irregular one (Yang, 2016). Irregular patterns are easier to learn in the strict sense because of their high distinctiveness (Ramscar et al. 2013).

the way it is normally discussed, and conclusions about its nature will depend on the approach to data.

1.3.1.1 Data Selectiveness - Compenence vs Performance, Abstraction and Theoretical Significance

Abstracting, competence-focused theories like OT and RBP often have internal reasons for extrapolating from the messiness of the attested data which, as we will see, has profound impact on their interpretation of AED data. This largely reflects the view that data is only of interest insofar as it bears on theoretical claims, and this is best achieved when the data is polished.

The goal of accounting for speaker competence rather than for performance justifies filtering the attested data to minimize the interference of performance factors. Intrinsically, linguistic output is tarnished by a variety of performance factors, such as the material nature of the vocal tract, memory restrictions, and competition from similar words or structures. To successfully work on competence, all these performance factors must be abstracted from in these theories, leaving the linguist with an idealised version of attested language. The distinction between competence and performance is in practice not a dichotomy, and there is disagreement within the generative community about whether something can be dismissed as performance or should be accounted within competence. Matters are further complicated because so-called "performance" factors are so entrenched in language: e.g are neighbourhood effects (which are highly relevant in the distribution of AED) competence - as they are synchronic knowledge that determines choices made by the speaker - or performance (as the ultimate reason they exist is usually to do with physiological restrictions and historical occurrences in the language)? There

are in practice no established or universally accepted guidelines for distinguishing competence- from performance-based factors[21], which means different analyses can discard different data, leading to even more variability in conclusions.

Therefore, especially for analyses of this type, if a datum contradicting the theory is found, it doesn't necessarily entail that the account has been falsified or should be changed. When faced with exceptional data points, it is possible to question whether performance factors are involved (therefore justifying discounting the data point), or whether the datum is being looked at at the right level of abstraction. And even when the possibilities above are not justifiable in the particular situation, there may be reluctance to abandon or reformulate the theory because of an exception as its successful empirical coverage is too great to warrant a complete dismissal. Chomsky, the father of the competence-performance distinction (1965) and a champion of the benefits of abstraction, has often spoken in favour of preserving a theory, even in the light of falsifying data. He refers to this as the "Galilean move towards discarding recalcitrant phenomena":

> "[Galileo] dismissed a lot of data; he was willing to say: 'Look, if the data refute the theory, the data are probably wrong.' And the data that he threw out were not minor"
>
> "Galilean style... [which] is the recognition that... the array of phenomena is some distortion of the truth... [and] it often makes good sense to disregard phenomena and search for principles" (Chomsky, 2002)

[21] This is well illustrated in the interplay of competence and performance in language change - when exactly in the evolution of a pattern does the generalisation come to be associated with competence rather than performance? Opinions differ both within believers in the dichotomy (Chomsky, 1965; Pustejovsky, 1995; Katz Fodor, 1964) and within those who do not (Labov, 1971; Evans Green, 2006; Bybee, 2001).

There is not so much disagreement about what the data says, but rather about the cutoff point of what data needs to be addressed within the theory, and the relative importance of the big picture or the small trends in the data.

There is one mechanism that crops up repeatedly when looking at the behaviour of "surface"/"performance-affected"/ exceptional data: analogy. From outliers to a pattern (examples in section 2) to speech errors, the causes of recalcitrant data for abstracting, competence-focused theories seem to be tied to notions of attraction between items based on similarity. This entails that some role within the theory will need to be accorded to analogy, even if only at the level of performance or non-abstraction, if a theory is relieved of the obligation of accounting for the particular offending data by any of the factors above. From the earliest writings on opacity within the generative tradition, analogy is thought of in terms of imperfect rules. Analogical processes can model the data but are thought not to be in line with the commitment to abstraction and higher level generalisations, leading to it being considered suboptimal as a solution. In his seminal generative work on sound change, Kiparsky (1965:2-40) refers to analogy and rules and their relationship in these terms:

> "Traditionally, sound change is granted a certain regularity whereas analogical change is considered to be a peculiarly sporadic and irregular kind of process. Actually the supposed sporadic character of analogy has been systematically studied only in the area of morphology and almost completely ignored in phonology and syntax, where the rule-bound character of analogy is clearly apparent. [...] The same generality prevails in "morphological" (sic) analogy to the extent that the relevant rules are structured along

> independent dimensions. [...] It is just where rules lack structure and their applicability is largely an idiosyncratic property of individual morphemes [...] that analogical change proceeds morpheme by morpheme in the sporadic fashion that has come to be regarded as typical of analogy in general."

There is an admission that analogy is necessary in explaining at least some of the data, along with an assertion that the work of analogy can in many cases be done by rules, which represent a more abstract of analogical processes.

Each linguist will have individual beliefs about what data needs to be accounted for in a theory, and the level of abstraction that should be operated at. This means that internal evidence can't likely be used to settle which of the various sides is correct on the nature of opacity as the data in its current form can be accounted for in an internally justified fashion by a number of analyses. External evidence is usually employed to evaluate the predictions in such situations, as it provides a different kind of data that is usually less intrinsically dependent on the analysis it is given. However, as will be seen in Section 5.1, external evidence on opacity is scarce, and that which exists is not conclusive, because of characteristics of its very nature. What is needed is enough control over the conditions in which the evidence is produced, which would not only allow us to ensure that it is competence rather than performance that is being examined, but to do so in a way that satisfies the standards of evidence of both sides. An experimental design has the best chance of achieving this, a possibility to be explored in Section 5.2-5.3).

1.3.2 Parsimony

It is a longstanding principle to attempt to make one's theory as parsimonious as possible, both in terms of the entities it postulates and of its mechanisms. Theoretical parsimony should be taken into consideration when deciding between competing theories, after ascertaining that they can model the facts equally well and that their logic is internally satisfactory. However, especially in a field as divided even about the most basic assumptions as linguistics is, parsimony shouldn't be a decisive factor in evaluating theories. Nevertheless it can be held as a desideratum or a soft principle, especially when the theories in question are incompatible and/or differ in fundamental ways.

Consider a scenario in which theory A needs to employ a superset of the mechanisms employed by theory B to account for the same data. All else being equal, theory B should be preferred as more parsimonious, and at the very least theory A should re-evaluate the assumptions that led to employing a greater number of mechanisms, and whether these are truly necessary in the light of the empirical success of theory B. This is parallel to the situation between the mechanisms adopted by RBP and an analogical model of language: RBP necessitates a word-based analogical component, even if it chooses to relegate it to the level of performance, to account for the data fully (from semantic substitution errors to interactions between paradigm forms and morphomes). A word-based analogical model, as will be exemplified in Section 2, can account for the data in a manner that is internally satisfactory using only one of the mechanisms needed by RBP, namely the analogical one. While this is not a decisive factor, it is worth considering that an added benefit to relegating the effect of levels (that of mirroring history) to the

lexicon is being able to account for both diachronic and synchronic AED (and the grammar at large) with a single mechanism rather than several.

1.4 The proposal

The conclusion reached in this section is that a maximally successful model of AED must take into account the historical origins and evolution of the pattern as directly as possible. Rule-based and multi-level frameworks have had greater success modeling the phenomenon than existing monostratal alternatives because they can mimic the time depth dimension with their serial architecture.

However, there are negative consequences to telescoping the diachronic dimension into the synchronic domain, such as redundancy stemming from positing that a word relives its history every time it is produced, or a necessary idealization of the history of generalisations which might lead to an inability to model the full complexity of language.

On the other hand, it is also undeniable that most patterns have a dualistic nature, both synchronic and diachronic. A model that reflects this should be well-equipped to handle AED data. A word-based lexicon is a good candidate for the purpose, which avoids the pitfalls of telescoping a language's chronology: words as the minimal units of language are already shaped by the pressures of history, which means that there is no need to derive these in real time, and in this arrangement, items can influence each other synchronically. This would allow the synchronic grammar to be monostratal, which is in line with most psycholinguistic evidence, and it has the advantages of avoiding redundancy, facilitating interaction between items in different parts of the grammar and allowing for analogical effects which

are so pervasive in language.

Moreover, different theories have differing approaches to data, which has led to differing conclusions about the nature of AED and what constitutes an optimal account for it. This thesis argues that including the full range of AED data in the analysis paints a potentially different picture of the phenomenon, one that is in line with the handling of exceptionality in historical linguistics and with the assumptions progressively evaluated in this section.

2 Case Studies

This section is dedicated to case studies of AED phenomena. Subsection 2.1 aims to show the treatment of AED within the context of Historical Linguistics - the two patterns presented have a well-attested chronology of development, are well-known within the field and there is little disagreement over the major points of their analysis. These case studies are used to illustrate the treatment of AED in historical linguistics, which takes an analogical, word-based, non-abstracting approach. This implementation of the properties isolated in section 1 will be evaluated.

Attention will be drawn to the importance of acknowledging the history of the pattern in explaining its distribution, to the role of the interaction between various components of the grammar in the origin of the pattern, and to the importance of analogy and frequency in shaping it, as well as the bottom-up, surface-oriented approach to data within historical linguistics. Subsection 2.2 features case studies of AED that have been treated as synchronic. The phenomena described are often

employed to exemplify opacity within RBP or OT, and as such are assumed to be considered excellent cases of the type of pattern being discussed in this thesis. The importance of factors isolated in section 1, and consolidated in section 2.1, will be emphasized, and the benefits of different approaches will be compared.

These case studies begin by describing the phenomenon and outlining a standard analysis[22], examine data available on the pattern, and consider the benefits of differing analyses. It will be shown that more than one framework can account for the data in an internally satisfactory manner, even though their theoretical positions on several matters are very different. After showing in this section that there are a number of options to model AED data, all relying on principles identified in Section 1, Sections 3-6 will evaluate competing alternatives from a cognitive perspective.

2.1 AED within Historical Linguistics

2.1.1 German Plural Formation

The first case study addresses the diachronic and synchronic status of German umlaut, and more broadly plural formation. The name refers to a change in vowel quality which has come to be associated with certain morphological features in a way that has subverted the original phonological motivation for the rule, extending AED in a series of different contexts.

Let us begin with a brief overview of German umlaut and its origins. Old High German (OHG) inherited a theme vowel system from Proto-Indo-European. As

[22]Because of the problems faced by OT in modeling most kinds of AED, the focus will be mostly on RBP.

stress in Proto-Germanic became fixed on the root vowel, phonetic elements in final position, which includes theme vowels, progressively became less salient (Waterman, 1966). The various theme vowels were then reanalysed as plural markers in the nominal domain, and as markers of other various properties in the verbal domain. Meanwhile, an umlauting rule came into existence in Middle High German: it is standardly viewed as being comprised of two main stages, primary and secondary umlaut, so named because of their chronology. The first consists of a raising of the root vowel from /a/ to /e/, and the second is a lesser raising of long /a/ to /æ/, originally a harmony process triggered by a high vowel in the desinence. The first two examples below illustrate primary umlaut and the last two secondary umlaut:

gast - gesti	"guest, guests"
lamb - lembir	"lamb, lambs"
zæhere	"tears" cf OHG zahari
slæ - slæfet	"he/she/it sleeps"

As with most harmony processes, there can be intervening blocking elements (Holsinger Salmons, 1999) - in this case, if the sequence /x, l, r/+C is between the root vowel and the desinence, umlaut is blocked (cf maht - mahti "power, powers" (also dialectal mehti); haltan - haltis "to hold, you hold" (also dialectal helti); starch - starchiro "strong, stronger" (also dialectal sterchiro)).

While the pattern originally only targeted /a/, it subsequently generalised to target all back vowels (therefore extending to long and short /o, u/), overriding the blocking conditions which were previously operative. (for an in-depth overview of the process, its causes and its timeline, see Salmons, 2012)

As can be seen, the original motivation for umlaut is phonological, even plausibly

phonetic. Correlatively, it was originally highly productive. This is no longer true of more advanced stages of the language in which, from a phonological point of view, we find both overincident and underincident AED. There is often a correlation between loss of productivity and progressive morphologisation of the trigger. This is a trend, rather than an absolute statement. The combination of a historical and analogical explanation both help motivate and acknowledge the trend while allowing for exceptions that indeed exist to it.

2.1.1.1 Umlaut and Plurality in the Nominal Domain Having outlined the origins of the phenomenon, let us look at the development of the situation in the nominal domain. From a relatively exceptionless phonological generalisation, the trigger of umlaut has progressively morphologised, and arguably even lexicalised, gaining an AED distribution, both within a paradigm and in the lexicon at large. Historical i-stem nouns are the ones that undergo pluralisation by umlaut. The i-stem vowel became reanalysed as a desinence denoting plurality, and given that a high front vowel in a desinence at the end of a word is the trigger for umlaut, this class of nouns provides the necessary environment. Because of the high type frequency of triggering desinences in the plural paradigmatic slots, umlaut in the nominal domain gradually came to be associated with a plural environment. Consider as an example the Old High German masculine i-stem paradigm of gast "guest:

	Singular	**Plural**
Nom.	gast	gesti
Gen.	gastes	gestio, gesteo, **gesto**
Dat.	gaste	gestim, gestin, gesten
Acc.	gast	gesti
Instr.	**gastiu**, gestiu, gastu	

Underincident AED can be seen in the instrumental singular: despite a triggering desinence -iu, the vowel doesn't raise. The opposite occurs in the genitive plural (overincident AED): the vowel raises in the absence of a triggering desinence. Looking at the rest of the paradigm by number, it can be gleaned that the unexpected phonological raising or lack thereof of the vowel of the core formative occurs by analogy with the rest of the cells with the same number features: the phonological nature of the generalisation is overridden by an analogy based on morphological factors, which disrupts the original pattern and its triggers.

Frequency is one of the key factors for analogy, and as such plays an important part in AED effects, as will be shown repeatedly in the case studies here. For a generalisation to spread outside of its original environment, or to restrict its domain to exclude a certain environment, there need to be certain prerequisites concerning type frequency of a form within an environment, that is the ratio of co-occurrence of the generalisation in question with particular features, which can be phonological, morphological or of any other kind:

Type Frequency within an environment:

$$(\mathrm{P}(\mathrm{F}_1|F_2)) = P(F_2|F_1)(F_1)/P(F_2)$$

F1, F2 are two distinct features; PFx is the probability that

a feature is present in a certain environment: if F1 is present in 1 out of 4 of the imperative forms in a language, PF1 = 0.25.

A high enough type frequency of a feature in an environment[23] provides the basis for an overextension of that feature to every instance of that environment, while conversely a low relative frequency of a feature in an environment will provide the basis for an association of the environment with the lack of the feature. In an analogical account, low frequency patterns are not noise as they potentially are in a more abstracting analyses, but rather enhance the robustness of the model: low frequency patterns contribute to uncertainty reduction, their existence is continued by the function they serve. The umlaut case study presents two instances of this: the role of frequency in association with plurality and disassociation with the preterite subjunctive. The same mechanism can be used to explain both overincident and underincident AED attested for this phenomenon.

AED within the paradigm for German plural nouns has been exemplified above. The next paragraphs will treat AED at the lexical level. In Middle High German the theme vowels continued their path towards reduction due to the position of the stress and neutralised to /ə/, obscuring the trigger for umlaut. In OHG, where the theme vowel was still visible, the motivation for the different plural formation mechanism of gast/gasti (guest/guests - an i-stem) and tag/taga (day/days - an a-stem) was transparent and available to speakers. In ModHG this is no longer

[23]Research on the exact threshold for these effects is ongoing. However, there is reason to believe that such a threshold exists: work by Divjak (2017) suggests that memory traces for strings tend to be found if the string has a frequency of more than 0.66 instances per million. Lieberman et al. (2007)'s work on the half-life of irregular verbs concluded that the persistence of the irregular form is exponentially related to its token frequency. It is not unreasonable to suppose that a similar datum would exist for analogical processes: the relation between token and type frequency is in many ways parallel to that of cooccurrence of a feature in an environment.

true, as the alternation is now respectively /gast - gestə/ and /tag - tagə/, where umlauting of the first appears unmotivated. This led to paradigmatically variable AED: it is highly challenging to predict which nouns will umlaut in the plural, as the information about the stem vowel of a noun is no longer available at this stage in the language. Umlaut pluralisation is therefore an accident of history, which is crucial in understanding its distribution.

As a consequence, while it is straightforward to devise a morphophonological rule that describes the umlaut pattern ("theme vowel raises in the plural"), or the larger system of german plurals, it is troublesome for a rule-based account to accurately describe its distribution:

> "By any standard, the German plural system is highly marked and its connection to umlaut especially problematic [...]. The role of umlaut in German morphology is [...] challenging, bringing forth a range of proposals [...]. Morphological uses of umlaut have wrought havoc in such prominent theoretical frameworks as Lexical Phonology/Lexical Morphology [...] This indicates unambiguously that German plural marking and German morphological uses of umlaut represent particularly difficult phenomena for linguistic analysis." (Salmons, 1994)

Proponents of rule-based analyses for German plural formation have suggested that there must be an element of rule-like order to the process, evident particularly in the behaviour of -s plurals. Clahsen (1999) has argued that the distribution of -s is predictable, as the desinence is that which applies by default, easily modeled by an elsewhere condition. A logical suggestion following this would be that all other desinences are in some way regular, in ways linguists haven't individuated yet.

It appears however that while there are indeed regularities in the distribution of -s, the conditions are more complex than what is normally assumed. Wunderlich (1999) suggests that -s is the plural for nouns when the nouns are atypical, which is in practice similar to being the default plural. This includes proper words, onomatopoeae, acronyms and truncation. If a non-nominal word in nominalized by insterting it into a [+N] context, it will take -s. This is why nonsense words (which are often used as a diagnostic for default generalisations) have consistently been found to take -s in the plural: not because it is the default desinence, but rather because nonsense words are not recognized as sufficiently noun-like to qualify for any other route of plural formation. Atypicality of the noun is given as the primary explanation for the choice of the -s desinence, its apparent default status is a consequence of its presence on a plethora of words which have little in common but their atypical status. The argument for rule-like regularity from perceived regularity in at least some plural formation routes is not without counterexplanations.

Because of their focus on input-output relations rather than the relation between outputs, rule-based frameworks in the form they usually take cannot make meaningful predictions about which words form the plural by umlaut, and many attempts to make such predictions to this day effectively amount to listing lexemes belonging to each class of plural formation: a noun is assigned to a class, the property of which is the formation of the plural in a certain fashion, thus rendering the relationship between class membership and plural formation circular.

It is the derivational focus of rule-based approaches that creates the issue. Rule based accounts intended in the most basic sense, that is "accounts involving rules", can potentially describe the data more insightfully, but at some cost to the assumptions that are normally associated with RBP. Crucial to the distribution of

the German plural is a concept of clustered similarity: words with properties that cluster together will act in a similar fashion (similarity of this kind is discussed in Section 1). This type of similarity cannot be described in terms of necessary or sufficient conditions, which rules can model well. Therefore to model this property of the data, a framework must incorporate clustering in some way.

Allowing clustering of rules themselves is an option: this would in a way be equivalent to a group of probabilistic rules competing for their application when an input that matches them all arises. While this may help to model cases in which there is uncertainty about the plural (eg sg. Mittwoch, pl. Mittwoche vs. Mittwochs), it still has to rely on the circularity of class assignment and plural marking. A rule-based model provides no insight into why German nouns form plurals the way they do. This doesn't appear to be an accurate depiction of the synchronic competence of the speakers: given a nonce or novel word (without any information about its class), speakers have intuitions about how such a word may or may not form the plural (as shown in Wulf, 2002; Zapf, 2004 among others), suggesting that they are employing some sort of mechanism of principled class assignment for newly encountered lexemes based on some combination of similarity metrics (phonological shape and morphological gender seem to be the main factors, but semantics and prosodic characteristics also play a role in this particular case).

A second option is manipulating the input directly: in a rule-based approach with a clustered word-based lexicon in which similar words pattern together, with rules in the form Cluster A $\rightarrow$ Plural A, can provide a much more insightful account of the distribution by invoking the variegated similarity of words that form the plural in the same way. Instances of variability of the Mittwoch type can be explained by positing that the word is a peripheral member of two adjancent clusters because

of its features, and as such can form the plural in more than one way. This would however be a very different approach to that taken by the rule-based tradition, namely that of a morphemic, comparted lexicon. It is evident that what allows the latter model to escape circularity of class assignment is the structure of the lexicon, not whether the process is a rule, a constraint or any other formalism. Clustering and variegated similarity in the lexicon then appear to be a crucial characteristic when accounting for AED data, but potentially for linguistic data in general. This would account for both the trends in the lexemes that undergo a generalisation such as German Umlaut, and the apparent lexical specificity of it. This case is a good example of how abstraction and discounting some of the data can lead to radically different conclusions about how it should be modelled, which are however equally internally justified given diverging beliefs about approaching data.

2.1.1.2 Umlaut AED in the Praeterite Subjunctive The same mechanism - relative frequency in an environment triggering analogy - is illustrated by the development of umlaut in the verbal domain: due to low frequency of umlauting in the preterite subjunctive for a series of reasons, this environment has come to be associated with lack of umlaut. The following example will serve to show that this model of the origin of exceptionality is not an exception but rather the rule, so much so that it can happen in multiple directions and because of multiple attractors even with the same formal pattern. The OHG preterite subjunctive lacked umlauting completely, even though some of its forms had the appropriate environment. Consider the following data from Braune Eggers (1986:27, 288-290, 293).

Infinitive	Praeterite	Praeterite Subj.	Past Part.	Gloss
brennen	branta	branti	gibrennit	"to burn"
decken	dahta	dahti	gideckit	"to cover"
zellen	zalta, zelita	zalti, zeliti	gizalt, gizelit	"to say, tell"

The table shows part of the OHG paradigm for -jan verbs (class I weak verbs). At this point in time, umlaut is not present where there is no trigger for it (as can be seen in the preterite indicative) but it is attested where *i/j had once followed root vocalism of (short) *a, whether the desinence was lost by weakening (*-jan $<$ -en in the infinitive - so zellen $<$ *zeljan instead of *zallen), or is still retained (as in the past participles, gibrennit instead of *gibrannit)[24] . An exception to this is the situation in the preterite subjunctive, which presents a trigger (the characteristic -ti desinence, with a high front vowel) but shows no umlauting of the root vowel.

The reason for this unexpected series of forms appears to lie yet again in frequency ratios in the data and the resulting generalisations that these would lead learners to make. Holsinger and Salmons (1999) [henceforth 'HS'] show that, as expected, the preterite subjunctive form of a verb is amongst the least well-attested in texts. Consider the very frequent verbs *senten* "to send" and *furhten* "to fear" - the former is attested in OHG texts in various forms around 200 times overall, with only 3 instances out of these being preterite subjunctives, and the latter is attested overall a similar amount of times with no preterite subjunctive forms at all. Given

[24]Although this pattern is very pervasive, there are still exceptions - forms like prehten "would have bought" are attested (Glosses) but these are decisively in the minority. Note that this is another example of exceptionality to a larger pattern, presumably caused by analogising the form with the rest of its paradigm This item's exceptionality is particularly notable as it has an intervening -ht- sequence between the trigger and the focus, which normally would block umlaut. This is therefore even more clearly a case of morphological analogy which likely has little to do with the phonetic/phonological origins of umlauting.

the relative scarcity of attested relevant forms, it is very likely that there would be high uncertainty surrounding the preterite subjunctive paradigmatic slots.

Another crucial factor for the situation is the form of the desinence for the preterite subjunctive, -ti. As mentioned earlier, intervening -hC- and -LC- clusters will block umlaut - therefore if a root ends in any of /h, l, r/ it will not show umlaut in the preterite subjunctive as the form will present the blocking combination. HS have searched Raven's (1963) OHG corpus and found a total of 65 preterite subjunctive forms. Out of these, 50 contain the classic blocking sequences described above, and therefore don't umlaut. Of the remaining 15 forms, 7 showed characteristics that correlate with umlaut failure such as intervening triconsonantal clusters or trisyllabicity. This leaves only 8 forms out of 65 that unambiguously would call for umlaut. Keeping in mind that the preterite subjunctive was a rare form to encounter, and even permitting that the corpus data we have might have been overrepresenting non-umlauting preterite subjunctive, it is likely that these would have still been encountered with a frequency above the critical threshold for justifying a generalisation about the lack of umlaut in the preterite subjunctive by L1 speakers, leading umlaut to underincide in the preterite subjunctive even though the right environment was available.

The evolution of Umlaut illustrates the role of history in creating AED, and how an acknowledgement of chronological stages is necessary to create a model with maximal generality. The progressive morphologisation of triggers along the chronological dimension correlating with a change in productivity is also clearly exemplified, and it is discussed how different models provide different levels of insight into why this is the case. Umlaut AED within the paradigm demonstrates the kinds of factors that are involved in creating the dissociation, emphasising the key role of

relative frequency, and the importance of the relations between items in a system. The role of analogy illustrates its status as a standard mechanism for explaning and modelling this kind of phenomena within historical linguistics. The emergence of lexical AED in the distribution of umlaut illustrates the different conclusions that different approaches to data can make. Data that is looked at in the fashion of historical linguistics - that is, a minimally sampling methodology which seeks to account for all the attested forms and the variation found in the data - will often be most insightfully accounted for analogically. Moreover, the importance of the interplay between different parts of the grammar in creating AED is evident throughout.

The next case aims to provide another instance in which analogy is the accepted cause of AED of a pattern, as evidenced by the recorded history of the generalisation.

2.1.2 Greek assibilation before nasals in specified morphological environments

The following case, unlike the AED in umlaut, is minimally morphologically conditioned and has chiefly phonological triggers, reinforcing the point that the trigger for analogy can come from any part of the grammar, and that the trend between exceptionality and part of the grammar of a generalisation is not absolute. It also involves desinence boundaries, which are often the locus of AED, as these are associated with high uncertainty for the hearer. As in the previous example, a pattern analogically extends to forms because of type frequency factors as well as similarities in conditions of the environment. This couldn't be concluded without careful attention to the attested data. Yet again the example highlights the importance

of history in generating exceptionality.

The phenomenon in question is assibilation and assimilation of segment before a nasal desinence in specific morphological environments (discussion based on Garrett and Blevins, 2009). Consider the perfect middle (1.SG) and present participle in Ancient Greek:

Perfect Middle

	Root		*1SG*	*Participle*
a.	poie-	"make"	pe-poie:-**m**ai	pe-poie:-**m**enos
	stel-	"send"	e-stal-**m**ai	e-stal-**m**enos
	der-	"flay"	de-dar-**m**ai	de-dar-**m**enos
b.	graph^h–	"write"	ge-gra**m-m**ai	ge-gra**m-m**enos
	plek-	"weave"	pe-ple**ŋ-m**ai	pe-ple**ŋ-m**enos
c.	peith^h–	"persuade"	pe-pei**s-m**ai	pe-pei**s-m**enos
	pseud-	"deceive"	e-pseu**s-m**ai	e-pseu**s-m**enos

The subset of forms in a. has roots ending in vowels or liquids, which take the nasal-initial desinences with no change at the point of contact. Subset b. consists of roots ending in a noncoronal obstruent with various laryngeal specifications, which assimilate to the nasal of the desinence in both nasality and laryngeal specification (note how grap$^{\text{h}}$ - loses its aspiration) - the place of articulation remains unchanged.

This is a very common type of assimilation cross-linguistically, and one which has a phonetic motivation. The situation in c. is however radically different: the roots ending in /t, d/ have the final consonant mutate to /s/ when they concatenate with the same nasal-initial desinence. This only occurs in particular, morphologically specified environments and does not have a phonetic motivation. The same

generalisation is found in deverbal nouns with roots ending in coronal stops and in paradigmatic slots characterized by a desinence beginning in /m/:

	Root		*Derived Noun*	
a.	peit^h–	"persuade"	pei**s-m**a	"persuasion"
	pre:t^h–	"swell"	pre:**s-m**a	"swelling"
	pseud-	"deceive"	pseu**s-m**a	"untruth"
b.	dat-	"divide"	da**s-m**os	"division of spoil"
	hed-	"sit"	he**s-m**os	"(a) swarm (of bees)"
	kne:t^h–	"scratch"	kne:**s-m**os	"itching"
c.	o:t^h–	"thrust"	o:**s-m**e:	"(a) thrust"
	od-	"smell"	o:**s-m**e:	"(a) smell"

These are the only environments in which this generalisation applies. A salient property of this pattern is that it never applies outside of desinence juncture: a:**tm**os 'steam' and sta**t^{h}m**os 'doorpost' show the coronal-nasal sequence unaltered. It is therefore a process typical of what is often characterised as "derived environments" (first highlighted in Kiparsky, 1973 and elaborated upon in Kiparsky, 1982). As such, it is inherently subject to underincident AED, as the generalisation targets some instances of a string of phonemes, but not others which appear identical on the surface. At the same time, desinence boundary effects tend to arise as the analogical extension of a pattern to all desinence junctures, so this instance (and many others) is also a case of Type 1 AED.

Derived environments have been identified in Section 1 as particularly fertile grounds for AED, as it reduces uncertainty for the listener. It could be argued that Ancient Greek assibilation before /m/ in fact removes information, as it has to increase uncertainty about the exact nature of the stem final consonant

(thereby reducing information about the semantics of the form at this particular point along the time dimension of the act of pronunciation) to decrease uncertainty about the desinence. This is not an uncommon mechanism - there's a tradeoff between increasing uncertainty about a feature and contemporarily decreasing it for another.

It is likely that a minor increase in uncertainty about the semantics of the stem is a reasonable price to pay for increased knowledge early in the processing of a word about its agreement desinences, especially in a language such as Ancient Greek, whose syntax is so reliant on them. The neutralization process conceals whether the stem ends in /t^h t d/ or /s/ - this is however not increasing the uncertainty fourfold as it's highly unlikely that the lexicon contains many minimal pairs that only differ in having one of these four consonants stem-finally, and in such cases context is usually helpful in disambiguating. In addition, recent work has been done on the importance of subphonemic factors in disambiguating portions of strings that look identical at the phonemic level - it is plausible that such contrasts would have been present in the neutralised /s/, bringing into question of whether we should be speaking of neutralization at all (Davis et al., 2002; Baayen et al., 2003, Kemps et al., 2005a, 2005b). The increase in uncertainty caused by this process, all factors considered, is in fact extremely minimal if at all present.

Let us illustrate all of this by examining the history of this exceptional pattern, and exploring how the key to systematic exceptionality lies in its history. The starting point of the analogical extension is to be found in the finite paradigm of the perfect middle. Consider its regular formation as illustrated in the paradigm of *stello*[25]:

[25] 3.PL.perf.mid is not shown as it is commonly replaced by a periphrastic form.

a. *Perfect Active*

Singular	Dual	Plural
1. e-stal-k-a	—	e-stal-k-amen
2. e-stal-k-as	e-stal-k-aton	e-stal-k-ate
3. e-stal-k-e	e-stal-k-aton	e-stal-k-a:si

b. *Perfect Middle*

Singular	Dual	Plural
1. e-stal-mai	—	e-stal-met^h*a*
2. e-stal-sai	e-stal-t^h*on*	e-stal-t^h*e*
3. e-stal-tai	e-stal-t^h*on*	—

The perfect active desinences are vowel-initial (with a -k- infix in this particular verb class, which however neither affects nor is affected by the surrounding sounds), while the perfect middle desinences begin with a consonant. There is no phonological interaction between them at the point of contact between desinences in verbs that end in vowels and liquids. However, as anticipated, there are assimilatory changes for verbs that end in non-coronal stops, illustrated here by grap$^{\text{h}}$o:

a. *Perfect Active*

Singular	Dual	Plural
1. ge-gra**p$^{\text{h}}$**-a	—	ge-gra**p$^{\text{h}}$**-amen
2. ge-gra**p$^{\text{h}}$**-as	ge-gra**p$^{\text{h}}$**-aton	ge-gra**p$^{\text{h}}$**-ate
3. ge-gra**p$^{\text{h}}$**-e	ge-gra**p$^{\text{h}}$**-aton	ge-gra**p$^{\text{h}}$**-a:si

b. *Perfect Middle*

1. ge-gra**m-m**ai	—	ge-gra**m-m**et^h*a*
2. ge-gra**p-s**ai	ge-gra**p$^{\text{h}}$t$^{\text{h}}$**-on	ge-gra**p$^{\text{h}}$t$^{\text{h}}$**e
3. ge-gra**p-t**ai	ge-grap$^{\text{h}}$-th-on	—

There is no assimilation in the active as the endings are vowel-initial (and this class doesn't have the -k- infix), but the middle presents it in large amounts: the surface laryngeal and nasal features of the root consonant are fully predictable from the first consonant of the desinence.

Coronal stems in the perfect middle have an added complication. Ancient Greek features the existence of fully regular spirantalisation of a coronal stop before another coronal obstruent (consider for example /'ɪd-te/ → ɪste 'you (pl.) know' and /anut-to-s/ → anustos 'practicable'). Given that the majority of perfect middle desinences do start in a coronal obstruent, this generalisation was well represented in this tense and aspect combination, for this type of stem[26]:

Perfect Middle /pseud-/ "deceive"

	Singular	Dual	Plural
1.	*e-pseu**d-m**ai	—	*e-pseu**d-m**et^h*a*
2.	*e-pseu**s-s**ai	*e-pseu**s-t^h**on	*e-pseus-t^{h}e
3.	*e-pseu**s-t**ai	e-pseu**s-t^h**	—

Perfect Middle /peit^h – /"*persuade*"

	Singular	Dual	Plural
1.	*pe-pei**t^h-m**ai	—	*pe-pei**t^h-m**et^h*a*
2.	*pe-pei**s-s**ai	*pe-pei**s-t^h**on	*pe-pei**s-t^h**e
3.	*pe-pei**s-s**	*pe-pei**s-t^h**on	—

At this reconstructed stage, the paradigm of the verb in this TMA combination still shows an alternation between final stop and the regularly derived sibilant, with a high type frequency of the sibilant stem form (5 out of 7). Because of the relative frequency of the allomorphs ending in /s/, this allomorph of the root was

[26]This stage can only be reconstructed as by the time Ancient Greek began to be written, other forces had obscured this generalisation.

extended prehistorically to the whole perfect middle paradigm by analogy, giving us the forms we find attested:

Perfect Middle /pseud-/ "deceive"

	Singular	Dual	Plural
1.	e-pseu**s-m**ai	—	e-pseu**s-m**et^h*a*
2.	e-pseu**s-s**ai	e-pseu**s-t^h**on	e-pseus-t^{h}e
3.	e-pseu**s-t**ai	e-pseu**s-t^h**	—

Perfect Middle /peit^h – /"*persuade*"

	Singular	Dual	Plural
1.	pe-pei**s-m**ai	—	pe-pei**s-m**et^h*a*
2.	pe-pei**s-s**ai	pe-pei**s-t^h**on	pe-pei**s-t^h**e
3.	pe-pei**s-s**	pe-pei**s-t^h**on	—

It is here for the first time that we can see what could be interpreted as a generalisation that a coronal obstruent assibilates before /m/, in the first person forms. In the postarchaic period, combinations of the form /tm, dm/ at desinience junctures can still be found - the generalisation that can be extracted from the 1st persons of the perfect middle appears to then have spread analogically to the desinence juncture of mediopassive participles (characterised by the desinence -menos, -a, -on) from a coronal stop stem, which have quite high frequency counts in the language, and likely therefore played a major role in helping spread the pattern to other desinence junctures with a /tm, dm/ combination.

The example illustrates how analogy can create underincident AED, by confining a pattern to a high-entropy environment (in this case a desinence juncture), and overincident AED by extending a pattern to, first, all forms of a certain TMA value which share a phonologically similar stem consonant, and subsequently to

other high-entropy environments which are phonologically similar to the original, with the function of reducing uncertainty. It is this very useful function of such extensions which explain their high crosslinguistic incidence.

As can be seen from its history, this type of pattern is the result of analogical effects based on phonological and morphological attractors. This and previous examples illustrate that it is in fact very common for analogical mechanisms triggered by frequency effects to act on patterns in a way that leads to AED even when the appropriate phonological environment is present or in items where their application is not phonologically justified. This is commonly accepted in historical linguistics, where analogy is often used as a tool to explain surface patterns that don't match the expected output of regular sound change conforming to the Neogrammarian hypothesis. In addition to this, an analogical explanation for this type of pattern foregrounds the functional purpose that AED of a generalisation may serve, by linking the two in the analysis. Looking at the history of a generalisation appears to be the best way to understand its synchronic distribution, especially when there are exceptions to it, and the causes that led to its latest form.

2.2 Synchronic AED and Interim Conclusions

Opaque data is shown to be much more complex than predicted by a simple rule-based framework, in a way that sometimes makes it impossible for a framework of this kind to capture the relevant generalisations insightfully, as is the case in the German plural example. A number of technical strategies are available within a rule-based approach. One possibility is to adopt a more elaborate rule inventory or to impose more intricate conditions on rule application at the cost of significantly

increasing a model's complexity. Another option involves invoking a competence-performance distinction and classifying some of the recalcitrant phenomena as outside the descriptive scope of the core system. Although rules are rarely claimed explicity to be exceptionless, they are often tacitly treated as such because of a characteristic focus on higher-level generalisations about language. In contrast, an analogical approach can, at least in principle, concern itself with all the small trends in the data, small as well as the large, gaining robustness.

Given such different theoretical commitments, implementations and approaches to data of the two types of theories, internal evidence is unlikely to be decisive one way or another. However, a minimal requirement for theoretical validity is that both theories should be able to account for the attested facts in a way that is internally consistent. This forms the topic of the next section. A textbook case of synchronic opacity will be analysed starting from the data, however messy it may be, and competing approaches to AED will be evaluated.

As suggested in Section 2 above, cases of synchronic opacity can be analysed in the same way as cases of diachronically emerged exceptionality. This may even appear preferable once the exceptions, the patterns and subpatterns, and their history are taken into account. The next subsection will feature examples of synchronic AED.

2.2.1 Polish Raising

The first case is Polish o-raising, which the theoretical literature has examined in conjunction with final devoicing, as devoicing can confounds the output of raising. Consider the masculine nouns in Table (2): the first form is the nominative

singular, which is without desinences, while the second is a form with a vocalic desinence.

	Nominative Singular	Genitive Singular	Lexeme Gloss
a.	/bup/	/bɔb-u/	"bean"
b.	/xut/	/xɔd-u/	"pace"
c.	/kɔt/	/kɔt-a/	"cat"
d.	/vus/	/vɔz-u/	"cart"
e.	/dzvɔn/	/dzvɔn-u/	"bell"

Let us now review the analysis commonly attributed to the phenomenon in theoretical accounts. The underlying generalisation is identified as the following: in Polish, /ɔ/ in a word-final syllable raises when followed by an underlyingly voiced non-nasal consonant As can be seen in the first column, Polish doesn't allow voiced obstruents in word-final position, and avoids this by devoicing the offending segment. This, unlike the o-raising, appears to be an automatic low-level postlexical process (Kenstowicz Kisseberth, 1979; Rubach, 1984; Bethin, 1992)[27]. Obstruents however are not neutralized in voice intervocalically, therefore a vocalic desinence such as the genitive singular /u/, /a/ is a good diagnostic of the underlying laryngeal qualities of the segment.

As can be seen in the data there is an alternation in the height of the root vowel between the two columns. It is usually assumed that /ɔ/ is the underlying form of the segment, which raises when in a word-final syllable and followed by a nonnasal voiced obstruent. Forms a) and b) show that raising is conditioned by underlyingly voiced stops, c) shows that underlyingly voiceless stops don't cause raising, d) illustrates that underlyingly voiced fricatives also trigger raising, and e) shows

[27]It is taken for granted to the point that there is incredibly little discussion about this process alone - most of the literature citing it revolves around its interactions with other generalisations.

that nasals do not trigger raising. In RBP terms, o-raising must be ordered before final devoicing to give the attested forms:

	/bɔb/, /xɔd/		/bɔb/, /xɔd/
Raising	bub, xud	**Devoicing**	bɔb, xɔd
Devoicing	bub, xud	**Raising**	—
	[bup], [xut]		*[bɔb], [xɔd]

This is a counterbleeding on environment effect: devoicing takes away the environment in which o-raising applies, making the raising appear unmotivated on the surface and therefore making it appear to have overapplied. Bethin (1978) notes that this also applies to loanwords, suggesting therefore that the pattern is still productive: the feminines *doz-a* "dose", *pagod-a* "pagoda", mod-a "fashion" show the alteration in the desinenceless genitive plural: [dus], [pagut], [mut][28]. This is the analysis of the phenomenon found in Kenstowicz and Kisseberth (1979), Bethin (1992), Kenstowicz (1994), and generally agreed upon in studies in this tradition.

This case is often thought of as a clearcut example of opacity. The surface overextension of o-raising exhibits strong similarities to the cases seen in the preceding section, the main difference being that there seem to be no morphological/semantic causes for it this time, and it seems confined to the phonology. It is worth considering whether it can be analysed in a fashion similar to that of the historical linguistics cases. The first thing to note is that there are a number of exceptions to the pattern synchronically. These can be best observed in oral sonorant stems, as in these the alteration is transparent, as sonorants cannot be devoiced: when the sonorant is word-final, /ɔ/ raises to [u]. It however doesn't raise when the stem is

[28]Even though the tendency to extend the pattern to masculines is not nearly as strong, discussed in greater detail in this section.

followed by a desinence, such as in the nominative plural, as /ɔ/ is then no longer in the final syllable:

Stem UR	*Nom Sing*	*Nom Plur*	*Gloss*
/dvɔr/	dv**u**r	dvɔrɪ	"mansion"
/bɔl/	b**u**l	bɔlɛ	"ache"
/pɔkɔj/	pɔk**u**j	pɔkɔjɛ	"room"
/stɔw/	st**u**w	trɔwɪ	"table"

The first table below shows exceptions in the native vocabulary - stems in liquids are shown, to illustrate exceptions to the transparent pattern, so that the confounding factor of devoicing can't be claimed to play a role. The second table below shows exceptions in loanwords - words in underlyingly voiced obstruents which undergo final devoicing are used, so that the exceptionality cannot be claimed to be related to the word not having been sufficiently assimilated into the native vocabulary. Such exceptions are not hard to find, especially in recent loans (Sanders, 2003), which potentially contradicts the characterisation of o-raising as a productive synchronic process, and suggests that it might be better characterised as an active one instead.

Stem UR	Nom Sing	*Nom Sing	Nom Plur	Gloss
/pɔr/	pɔr	*p**u**r	pɔrɪ	"leek"
/kɔlɔr/	kɔlɔr	*kɔl**u**r	kɔlɔrɪ	"card suit"
/xɔl/	xɔl	*x**u**l	xɔlɛ	"lobby"
/parasɔl/	parasɔl	*paras**u**l	parasɔlɛ	"umbrella"
/kɔvbɔj/	kɔvbɔj	*kɔvb**u**j	kɔvbɔjɛ	"cowboy"
/ɔɕɔw/	ɔɕɔw	*ɔɕ**u**w	ɔɕɔwɪ	"donkey"
/grut sɔw/	grut sɔw	*grut s**u**w	grut sɔwɪ	"gland"

Stem UR	Nom Sing	*Nom Sing	Nom Plur	Gloss
/glɔb/	glɔp	*gl**u**p	glɔbɪ	"globe"
/snɔb/	snɔp	*sn**u**p	snɔbɪ	"snob"
/ɛpʲizɔd/	ɛpʲizɔt	*ɛpʲiz**u**d	ɛpʲizɔdɪ	"episode
/kɔd/	kɔt	*k**u**t	kɔdɪ	"code"
/nɛkrɔlɔg/	nɛkrɔlɔk	*nɛkrɔl**u**k	nɛkrɔlɔgi	"obituary"
/rɛkɔrd/	rɛkɔrt	*rɛk**u**rt	rɛkɔrdɪ	"record"
/fʲɔrd/	fʲɔrt	*fʲ**u**rt	fʲɔrdɪ	"fjord"
/xɔwd/	xɔwt	*x**u**wd	xɔwdɪ	"homage"
/t sɔwg/	t sɔwk	*t s**u**wk	t sɔwgi	"tank"

A rule-based account does not strictly predict any of the forms above. Assuming that a rule-based theoretician cannot dismiss all of the above forms as being exceptional for other reasons, there are several possible causes and solutions for this shortcoming. The most salient issue to consider is that of the consequences of telescoping history: o-raising is indeed a very pervasive process in the language, but it seems it's synchronically active rather than productive, as there are many items which fit its structural conditions that eschew it. Rules of this type would be lexically pervasive enough to appear active, but would still present a number of exceptionsm which an approach that focuses more on generalisations than on deviant items may not give enough weight to. While this points to o-raising being chiefly diachronic in nature, a model such as RBP will likely include it in the synchronic grammar because of its very high frequency and regularity of application in the language. However, incorporating less-that-fully-productive generalisations in a synchronic grammar with a serialist mechanism has the consequence that a number of predicted outputs will be incorrect. A realisational word-based lexicon

doesn't encounter this problem: o-raising is posited once in the history of Polish and many words still preserve it to this day - the generalisation has extended to some words based on similarity metrics, but not to others (later in the section it will be shown that analogy plays a sizeable role in the synchronic situation). Models that function by mirroring the chronology of the language have a choice to increase their robustness: either mirror history as closely as possible, avoiding abstraction and idealisation, or give a diachronic explanation to patterns with a diachronic element. The two options are in fact very similar in practice, the main difference being whether to fully bring these patterns into the synchronic or the diachronic domain.

After revealing the exceptions, which seem to not be following a clear pattern, raising begins to look similar in some ways to the patterns in the previous section: there are plenty of synchronic exceptions that cannot be neatly explained with blocking rules, or by tweaking the environment of the generalisation. To establish further similarity it is reasonable to look at the history of the pattern to trace its origins and possible reasons for exceptions. For a comprehensive analysis, see Sanders (2003) and Bethin (1978).

Lechitic, Polish's ancestor, underwent vowel lengthening in closed syllables, but exclusively when the final consonant was voiced. Later Lechitic lost vowel length before nasals, so Modern Polish only shows the lengthening before oral sonorants and underlyingly voiced obstruents. There is a direct connection with the back vowel alternation: long Lechitic /ɔː/ was eventually raised to Middle Polish [u] while short /ɔ/ remained unaffected, which is why o-raising doesn't occur before nasals. Following the completion of this stage, Polish acquires a final devoicing pattern between the 14th and 15th century, which obscured the cause of the length-

ening change preceding an obstruent. Around the same time, vowel qualities were also changing. The long mid vowels /ɛː/ and /ɔː/ began to be pronounced slightly higher (likely as [e:] and [o:], Stieber 1968) compared to their short counterparts, adding to the dimensions of contrast between mid vowels not only length, but also tenseness. By Middle Polish, vowel length contrasts had faded, reducing the number of oral vowels from 10 to 7.

Early Old Polish		Late Old Polish	
i iː	u uː	i	u
eː	oː	e	o
ɛ	ɔ	ɛ	ɔ
a aː		a	

Finally, there is a second process of vowel raising that occurred historically - and potentially is still occurring - in Modern Polish. While in Kashubian and other Polish dialects, the reflex of Middle Polish *o is still pronounced differently from both [ɔ] and [u], in the standard it has fully merged with /u/. This brings us to the present-day situation: /o/ raising to /u/ before voiced segments (except for nasals) word-finally, an alternation which is masked by devoicing. It is evident that o-raising is diachronically not a single process at all. Every historical change will have exceptions for various reasons, and o-raising actually presents many apparently unrelated exceptions of this kind. To account for all these exceptions more accurately, a derivational model would have to include each of these steps as a synchronic rule, even though many of the stages above are known to be complete and not active. However, this still wouldn't make accurate predictions about the data, as it appears that analogy is heavily involved in the distribution of this pattern, so an analogical component too would have to be incorporated.

Baranowski and Buckley (2003) tackle exactly the issue of the degree to which analogy is involved: they examined words which show an alternation between forms with and without o-raising. This is quite a sizeable neighbourhood of words, with fairly high activation, given that, as we have seen, many of the words that undergo o-raising are very common. There are, however, words, both in the native and borrowed vocabulary, that raise unexpectedly or fail to raise when expected to, both in words affected by final devoicing and in words which are not. To stick to the native vocabulary, consider stop-a - stóp[29] "foot", which raises even though it precedes an underlyingly voiceless consonant, and the opposite case of tor-y - tor "track", which fails to raise even though it is followed by a voiced consonant (along with all examples in the first table above). Because these are quite common words it's hard to ascribe their behaviour to uncertainty surrounding their pronunciation, and because they are part of the native vocabulary, exceptionality cannot be claimed as a property of borrowed items.

Arguably, o-raising is more accurately portrayed as a fact about the individual lexemes than about the grammar, similarly to the German Plural example. A lexical locus of this generalization, would help to explain why there are so many exceptions to the pattern, and why their scope is so hard to characterise. To explain the wide scope of the pattern, we can appeal to a lexically-driven process of analogy. The pattern was exhibited initially by a few words which were common enough and similar enough in shape to others to induce analogical extensions that spread the pattern.

Evidence that analogy is and was a likely source for this diffusion, rather than a

[29]Raising is indicated in Polish spelling by an acute accent - <ó> is pronounced [u]. As there are no exceptions to this, the written form of the items will be used throughout.

more general rule type, comes from the differential treatment of borrowings which are quite well integrated in the language. Some do not undergo the alteration at all, especially if they are masculines in citation form, and without any following desinences. In contrast, borrowed feminine and neuter nouns tend to undergo the alternation, especially if the borrowed citation form has a desinence.

Note the importance of grammatical gender as a factor, something which analogy is normally assumed to be able to take into account. The difference determined by whether the citation form appears with a desinence or not is connected to the mechanisms that help us predict a form of a word given another. Gender is indirectly correlated with this, as words ending in a consonant tend to be borrowed as masculine, but words ending in a vowel tend to be borrowed as feminine. Take the word snob "snob" (nom. sg. masc.), which in its citation form shows the perfect environment for raising (/o/ syllable-finally, as well being followed by a voiced stop that fails to undergo devoicing on account of being borrowed), but lacks raising - the learner will interpret this as clear evidence that the lexeme doesn't raise in any of the forms. However, a borrowing with a potential desinence like mod-a "fashion" (from Italian moda, borrowed into the language and reanalysed as having the typical nominative singular feminine desinence -a) shows the /o/ in a non-raising environment, as the syllable it belongs to is not word final. This leaves open the possibility that the lexeme in fact might raise /o/ in the right environment. Learners can 'choose' on the basis of similarity with lexemes that raise /o/ whether the new borrowing will too, as it does in this case: men. pl. fem).

To understand what the attractors might be in this situation, it is also worth noting that based on the data in Tokarski (2002) from over 4000 words, there is

a wide range of differences in the degree to which different stem-final consonants trigger raising:

	b	**d**	**g**	**dz**	**dź**	**z**	**b**	**ż**	**ł**	**j**	**l**	**r**
ó	48	142	104	3	8	54	40	15	53	90	6	129
o	20	38	201	0	1	1	130	4	43	14	170	817
	70%	79%	34%	100%	89%	98%	24%	79%	55%	88%	2%	14%

The variation between the highest and lowest values is in part due to the types of words that tend to end in the relevant consonant, which reinforces the possibility that analogy may be at work. If there is a large neighbourhood of loanwords (which largely don't raise) ending in a certain consonant, its likelihood of raising will be lower. Consider for example Latin or Greek words in *-or (aktor), -ora (metafora), -log (katalog), -ol (metanol),* and *-oza (glukoza).* None of these undergo raising, which is why the percentage for stems in consonants like /r/, /l/, /z/, /g/ is particularly low. However, even after discounting loanwords, the rate of raising ranges from 21 to 100% - so the final consonant (and similarity in word shape more generally) is also certainly a factor in itself.

Baranowski and Buckley (2003) also conducted analyses to try to identify potential factors for attraction. They focused on liquid stems as these are the ones that show the most inconsistency even in the native vocabulary. In monosyllables, gender appears to be a factor in the analogy: words resembling[30] *gol "goal" (masc.)* didn't raise, but words resembling *sól "salt" (fem.)* did. There is a possibility of analogy across classes if the phonological similarity is very strong, in which case the gender tendency can be overridden. However, as monosyllables don't have scope for as many distinctive properties, it is often hard to pick out the factor that triggers

[30]Resemblance here can be characterised in terms of edit distance for the various measures.

analogy. For polysyllables this was easier to ascertain. Baranowski and Buckley asked adult speakers to give the genitive plural for a series of polysyllabic nonce words that had variable similarity to *gondola - gondol "gondola"* and *topola - topól 'poplar'*[31]. Speakers varied in the degree to which they raised overall (one speaker never did - but some variation in the generalisations drawn from common data are to be expected if a process operates analogically). A similar experiment was conducted on masculines[32]: nonce words that resembled either *potwonster"* or *kaczor "drake"* were created and introduced to the subjects in a desinenced form, and the subjects were asked to complete a sentence requiring the word in an undesinenced form. Nonce words resembling the former raised drastically more often than the ones resembling the second (only two tokens of raising in words similar to the latter were found). Similarity to existing words rather than the application of generalisations seemed to be the best predictors of whether a nonce word would raise or not. The behaviour of liquid stems seems to show that analogy is most definitely at work, rather than an active across-the-board generalisation.

Analogical underincident AED can be seen in stems ending in a voiceless stop, which are traditionally described as non-raising. They do in fact show significantly less raising overall compared to their voiced counterparts - however a few stems in the native vocabulary do raise. As expected given B&B's work, stems with similarity to *zatoka - zatok 'bay'* showed just one raised token, while those similar to *sobota - sobót 'Saturday'* (and robota - robót 'work') raised significantly more. Interestingly a few tokens with final /k/ were also raised, even though Polish

[31]Both are feminines in which the genitive plural is an unsuffixed context, which therefore allows raising.

[32]In which the nominative singular is the unsuffixed citation form with the right context for raising.

provides the speaker with no examples of raising in this environment, as once again the overall similarity to existing stems, rather than single characteristics about their shape, was found to be a better predictor of raising.

As we have seen in the diachronic description of the pattern, no stems ending in a nasal ever raise. However, when this generalisation was tested under experimental conditions, it was observed that some nonce words in nasals did raise if they were similar enough to raising words ending in a raising consonant. Almost all their participants raised *potwón*, almost certainly because of its similarity with *potwór "monster"* - if this similarity is the operative factor, it would be misleading to suggest that the pattern is rule-governed.

Therefore, even phenomena that are often used as textbook cases of opacity seem to exhibit surface patterns that appear difficult to describe without invoking analogical factors. In fact, a completely analogical account could be imposed on them: if we assume the process is indeed lexicalized, there are two groups of words - those that raise and those that do not. These seem to be closely connected in neighbourhoods based on phonological shape and gender as the two main factors, as shown by the treatment of polysyllabic nonce words (feminines tend to raise more than masculines, and regardless of gender those with a shape more similar to raising words tend to raise themselves). The devoicing generalisation itself could be treated as a purely phonetic process that has articulatory motivation, given its automaticity and pervasiveness. If it were to show even minimally idiosyncratic behaviour, an analogical account of deviations too could also be proposed. A lexicalized and paradigmatic approach which imposes no ordering offers an explanation for why the presumed ordering of the generalisations appears sometimes to be reversed, or why either may fail to apply to a form. As in other cases, knowl-

edge of the history of the pattern yields insight into the apparent anomalies in the synchronic pattern. The fact that devoicing only became active after the various stages that led to o-raising helps to explain why it would mask the generalization. A historical perspective identifies the cost of collapsing processes that applied at different times and is compatible with the observation that the pattern diffuses through the based on similarity in form and features.

2.2.2 Canadian Raising

Similar analyses seem to be equally applicable to many opaque patterns. Such an analysis is easier to justify when the history of the pattern is well known and well attested, and when there is a record of exceptionality to the ordering relationship proposed. In situations such as Canadian Raising, the next case study, it appears harder at first glance to motivate an analogical explanation for the pattern observed as it is commonly treated as being exceptionless, or as having exceptions that behave in a fully predictable manner (Halle, 1962,; Chomsky, 1964; Paradis, 1980; Pater, 2014). Moreover, the interaction is between two low-level phonetically motivated processes - which are commonly regarded as the most regular and productive kind of phonological process. Relatedly, CR is a relatively recent phenomenon (first pointed out by Primer, 1890; described in Chambers, 1989; Thomas, 1991), with most estimates suggesting it is around 100 years old in Canada itself and even more recent in North America. Given the importance history has had in motivating an analogical analysis for previous examples, the absence of significant information on the diachronic dimension of this pattern may hamper the formulation of an analogical alternative with the robustness of previous case studies.

The generalisation is formulated (originally by Joos, 1942) as the raising of the onglide of the diphthongs /ai/ and /au/ to [ʌi] and [ʌu] respectively before a voiceless consonant. This is masked in diphthong + coronal stop environments by flapping, which neutralises the voicing contrast intervocalically. As a result, raising or non-raising of the diphthong may be the only indicator of the underlying voicing of the following coronal stop. From a surface perspective, it appears as if raising before a voiced consonant is overincident. The na expectation would be that all instances of /ai/ and /au/ preceding a surface tap (a voiced sound) would stay unraised.

Formal analyses have tended to focus on general patterns rather than on the exceptions to the pattern. The variety of Canadian Raising attested in Canada has been the object of a great deal of attention mainly because it bears on claims about the opacity of serial derivation. First of all, it must be pointed out that CR is not an exclusively Canadian phenomenon: an extended range of patterns can be found by examining the full extent of the Canadian Raising isogloss, a generalisation with a misleading name as it extends beyond the borders of Canada. In the map in Figure 3 (from Labov, Ash Boberg; 2005), the green dots represent informants whose pronunciations of the nuclei in /ai/ before a voiced or a voiceless stop differed by at least 60Hz, which was the diagnostic they used for CR.)[33]. While most speakers with CR in this map are located in Canada or near its southern border, isolated informants with the feature are present throughout the US.

Before discussing the synchronic situation of the generalisation in the different areas, let us review what is known about its history and origins. As previously noted,

[33]Not only is CR a feature not exclusive to Canada, but it is also found in areas far removed from it, such as Martha's Vineyard (Labov, 1972) and Virginia (Shewmake, 1943), amongst others across the globe.

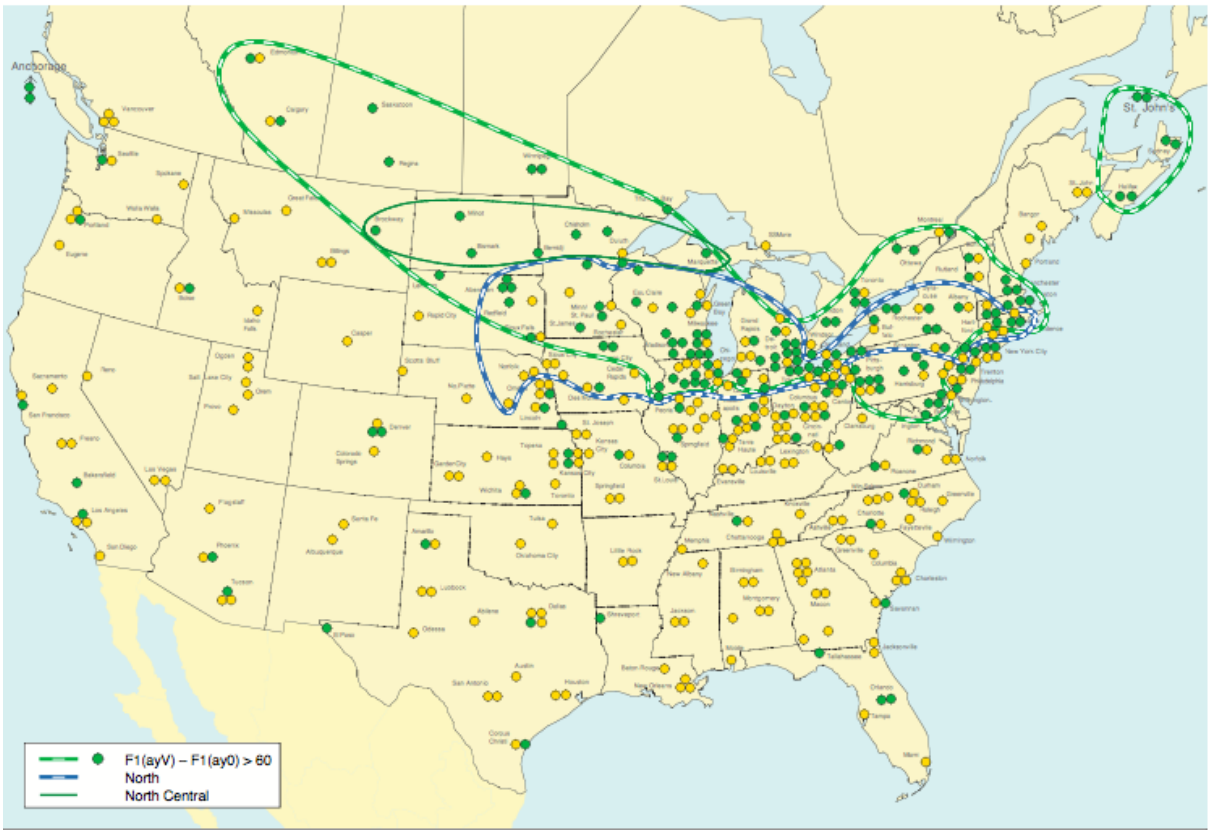

Figure 3: Isolgloss of /aɪ/ raising in North America

the pattern is relatively new in North America (about 100 years old in the North of the continent, the first area to be affected) and is gradually spreading southward. This pattern is well-documented in linguistic atlases and dialect surveys. It can be diagnosed by measuring the mean difference in the frequency of the nuclei of the diphthongs before a voiced and a voiceless obstruent in the different areas of the continent. The North presents the greatest mean differences, signifying a more advanced stage of the change, which progressively diminish as one moves south (Thomas, 1991).

North American English is not the only variety to have a pattern of the CR type - dialects like Scottish English[34] (Chambers, 1973) and Caribbean English (Trudgill, 1986) also present a raising of low-onglide diphthongs before voiceless segments. The origin of this common sound change is thought to lie in constraints of timing units combined with articulatory pressures: CR-like processes cross-dialectally occur in positions that favour vowel shortening, namely closed syllables and before voiceless consonants (Chen, 1970; Kluender, Diehl Wright, 1988). Shortening environments place pressure on long sounds in general, but particularly on diphthongs with a low onglide, as the distance between the different parts of the sound, the onglide and the offglide (front or back), is greatest in this type of segment (Chambers, 1973). Hence for the phoneme to complete its trajectory in the shorter span of time allocated to it, the gesture for the onglide begins higher than in non-shortening environments (Myers, 1997). This has been progressively phonologised into a generalisation that raises the onset of the diphthong before a

[34]Linguistic drift had been commonly assumed to have caused CR, as Scottish English (the variety spoken by the early colonisers of the area) also features a similar phenomenon. However, more recent work in experimental phonetics outlined in this section suggests that the patterns' origins are likely due to articulatory pressures, and so there is no a priori reason to posit a common origin. Moreover CR is distinct from Scottish raising in a number of ways, so treating them as distinct phenomena appears preferable (Thomas, 1991).

voiceless sound. The transition from phonetic to phonological has occurred slightly differently in different dialects (Myers, 1997). In all varieties the raising occurs in the environments where vowel duration is shortest, however the cutoff point differs, with Western NY including /_r/ as an environment for raising while this is excluded in Canadian varieties.

Vowel Length

Environment	**(msecs)**	**Canada**	**Western NY**
_t	210	ʌɪ	ʌɪ
_s	269	ʌɪ	ʌɪ
_r	296	aɪ	ʌɪ
_d	318	aɪ	aɪ
_z	390	aɪ	aɪ

Especially in the North therefore it appears clear that the pattern, while originally phonetically motivated, is no longer phonetic.

The history of the pattern, while not long or particularly well documented (Thomas, 1991) anticipates the synchronic situation. Diphthongs with low onglide are raised before voiceless segments (what is classed as a voiceless segment exactly depends on the dialect) tautosyllabically. It seems that even such a young pattern does not avoid behaving in idiosyncratic ways which are not straightforward to characterize. As a young, phonetically based pattern, the generalisation is expected to behave regularly and to keep idiosyncrasies to a minimum, especially in its earlier stages, so the presence of exceptions to the generalisation is particularly noteworthy in this case study. These exceptions suggest that complex AED patterns may be present since the earlier stages of phonologisation and that they aren't necessarily the product of a long history.

More work has been done within the sociolinguistic and descriptive traditions on the situation in the Northern US states, a stage of the change which should be equated with earlier stages of the pattern, which in theory should then present very few irregularities if any. The examples below will come from the Northern US for this reason.

Let us begin with data from the Northern US (Vance, 1987). The first thing he notes is that there is an asymmetry in the overall raising of the diphthongs depending on the frontness of closing: the raising of /ai/ is generally more widespread than that of /au/. This suggests from the outset that the generalisation doesn't seem to be operating across the board in the same way - there is at least a need for two separate generalisations. Let us therefore focus on the distribution of the raised and unraised variants for /ai/.

There is no raising if the diphthong and the voiceless consonant belong to two separate morphemes: there is no raising in *dry-clean*. However, some informants had raising in *high school* and Vance's speakers had it in *high chair* (no other compounds with high- seemed to elicit raising, but lexicalization of these compounds in at least some of the informants might be adduced as the reason for the exception). This suggests a relative (but not absolute) sensitivity to morphological boundaries. Moreover, Chambers (1973) notes that the lower variant, regardless of the voicing of the following consonant, generally occurs in unstressed syllables which immediately precede a stressed syllable. This suggests a relative (but yet again not absolute) sensitivity to stress of the pattern. A different picture is emerging here: this now appears to be a complex pattern, sensitive to a number of things (voicing of the following consonant no longer seeming the most prominent factor, as sensitivity to morphological structure and stress also play a role), but which

doesn't appear characterisable by a series of rules parsimonious enough to not defeat the point of attempting a rule characterization in the first place. The pattern seems to necessitate analogy to be modeled accurately: such an analysis would capture the trends while at the same time allowing for the exceptions.

Let us now get into even more detail to zoom in on the amount of quirkiness present in what is usually described as a textbook example of regular opacity.

Informant judgements for Chambers' Data (1973, 124-127)							
	NR	JV	TV		NR	JV	TV
citátion	ai	ai	?	*isósceles*	ai	ʌi	?
dichótomy	ai	ai	ai	*micrómeter*	ʌi	ʌi	?
hypótenuse	ai	ai	?	*psychólogy*	ai	?	?
Informant judgements for words having same stress pattern as Chambers' data							
bicárbonate	ai	ai	ai	*mitósis*	ai	ai	ai
disúlfide	ai	ai	ai	*psychótic*	ai	?	?
icónic	ai	ʌi	?	*tycóon*	ai	?	ai
itínerary	ai	ʌi	?	*typhóon*	ai	?	ai
itálics	ai	ʌi	ai	*vitúperate*	ai	?	?
licéntious	ai	ai	?	*vitálity*	ai	?	ai

Vance's informants' performance on Chambers' word list, (NR from Rochester, JV Minnesota/Minneapolis, TV, Minneapolis/St Louis/Chicago) whose speech he deems representative of the middle class of their geographical area, but also presents a relatively detailed account of larger patterns he notices in the speech of the areas, as well as summarizing work done before him on the issueA question mark indicates uncertainty about the pronunciation, not necessarily due to not being aware of the word, so the label subsumes uncertainty about the raising with uncertainty about other feature of the word

Even with just three speakers, it is apparent that there is plenty of inter-speaker variation within what is supposed to be the same isogloss. Different speakers presenting different generalisations for the same pattern (especially where these differences cannot be easily subsumed by subrules) is to be expected if the pattern operates at least partly analogically.[35]

Chalmers compares *biséxual*, in which his Canadian informants had [ai], with *bícycle*, in which they had [ʌi]. As these two words have the same stem+prefix pattern (of arguably similar synchronic transparency, although there is the confounding factor of the influence of literacy), he uses this minimal pair to suggest that the stress is the main conditioning factor rather than morphological structure. However Vance's speakers show that morphological structure is relevant for them: *bíceps, bífocals, trípod* and *víscount* all have the stress on the diphthong and didn't raise for any speaker. So far, this is in line with Chalmers' observation. However, the unraised variant was also found in *bicenténnial, trisyllábic* and *anti-semític* - not only is the stress not on the diphthong, but it is also not on the immediately following syllable. This therefore shows that Chalmers' generalisation is inaccurate, and there must be additional factors at work.

McCarthy (1982) suggests that [ai] occurs before a voiced consonant when a stress-neutral juncture intervenes However, the analysis doesn't quite hold up. Prefixes cannot be inherently specified as stress-neutral or not, as their behaviour tends to vary: *bi-*and *tri-* are stress-neutral in *bicenténnial* and *trisyllábic*, but not in *bícycle* and *trícycle* (words in which Vance's speakers had the raised variant, assuming that

[35] Arguably, a rule-based account in which speakers just make different generalisations could be given - the crucial issue is that these generalisations do not appear to be easily expressable in terms of rules, which one would expect especially in newly formulated generalisations made by individual speakers.

these are the same element, which McCarthy does). So adding the assumption that a prefix will be stress-determining in some words but not others, McCarthy's analysis could be reformulated as to only apply for the latter kind. This is still however not quite accurate, as it appears that two distinct boundaries are required in the stress-determining cases: compare *bícycle* with *bífocals* and *bícuspid*: in *bícuspid*, the prefix is stress-neutral, and the diphthong is unraised. In *bícycle* and *bífocals* the main stress is on the prefix: however all three of Vance's speakers had [ai] for the former and [ʌi] for the latter. The proposed analysis of this deviance is to do with whether the quality of the first vowel is preserved or not by prefixing, indicating a closer relationship between the two morphemes if the vowel is reduced in the unstressed position, as is the case in bicycle but not in bifocals. So what we see is a continuum of juncture salience, which in turn will influence stress assignment and therefore raising or lack thereof. The salience of a desinence juncture will likely be influenced by factors such as the history of the word (how productive the pattern is/has been; whether it is still synchronically productive; whether it's a borrowed prefix/root etc), the transparency of the affixation, and its token and type frequencies, which correlate with how familiar it is to the speakers (one assumes that the more frequent it is, the more familiar it will be to speakers and). This process too could therefore be interpreted as lexicalized, or at least as more parsimoniously and accurately described by a word-based model.

The place of the individual lexeme on the continuum does not, however, seem to tell the whole story: there is also a non-negligible number of items which are exceptional, even when stress and morphological structure are taken into account:

Informant judgements: Exceptions							
	NR	JV	TV		NR	JV	TV
bíson	ʌi	ai	?	*líke*	ʌi	ʌi	?
colítis	ʌi	ʌi	ai	*neurítis*	ʌi	ʌi	ai
Cýclops	ai	ai	?	*níce*	ʌi	ai	ai
Elísha	-	ai	ai	*nítrate*	ʌi	ai	ʌi
glýcogen	ʌi	ai	ai	*pýthon*	ai	ai	ʌi
ícon	ai	ai	ai	*stípend*	ʌi	ai	ai

*NR had neither [bʌisn̩] nor [baizn̩], but JV and TV had [baisn̩]. Chambers (1973, 117) notes that some of his Canadian informants also had [ai] in *Cyclops*.

Not only do items frustrate attempts to state generalisations, there is also persistent speaker variation. The words included as exceptions range widely in token frequency, so their exceptionality cannot be chalked down to frequency factors. This supports a word-based analysis of CR, which is less costly for the speaker than having to learn convoluted generalisations with many special conditions, which still do not cover all the attested forms.

The raised variant is also found in unexpected environments (i.e. not preceding a voiceless consonant): a large group of examples of this are words in which /ai/ is followed by /r/ - all three of Vance's speakers had [ʌi] in *fire, firing, fiery, inquire, iris, inspire, Ireland, Irish, iron, pirate, spiral, tried, wire, wiry*. This is true whether the /r/ is syllabic or not (cf *iris* vs *iron*), but there are also several words in which all three speakers have [ai] before /r/: *briar, crier, diary, flier, friar, gyrate, higher, liar*. It doesn't seem to be the result of morphological boundaries (as /ai/ is followed by a desinence juncture only in *crier, flier, higher, liar* - there

is no juncture in *briar* and *friar* unless we assume a folk reanalysis. As for diary, all three speakers have a disyllabic pronunciation and the word doesn't present particular opportunities for phonological reanalysis). A phonological attractor here appears to be implicated in a deviant trend which is symptomatic of analogical pressures.

To conclude, an examination of the full range of attested CR patterns appears to motivate a word-based analogical treatment of the phenomenon.

3 Interim Summary

As was shown, systematic exceptionality in practice is not so strictly systematic after all: there are many patterns and sub-patterns that seem to be motivated by factors in all areas of the language. These can be treated, elegantly and naturally, in terms of analogical pressures or attraction. A formal analysis in terms of rules or constraints may choose to dismiss the messy component of the data for the purpose of focusing on higher order generalisations. Nevertheless, even this type of analysis accords analogy a role in accounting for the messy residue, since a full account of the data requires at least some invocation of analogical pressures.

4 External Evidence on Opacity

The problem of opacity ultimately fits into the greater debates about abstraction - whether there is any, to what degree, whether there are any sub-word (or sub-morpheme) units and ultimately what form does this all take in the mind,

which makes opacity an empirical issue on which either side can make testable predictions.

The closer fit to the attested data illustrated in Section 2 may be accepted as good evidence in favour of their model by believers in word-based, surface-oriented models - however, RBP proponents, whose framework imposes different theoretical commitments, might retort that these exceptions to the opaque rule interaction are due to extralinguistic factors and are simply rote-learned by the speaker[36] as exceptions, and as such a theory seeking to model and explain synchronic competence shouldn't concern itself too much with smaller deviant sub-patterns. Because of these irreconcilable differences and approaches, internal evidence can only take us so far when most often, to be theoretically relevant, it must first be analysed within a framework, making it hard for it to settle a debate.

To move towards a solution, what is needed is external evidence as this is in fact ultimately a psycholinguistic issue about the representation of the lexicon in the mind. While other questions in phonology have attracted much more effort to seek relevant evidence of this kind, opacity surprisingly has not done so to nearly the same extent. It is of interest itself that no attempt at such design exists already, given the heated debate on the nature or AED, and the fact that all theoretical contenders claim cognitive relevance. All evidence available has rather indirect (and often ambiguous) bearing on cognitive matters. Without more unequivocal external evidence in favour of it, opacity in the generative sense cannot be understood as anything more than a way of organising the data.

[36] As discussed, this is in fact acknowledging that analogy and whole-word storage is necessary for at least a partial analysis of opaque patterns, which is an argument in favour of an analogical approach: it is simpler and explains more data. However as the two families of frameworks have different ideas about what a theory of language should include, RBP's response is arguably internally justified.

In this section I will briefly survey existing external evidence on opacity and explore what conclusive external evidence that is accepted by both sides would have to involve.

The area in which most external evidence on opacity has been gathered is language acquisition. AED effects are putatively present in both L1 and L2 acquisition. They are spontaneous processes, not explainable by characteristics of the target grammar - and in the case of L1 chain shifts, nor even potentially by the initial state grammar, as L1 learners have none. Therefore the historical stratification approach cannot be invoked as an alternative explanation. Below is an example of an L1 chain shift, the famous case of Amahl, detailed in Smith (1973).

In this example (a screenshot of Amahl's grammar at age 2;2- 2;11), various processes interact to yield a chain shift: stridents lose their stridency, turning into stops, and coronal stops velarise.

a. /s, z, ʃ, tʃ, dʒ/ → [*t*, *d*]		b. /t, d, n/ → [*k*, *g*, *N*]		c. /k, g, ŋ/ → [*k*, *g*, *N*]	
[pʌ**d**əl]	"puzzle"	[pʌ**g**əl]	"puddle"	[pi**k**əl]	"pickle"
[pɛ**t**əl]	"pencil"	[tʰə**ː**k**k**əl]	"turtle"	[bʌ**g**əl]	"buckle"
[bɛ**t**əl]	"special"	[tae**ŋg**əl]	"sandal"	[ʌ**ŋk**əl]	"uncle"
[aen**d**ələ]	"Angela"	[dzə**ːŋ**əl]	"journal"	[tʰaiae**ŋg**əl]	"triangle"
[pa**ːt**liː]	"parsley"	[bʌ**k**lə]	"butler"	[tɔ**k**lit]	"chocolate"

This is taken to be strong evidence in favour of a synchronic, derivational account for AED. Children are known to create generalisations for which there is little or no evidence in the target grammar (Gierut & Champion, 2000; Gierut, 1993; Edwards, 1996; Smith, 1973), and that these are productive for periods of time and assumed to have psychologically real status. Therefore, if this is the status to be assumed

for the two steps of Amahl's chain shift, the existence of the surface pattern would constitute strong evidence that cases of opacity can indeed be productive and synchronic.

But, as with most cases of evidence, this interpretation of the facts has been criticized. The first issue is the competence vs performance divide. Chain shifts in acquisition have been treated as competence phenomena, but as discussed in 1.3 the dichotomy itself is in question, and so is its cutoff point. Positive evidence obtained in a controlled environment to classify a phonological phenomenon as competence in L1 acquisition is hard to obtain, precisely because of factors characteristic of the acquisition process: children have poor control over their vocal mechanism, which could explain even highly regular substitutions, and it is challenging to submit the children to rigorous experimental conditions due to factors such as poor attention span and difficulty in getting them to follow instructions. In the absence of positive evidence of this kind, the alternative that chainshifts may be performance phenomena needs to be entertained.

The most prominent proponents of this possibility have been Hale Reiss (2008)[37]. The first step in making the case for the performance account of early acquisition chain shifts is to state the relatively uncontested claim that producing a sound [s] is not the same as pronouncing the phoneme /s/ - the sound may be made in imitation or as a speech error or for a number of reasons, the important thing is that the two are not equivalent. Producing a phoneme requires a phonetic output

[37]The authors of the argument have many theoretical beliefs in common with those that argue L1 chainshifts are synchronic and competence-based. Disagreement about the phenomenon is present amongst theorists who have taken the same side on many issues. It is unsurprising that a linguist with an even more different view of language might not even engage with the evidence if it is analysed in a framework incompatible with their wordview - this is precisely an example of the mechanism that has led to the formation of very closed communities within linguistics and a breakdown of communication between them.

representation in the speaker's mind as well as the physical ability to produce the congruent acoustic and articulatory event. Before resolving that the children with the chainshift grammar have a non-adult-like mental phonetic target for the same phoneme one must rule out that it is not an issue within the performance system. The misarticulated sound of the child may sound to adults like the adult target pronunciation of another sound. Evidence in favour of this comes from child comprehension: if the experimenter (Smith, 1973) pointed at a sink, referring to it as [θɪnk], the child would protest: "no, the [θɪnk]!". This suggests that the child has the correct phonetic target for each of the sounds in the chain shift, as he can recognise when an adult is not pronouncing the target word correctly. If it was truly the case that chainshifts were a competence issue, the child would have had no issue with the incorrect adult output as it corresponded to his own. This at best indicates that it is unclear whether children's chain shifts are in fact a case of spontaneous opacity as it is not evident that they are a competence issue. Data on opacity of this kind therefore has little hope of settling the debate: it is necessary to sort these phenomena and their causes along the competence-performance dichotomy in order to establish what (if any) the next steps to provide insight into the nature of opacity would be - this is made very complex by the inherent muddling of competence and performance in children's output.

Spontaneous opacity is also found in L2 acquisition, in which the performance-competence distinction is easier to draw, and which more comfortably lends itself to experimental probing because of the mental maturity of the subjects. The most famous such case is the front fricative shift before high front vowel in L2 learners with Korean L1 (Lee Cho, 2000) - /θ/ → /*s*/ → /ʃ/

English Target	L2 Production before /i/	L2 Production before other vowels
[θ]	[s/] "thin, thing, think, thick"	[s] "thank, thirst"
[s]	[ʃ] "sit, sick, sink, sing"	[s] "circle, sun, soap, sand"
[ʃ]	[ʃ] "ship, sheet, she, sheep"	[ʃ] "shoes, shop, shirt, shell"

The competence-performance issue is less salient with cases of L2 chain shifts, as adults supposedly have better control of their motor skills, and as such there is less chance that the effect is due to poor accuracy of pronunciation. Moreover, because the subjects are no longer children, it should be easier to devise an experiment that would shed light on the issue, although to my knowledge this hasn't happened so far. Nevertheless, the "opacity" interpretation of this evidence is not without its criticisms. Because L2 learners necessarily have an L1 system with different characteristics to those of the target, data that looks opaque could be interpreted simply as a transfer effect, due to characteristics of the L1 creating what looks like a chain shift. In this case in particular, Korean is known not to have a /θ/ phoneme nor a [θ] sound. It is reasonable then that, especially in the early stages of the learning process, [θ] would be mapped onto a sound already present in Korean, the closest being /s/. As for the other two steps in the alleged chain, they could be argued to be an imposition of Korean generalisations onto English words. In Korean, /ʃ/ and /s/ are separate phonemes. English [ʃ] maps naturally onto /ʃ/ in all environments. [s] in an environment other than preceding a high front segment maps to Korean /s/. However, when [s] precedes a high front vowel it is mapped to /ʃ/. This could be the result of transfer of the generalisation that, in Korean, /s/ goes to /sʲ/ (very similar to [ʃ] in sound, the latter of which is easier to articulate as it doesn't require double constriction) when preceding a high front

vowel. Under this new analysis, what looks on the surface like a spontaneous, synchronic and productive chain shift is actually just the effect of the mapping of sounds between one language and the other. More evidence is needed to decide between the various explanations, either apparent shifts that cannot be described as transfer effects or transfer effects that can't be described as shifts[38].

Different approaches to data have already been discussed in section 1.3, but it is worth bringing back the discussion to see what impact it would have on the evidence above. The hypotheses outlined in the previous paragraphs all tend to come from an competence-focussed viewpoint, which tends to abstract from data and leaves open the possibility of discounting certain data points. What happens then when we do not abstract, when the analysis is (as far as possible) not based on sampling methodology, and we include potential external conditioning factors? Ettlinger (2008)'s analysis of M's /s/-/t/-/k/ chain shift is an example of just that. Below is a summary of the phenomenon:

	Stage 1 (1;0-1;4)	Stage 2 (1;4-1;7)	Stage 3 (1;7+)
a. cookie	**k**ʊki	**k**ʊki	**k**ʊki
b. talk	**k**ʌk	**k**ʌk	**t**ʌk
c. sock	n/a	**t**ɑk	**t**ɑk
d. table	n/a	**t**ejbo	**t**ejbo

Stage 1 shows velarisation, stage 2 shows stopping and stage 3 shows the resolution of the chain shift. Velarisation appears to start in stage 1 and continue in stage 2 (*talk*). How should the correct pronunciation of *table* in stage 2 be explained then? The author's proposal is based on lexical inertia (Menn Stoel-Gammon, 1993),

[38]Many more chain shifts, both in L1 and L2, exist - Jesney (2005) has summarised a number. Different alternative analyses have been adduced for each, but exploring them is beyond the scope of this thesis. The point is that there is no single explnation for the data.

the observation that an existing lexical item will have a period of inertia before conforming to a change in the grammar. Note that table is a newly acquired word in stage 2: it could be hypothesised that velarisation is no longer active at stage 2, that the realisation of *talk* in stage 2 is still lexically inert from stage 1, and that the newly acquired *table* does not velarise as velarisation is no longer active at the time of acquisition. Under this view, the chain shift is an epiphenomenon stemming from generalisations that were once active lingering in the lexicon, removing the need to entertain an opaque analysis of the data.

Support for the lexical inertia account comes from the introduction of the variable for the age of a word in the child's lexicon into the analysis. This is called Word-Age (WA), in Ettlinger's paper, and obtained by subtracting the first attested instance of the word from a later time T.

M's Age(months)		12		14		16		18		20		22	
		WA	n	WA	n	WA	n	WA	n	WA	n	WA	n
k		**0.5**	**5**	**1.2**	**18**	**1.6**	**34**	**2.9**	**51**	**4.4**	**62**	**6.9**	**71**
	[k]	0.5	5	1.2	18	1.6	34	2.9	51	4.4	62	6.9	71
t		**0.8**	**12**	**1.8**	**24**	**1.7**	**44**	**2.1**	**49**	**3.9**	**68**	**6.7**	**73**
	[k]	0.8	12	1.8	24	1.8	41	3.9	18	6.1	10	9.0	1
	[t]	0.0	0	0.0	0	0.2	3	1.0	31	3.5	58	6.7	72
s		**0.0**	**0**	**0.7**	**6**	**1.7**	**8**	**2.3**	**38**	**4.3**	**42**	**7.1**	**41**
	[t]	0.0	0	0.0	0	0.0	1	0.9	20	4.2	41	0.0	0
	[s/f]	0.0	0	0.7	6	1.9	7	3.9	18	7.1	1	7.1	41
Total		0.7	17	1.4	48	1.7	86	2.4	138	4.2	172	6.9	185

Looking at M's lexicon, it is around 16 months that the first correctly articulated coronals begin to appear. From 18 to 22 months the number of correct coronal

articulations begins to increase and the number of of velarized tokens decreases, approaching but not quite reaching 0. At 22 months, only one word is still incorrectly velarized. If stopping begins around 18 months and velarisation stops around 16, the WA of words correctly and incorrectly velarized during this time period can help ascertain whether the AED is synchronic or merely the result of lexical inertia (a situation very similar to that discussed in section 1 and 2, of history having an effect on the lexicon, just this time on a much smaller time scale). At 18 months, 31 out of 49 tokens are correctly alveolar, with a mean WA of 1.0 month, while the incorrectly velarized tokens have a mean WA of 3.9, making them much older, and supporting the lexical inertia hypothesis. At 16 months, velarisation is beginning to disappear (41 out of 43 target alveolar tokens present it), with velarized words having a WA of 1.8 months. However, at this point in time only 1/8 of the words present stopping, which has just started to apply, so the periods of synchronic velarisation and synchronic stopping do not overlap. This corroborates the idea that there is no synchronic chain shift, and that the appearance of a shift is in fact an epiphenomenon of lexical inertia[39].

Ettlinger's conclusions are the result of a different approach to the data, and his results fit in well with an analogical, diachronic account of AED. However, it is still possible to see this evidence as inconclusive and argue that lexical inertia is a performance effect and that the chain shift is synchronic, or even that the apparent gradualness of application of a generalisation is a result of lack of abstraction.

Another piece of evidence in support of AED being synchronic and rule-based comes from language games. Andersson (2017) used the Swedish game R'ovarspråket

[39]To my knowledge, no similar study was done on L2 acquisition, so the status of purported L2 chain remains open.

(C → /C$_i$ɔC$_i$/) to test the allegedly opaque interaction between centralization (which neutralizes the phonemic distinction between /œ/ and /ɵ/ to [ɵ] before /r/, or any of the retroflexes formed by coalescence /rt, rd, rs, rn, rl/ → [ʈ, ɖ, ʂ, ɳ, ɭ]) and unstressed vowel shortening (which creates new instances of [œ] when /ø:/ is placed in an unstressed syllable). The two processes are in a counterfeeding order:

UR	/føːr'kjlɑːra/
Centralisation (opt.)	—
Shortening	fœr'k^{j}lɑːra
Other Rules	fœr'k^{hj}lɑːra
SR	[fœr'k^{hj}lɑːra]
Translation	"explain"

It is not however unambiguous that this is a case of opacity: all the examples of environments for centralization that the author could find occurred in stressed syllables. As shortening only occurs in unstressed syllables, it is possible that the apparent opacity is simply due to a difference in environment. The only case in which a /ø:r/ sequence is unstressed is in the prefix fø:r- as in the example.

Therefore another possibility is that the opacity is not a fact about the language but about the prefix fø:r-. Disambiguating between these possibilities is impossible relying only on internal evidence, as the environments necessary to test the prediction are not available. R'ovarspråket can however create these environments, as the stress in R'ovarspråket words usually falls on one of the dummy vowels created. What is found is that the interaction appears to be in fact productive and synchronic, and not an artefact of marginally differing environments or a morphologically specified phenomenon:

Rˈovarspråket UR	/bɔbøːˈrɔr/
Centralisation (opt.)	—
Shortening	bɔbœːˈrɔr
Other Rules	bɔbœːˈrɔrː
SR	[bɔbœːˈrɔrː], *[bɔbɵːˈrɔrː]
Translation	"ought to, should"

Interpretation of the data, however, is not unique, and the type of evidence has received criticisms. Language games have been criticized for having low ecological validity and being subject to their own rules, which may be different from those of the wider grammar until proven otherwise. Moreover, an analogical lexical explanation that doesn't involve opacity is also possible for the data: when presented with an unfamiliar string (an unstressed instance of /øːr/), it will be treated as the most similar familiar string (stressed instances of /øːr/).

None of the evidence above can be unequivocally interpreted, both because of the nature of the evidence and because of different approaches to data and theoretical beliefs of different frameworks. An experimental setup is the type of evidence that offers the most control over the conditions and best allows us to zoom in on the features being investigated.

5 The Experiment

This section will be focused on the shape of an experimental design on opacity. Differences in predictions will be isolated, as a starting point. An experimental design will then be formulated. Before more sound conclusions can be arrived at, it is necessary for the different sides to work out their predictions more explicitly,

especially in more neglected areas like comprehension, in which it appears there could be testable differences.

The experiment is preliminary to further, more robust, work on the subject - at this stage it relies excessively on non-explicit predictions to yield conclusive evidence. It is meant to be a starting point for work on the issue that takes into account the standards of evidence of the different theoretical sides, which is the only pathway towards resolving the debate on opacity. The end of the section will present suggestions for what a more robust design, given fewer time and resource constraints, would comprise.

5.1 The predictions

As a first step, a testable hypothesis is needed. Given two minimally different words, one transparent and one opaque, once token frequency and neighbourhood effects are accounted for, both generative theories (RBP and OT) predict that there'd be little or no difference where production is concerned. RBP has rules ranked in a certain order, the UR is run through each of them in this order (regardless of whether they apply or not - when they do not, an unchanged output is returned). So assuming that all else is being controlled for, the theory doesn't predict that a word with a derivation in which less rules return an unchanged output will be somehow slower to produce compared to one where more rules return an unchanged output, as both words will go through the same set of rules before their SR is returned. In OT production, setting aside the practical issues of modelling opacity in the framework, no difference is predicted all else being controlled for, as all candidates are evaluated simultaneously, and the constraint ranking is

taken to be constant in adult production. An analogical model makes the same prediction: all else being controlled for, a "transparent" word won't be any harder to access than a minimally different "opaque" word - this approach doesn't force a distinction.

Differences are however predicted in comprehension. As there isn't a lot of work on comprehension models, the fewest assumptions possible will be adopted. While in production there is essentially a one-to-one (RBP) or many-to-one (OT) mapping - the target is clear - comprehension consists of a one-to-many mapping because there is uncertainty about the target. This uncertainty is predicted to be minimised when a word is transparent, as it can be run backwards through the ordered rules and it is clear which have applied and which haven't (RBP). The same is true within a 'minimal' model of OT comprehension, where the SR is "evaluated" by the constraint set ranked backwards to see which of the possible URs it can correspond to (a one-to-many mapping)[40]. For opaque words, the uncertainty is increased: as opacity is defined as the obfuscation of the output of a process that does crucial work in the analysis, all kinds of difficulties in working backwards to the UR are predicted. Opaque forms such as the ones in Canadian Raising (obfuscated by a neutralisation process) would necessitate the exploration of two parallel derivations at once (RBP) or the impossibility to individuate conclusively the UR of the word in question without the aid of semantics (OT).

Support for this difference in prediction comes from reading comprehension of words with opaque spelling in alphabetical languages. Transparent spelling involves a regular mapping between graphemes and phonemes - any irregularity in the mapping will render the spelling opaque. Orthographies of different languages

[40]And for versions of OT mimicking levels, the same rationale as RBP applies.

can be said to be more or less opaque (English is more opaque than Italian), and words within the same language can have different degrees of opacity (English <Worchestershire>, /'wʊstɜːʃɜː/ is more opaque than <incline>, /ɪn'klain/). The different predictions of a derivational model and an analogical word-based one can be likened respectively to the approach to opaque orthography of a child and of an adult. Adult reading in English relies mainly on whole word recognition rather than the reading of every letter separately, although both mechanisms may be available (Andrews, 1989; Balota, Cortese, Sergent-Marshall, Spieler, Yap, 2004; Coltheart et al., 1977; Mulatti, Reynolds, Besner, 2006 on showing that whole word effects are present in reading), while the reverse is true for child reading, especially in the early stages (Ehri, 1995, 2005; Frith, 1985; Marsh, Friedman, Welsh, Desberg, 1981; Share, 1995, 1999).

The way that adults and children deal with opaque spelling, which lacks a 1-to-1 correspondence between graphemes and their pronunciation, as with opaque words, depends on the reading strategy. Adults approach both known opaque and transparent words as potential wholes - after accounting for confounding factors, the difference between the two categories is small[41]. Children will rely on the correspondence between the graphemes and the sounds, and will have more difficulty with opaque words (Katz Frost, 1992 - the Orthographic Depth Hypothesis and derived work), which thwart the expectation of unique mapping.

Comprehension might therefore provide fertile ground for testing the cognitive status of opacity, even though more explicit predictions are necessary before the results can be deemed conclusive.

[41]Yet again, this only pertains to languages like English, the picture is somehow different for e.g. agglutinative languages.

5.2 Methodology

An auditory lexical decision task was performed. The phenomenon being examined is Canadian Raising, because of its well-established status as an opaque effect, and the minimal interference of non-phonological factors. After an initial screening, 12 participants were selected. They fulfilled the following conditions: a) had all been in the UK for less than 5 years, b) identified as Canadian, c) had lived in Canada for most of their life, d) identified Canadian English as their mother tongue, e) responded positively when asked whether people knew they were Canadian from how they spoke, f) showed CR.

The lexical task was auditory only, to minimise effects of the spelling on reaction times. A total of 155 test words were presented to the subjects in a randomised order differing for each participant, with each word being presented twice - of these, 50 were distractors. The first reaction time for each word was recorded - the second trial served the function of collecting reaction times for words which the subject had not given a response to in the first trial.

Test words are divided in five groups:

	Real Words	Nonwords	Distractors
Transparent	Group 1	Group 2	Group 5
Opaque	Group 3	Group 4	

All non-distractor words involved the opaque interaction between CR and either final devoicing or flapping - this should increase the validity of the results for theorists who conceive of AED as an interaction between two generalisations, rather than a property of a single generalisation.

All groups of words had roughly the same number of items. The relatively low number of items is a result of the attempt to find real word transparent-opaque pairs (words with a Levenshtein distance of k=1, where the change involves the voicing value of the stop after the diphthong), and to not have the number of nonwords significantly exceed that of the words. Minimising the difference in shape between transparent and opaque words was seen as more important than matching them for characteristics like frequency: frequency effects and the like can be added as moderating factors in the analysis, while it is not as straightforward to formally quantify differences in shape without incurring in theory-dependent issues. However, all the test words are relatively prominent in the language (the word with the lowest frequency is "tidying" - a normalised frequency of 4.47 within the HAL corpus), so there shouldn't be problems of low familiarity with the test items. Nonwords were derived by inputing the real-word list into Wuggy (Keuleers & Brysbaert, 2010), which means that they are matched for neighbourhood size and density, length, morpheme and syllable structure. Data about bigram frequency and neighbourhood size was obtained by running the obtained nonword list through the English Lexicon Project (Balota et al., 2007)'s function generating lexical characteristics for nonwords. Groups 1-4 all contain words with legal English phonotactics, and which are characterised by the presence of an opaque interaction (groups 3 & 4) or its minimally different transparent counterpart (groups 1 & 2). Distractor words are a mixture of phonotactically illegal words and both real and nonwords which do not feature the particular phonological phenomena under scrutiny.

5.3 Results

The analysis was performed in R. Only correct responses were included. Reaction times lieing more than 3 standard deviations away from the mean (which only affected the right tail), and RTs under 100ms were excluded, as impossibly short. The median remained unaltered at 1.0376s, and the mean changed from 1.2157s to 1.2080s.

Two separate linear mixed effects model were devised, one for words and one for nonwords. The choice was motivated by the fact that many measurements available for words such as token frequency were not available for nonwords, in the case of which a combination of bigram frequency measures were employed instead. After establishing covariance between variables, the following fixed effects were included in the model.

Words: Token Frequency (as measured in the HAL corpus), Number of Phonemes, Phonological Neighbourhood Size, Mean Token Frequency of Items in the Phonological Neighourhood, Order of Presentation, RT of the Item immediately preceding.

Nonwords: Number of Phonemes, Bigram Frequency Mean, Orthographic Neighbourhood Size, Order of Presentation, RT of the item immediately preceding.

Both models included random effects for word and participant.

The opacity of the word wasn't significant in either model. For real words, their opacity condition had a t-value of 0.293 with a Pr(>|t|) of 0.77, and a narrow confidence interval straddling 0 of -0.0266-0.0456, which does not point to significance. The marginal R^2 (the value associated with the residuals from fixed effects only)

increased from 0.06955 to 0.07122, again suggesting it does not contribute significantly to the model. Results were similar for nonwords: the opacity condition had a t-value of -0.896 with a Pr(>|t|) of 0.38, also with a narrow confidence interval straddling 0 of -0.0735-0.0146. The marginal R^2 change is of a similar, negligible magnitude to that of the real words model, going from 0.019 to 0.021.

While this is by no means conclusive evidence against the positive cognitive status of opacity - some may object that different results would be had by choosing a different phenomenon, perhaps more morphologised, or would propose a different analysis of the data, or in general have a number of objections - it is a starting point for further work on the matter. Before any sturdier conclusions can be drawn, the predictions need to be made more explicit.

6 Further Research

There is a need to make a model's predictions more explicit, before anything concrete can be deliberated on the nature of opacity. Predictions in OT and RBP about comprehension (and to a lesser extent production, especially in adults) need to be explicitly worked out, and should then be used as a springboard to conduct experiments. One of the main hindrances in discussing evidence on AED has been the fractured landscape of theoretical commitments, and beliefs and weighting of evidence in the linguistic community, resulting in a situation of disagreement about the interpretation and significance of evidence. An ideal setup to overcome the issue would involve multiple teams composed of people with different theoretical perspectives and backgrounds, similar to what was done by Silberzahn et al. (2017) - the ideal scenario would involve input from scientists with a spectrum

of theoretical positions and subject specialties along every step of the experimental process, so that the conclusions obtained would be indeed truly conclusive. In practice, experiments like these rarely happen, especially in linguistics, but without constructive confrontation and collaboration, issues such as the cognitive status of AED are unlikely to be solved.

Predictions about AED would involve differences in complexity of processing. Reaction times are one way of measuring this, but they are also a relatively indirect correlate of processing cost, and control over confounding factors is not particularly great. Future research might wish to investigate designs involving brain imaging techniques, or even eye-tracking (if the worked out predictions suggest that reading of phonologically opaque or transparent words is comparable to auditory processing).

A tangential line of inquiry would concern looking more directly at whether rules or constraints or analogy are at work. As mentioned, rule-based approaches have often maintained that analogies are merely messier versions of rules. The two frameworks, however, would have completely different cognitive implementations: rules would involve a procedural view of language, while analogy would imply a declarative view. These in turn predict measurable differences that can be investigated fruitfully by research on memory and language.

English is not the optimal language to conduct experiments of this kind in. Its irregular and opaque spelling conventions are a confounding factor for auditory processing in adults. An ideal language would have transparent spelling conventions (or perhaps even be ideographic) and a well-recorded history.

7 Conclusions

This thesis aimed to contribute to the understanding of the phenomenon of AED itself and the factors that contribute to its successful modelling. A number of factors desirable in accounting for opacity have been identified. The history of a pattern is crucial to explaining its synchronic distribution, especially for generalisations that show dissociations between alternation and environment. At the same time, these patterns have a synchronic facet as they may still be active in the language. A successful model of AED needs to represent this dualistic situation. Models like RBP fulfil this condition by telescoping an idealised historical trajectory of the language into the synchronic grammar. However the idealisation, the telescoping and the related derivational focus can lead to difficulty in explaining all the attested forms with AED, which in practice don't behave entirely regularly, and may often reflect the interaction between outputs. A word-based lexicon is suggested as another potential locus of AED. Adopting words as units allows one to mirror their historical trajectory as closely as possible (by effectively fossilising it into the form, thereby removing the possibility of making erroneous predictions about AED in the form). Word-sized units can also to interact with one another. It would appear that any model that wishes to account for the full range of AED phenomena should incorporate a mechanism or level of description that, directly or indirectly, encodes the diachronic dimension of synchronic patterns.

The case studies showed how models with this characteristic could model AED data in an internally satisfactory way, each with their own strengths and weaknesses related to the theoretical background and implementation of the model.

The ultimate question however is the cognitive status of AED, an issue on which different models make differing predictions. There has been surprisingly little work on this aspect of the nature of AED, both in terms of producing evidence and in making explicit predictions about the processing of AED, given that all the main frameworks in the opacity debate are explicitly committed to cognitive relevance. A further difficulty in reaching a conclusion on the nature of AED is the different approaches to data and weighting of evidence in alternative theories. This thesis has provided an example of how one could, at least in principle, seek more conclusive evidence.

This work fills a gap in the literature about the broader questions associated with the treatment of AED and suggests empirical directions for more conclusive evidence on what is currently an active area of research in phonological theory.

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