The L2 Phonetic Acquisition of Nuclear-/r/: The Case of English and German

Submitted in Partial Requirement for a B.A. Honours in Linguistics
By Scott Moisik
University of Calgary

Dr. John Archibald
Dr. Michael Dobrovolsky

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0.0 Introduction: Rhotic Consonants and Syllable Nuclei

German and English both exhibit syllabic consonants. In these languages, both lateral approximants and nasals may head a syllable nucleus. In English, words like *button* and *bottle* contain the syllabic consonants [n̩] and [l̩]. The German words *verboten* [fɛɐbo:tn̩] 'forbidden' and *Himmel* [hɪml̩] 'heaven' also are frequently produced with [n̩] and [l̩]. It is well established (West and Kantner 1933, Uldall 1958; Hagiwara 1994, 1995; Barry 1997) that /ɹ/ in English has a syllabic allophone in words such as *bird* [bɹ̩d] and *pervert* [pʰɹ̩vɹ̩t]. German /ʁ/, however, is apparently without a syllabic allophone. Cognates shared by English and German, such as the word for 'butter' (*butter* and *Butter* respectively), show that, where English [ɹ̩] is found, the German word exhibits [ɐ], known as 'dark-schwa', purportedly a non-rhotic vowel (Barry 1995, 1997; c.f. Moisik 2006). This constitutes an ostensible gap in the system of syllabic consonants in German: syllabic sounds of lesser sonority imply the presence of syllabic sounds of greater sonority (Zec 1995). Whether the lack of a syllabic-/r/ in German is a problem, however, is contingent upon the placement of *nuclear* rhotics in the sonority hierarchy. If dark-schwa is considered part of the rhotic class in German, this syllabicity gap is not an issue as it can occur in a syllable nucleus. In a manner similar to the high vowels and their corresponding glides (n.b.: /i/ ~ /j/, /u/ ~ /w/, /y/ ~ /ɥ/), rhotics in English and German behave both vocalically and semi-vocalically (/ɹ̩/ ~ /ɹ/; /ɐ̩/ ~ /ʁ/). Typically, rhotics are either given their own class in the sonority hierarchy (Selkirk 1984; Parker 2002) or placed in the category *liquids* with laterals (Clements 1990; Gnanadesikan 1997). The proposal here is to analyze English [ɹ̩] and German [ɐ̩] as members of the rhotic class that rank as vowels in the sonority hierarchy.

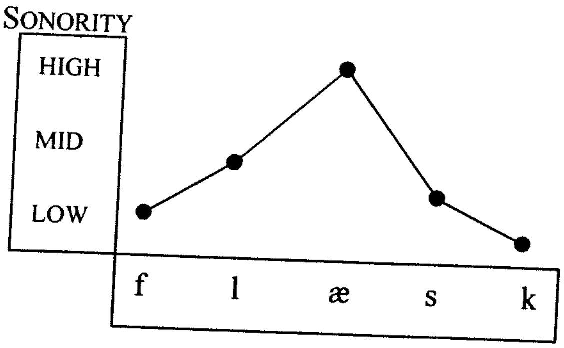
Rhotic sounds are among the most diverse groups cross-linguistically (Barry 1997; Lindau 1985). Consequently, the phonological status of rhotic sounds is unclear: where are we to place them in the sonority hierarchy if they show vowel-like properties in some contexts, and consonant-like properties in others? For example, in Serbo-Croatian /r/ (an apical alveolar trill) can be used as a syllabic consonant in words such as [tr̩v]*enje* 'friction' and [gr̩d]*iti* 'to scold' (Rowicka 2003: 515) . On the other hand, /r/ is frequently realized as non-syllabic obstruents, such as in French *huitre* [ɥitχ] 'oyster'. In addition to this cross-linguistic variation in the sonority of rhotics, within any given language rhotics may vary in sonority according to syllable position or segmental environment. For example, Icelandic /r/ is voiced initially and intervocalically (*renna* [rɛn:a] 'run'; *vera* [vɛ:ra] 'to be'), but devoiced in the environment of voiceless consonants (hrífa [hr̥i:va] 'to rake') and in codas after /a/, /ʏ/, and /i/ (Einarsson 1945: 20-1). Any modification to the sonority hierarchy concerning /r/ will certainly present a monumental challenge, and this thesis recognizes this fact by not attempting to make any strong claims about the *universal* sonority hierarchy. Rather, the focus is on the language specific hierarchies of German and English.

The goal of this thesis is to examine the behavior of two groups of second language (L2) learners: English learners of German and German learners of English. Specifically, an acoustic analysis will be brought to bear on production data from both groups allowing for an investigation into the interlingual production of target nuclear-/r/ sequences in both languages. German speakers demonstrably perceive and produce English [ɹ] as some form of high front rounded vowel, while English speakers appear to perceive and produce German [ɐ] as a non-rhotic reduced vowel. This is taken as evidence to support the claim that both nuclear-/r/ sounds rank as vowels in the sonority hierarchy, as well as evince the affiliations these sounds have acoustically to particular types of vowels. In addition, this paper also examines the learning theory as it pertains to the acquisition of phonetic categories. Strong emphasis is placed on the primacy of the Speech Learning Model (SLM) as it is developed by Flege (1992a et seq.), in delineating the phonetic pattern of interlingual production via equivalence classification. The results of this study indicate that the model correctly predicts the behavior of German learners of English, but not that of the English learners of German.

1.0 Phonological Issues: The Sonority Hierarchy and Syllabicity

In an attempt to explain the distribution of phones within syllables, phonologists have adopted the assumption that syllable structure is constrained and organized in terms of the relative sonority of its constituent segments. The sonority sequencing principle (SSP) has been developed as a means of making the interaction between sonority and syllable structure explicit. This principle states that - optimally - syllables rise in sonority from the margins to the nucleus (Clements 1990). For example, the word 'flask' [flæsk] is well formed in English because sonority increases from the syllable margins to the nucleus. Compare this with a non-attested word such as 'lpatn' [lpætn], which is not a well-formed English word because its clusters grievously violate the sonority sequencing principle.

(1.0) A visualization of a peaked sonority contour for the word *flask*:



Phonologists have attempted to come up with a universal ranking of sounds according to their relative sonority. This is done because sonority hierarchies are useful tools for explaining phonological phenomena, particularly that of syllable structure. The efficacy of the sonority hierarchy is demonstrable in explaining the range of consonants tolerated in onset clusters across the world's languages. The concept of minimal sonority distance (MSD) is one such application of the sonority hierarchy; it is used to explain the observed cluster variation by asserting that languages vary in how far apart on the sonority scale segments must be before they can be syllabified as a cluster (Broselow and Finer, 1991). Greek, for instance, permits plosives to precede fricatives and nasals in clusters such as ψεύτης 'liar' [pseftis]. Typically, English will only permit segments with greater sonority than nasals to enter into clusters (e.g. [pl]*ay*, [pr]*ay*, [pju]trid; with the exception of /s/ in [st]one, [sk]old, [sp]ear, etc.). Loans from Greek into English reflect the MSD setting of English (e.g. *psionic* is pronounced without the [p] in English).

Other arguments based on the sonority hierarchy come from first language acquisition. Children typically simplify complex structures when there are potential violations of the sonority hierarchy. For example, the onset of *stop* contains a segment of greater sonority [s], followed by one of lesser sonority [t]; to facilitate production of this word, a child might employ deletion to repair the sonority contour of this onset, producing [tɑp] for instance (O'Grady 2000: 378; Young-Scholten and Archibald 2000: 65).

The Sonority Hierarchy is argued to be a component of Universal Grammar (UG) and therefore plays a role in linguistic development (Archibald 2000, 2003: 149-50; Parker 2002: 240; Tropf 1987). In Parker (2002), a thorough treatment of the history of the sonority hierarchy is provided, which includes in depth discussions on the issues that both phonologists and phoneticians have faced. In the history of the sonority hierarchy, both universal and language specific hierarchies have been proposed (Parker 2002: 62). For UG, the only suitable hierarchy would be one that is universal; understanding the universal hierarchy is necessary for understanding how sonority influences L2 acquisition:

(1.1)
High Sonority---------------------Low Sonority
vowels > liquids > nasals > obstruents [1]

The most basic version of the hierarchy as seen in (1.1) demonstrates the primary function of all the hierarchies that have been proposed. The hierarchy delineates and ranks natural classes of sounds based on their sonority. Parker (2002) credits Clements (1990) with creating the most frequently cited sonority scale. This particular hierarchy maintains a distinction that will be of import to this study: Clements places glides in their own tier of the hierarchy. Parker makes note that such a distinction has not been without controversy (see Selkirk 1984, among others). The argument against such a distinction is that both phonologically and phonetically, glides differ from vowels primarily in terms of duration or timing, but not sonority (Parker 2002: 63). Nevertheless, Parker (2002: 240) himself places glides in their own sonority category in the phonological version of his universal sonority hierarchy.

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[1] This scale is obtained from Parker (2002: 63), which is a modification of Clements (1990). The key difference is that the ranking of glides in between vowels and liquids is eliminated in favor of simplicity.

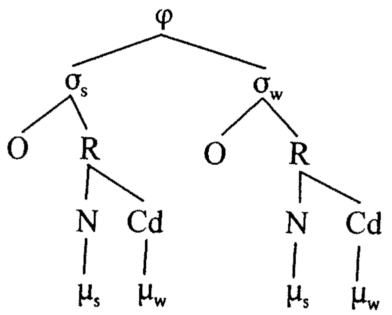
Parker (2002) also performed an exhaustive empirical study on the phonetic correlates of sonority in determining the ranking of his own version of the hierarchy. His experiments consisted of five acoustic and aerodynamic measurements (intensity, peak intraoral air pressure, F1 frequency, peak air flow, and total segmental duration) of the constituents of the standard hierarchy. The breadth of the study was considerable; he analyzed the entire phonemic inventory in both onset and coda positions, of two different languages for both males and females. From this data, Parker concludes that *intensity* most strongly correlates with the standard sonority indices and thus the sonority hierarchy reflects the physical properties of speech sounds.

Before continuing, a brief presentation of the model of syllable and metrical structure assumed for this discussion is provided to enhance the precision of the concept of *syllabic* as it is used in this thesis.

Ultimately, it is assumed that the prosodic word is minimally made of a single foot, which is optimally bimoraic. Mora (as expounded upon in Moraic theory (see Hyman 1985)) refers to an abstract unit of time utilized to account for phonological patterns involving segmental length, and weight, particularly when it comes to prosodic factors such as syllable stress. In syllable structure, syllables typically are composed of either a single mora, or two morae; onsets are typically not treated as possessing this unit of phonological weight. In a syllable of two morae, the first mora, referred to as the strong (leftmost) mora, is ultimately the peak of the syllable. It correlates with phonetic prominence in the form of amplitude (intensity), F0 (high or low pitch), and so forth.

The second mora is said to be the weak (rightmost) mora of the syllable (Zec 1995: 89-90).

(1.3) Arboreal Presentation of Metrical Structure



φ – Foot tier: maximally composed of a stressed (head/strong) and an unstressed (weak/dependent) syllable
σ – Syllable tier: maximally composed of an Onset and Rhyme

O – Onset ; R – Rhyme

N – Nucleus ; C – Coda

μ – Mora, a phonological timing unit; leftmost represent the syllabic / nuclear position of the syllable

While some have focused on the phonological indexing of the hierarchy to explain linguistic variation in consonant clusters, the hierarchy can also serve to illuminate the typology of syllabic segments amongst the world's languages. Zec (1995: 122), in her discussion of how segmental weight interacts with sonority, implies that there is an implicational hierarchy of syllabic segments based on sonority. This syllabicity hierarchy can be viewed as a function of the standard sonority hierarchy.

(1.2) Implicational Relationship between Syllabicity and Sonority:

If x is less sonorous than y and can be syllabic, then y can be syllabic

By *syllabic*, the following significations are implied: a segment that bears a strong mora, a segment occupying the nucleus of a syllable or, alternatively, a segment in the head of a syllable. This implicational relationship is born out in a small typology of languages presented by Zec (1995):

(1.4) A (small) typology of syllabic segments from Zec (1995):

Vowels >	**Sonorants** >	**Obstruents**
Lithuanian	English	Berber (ITB)

As the table shows, where Lithuanian is a language in which only vowels may be syllabic, English allows its sonorants to be syllabic and Imldlawn Tashelhit Berber permits any segment in its syllable nuclei. Note that the category ranking in (1.4) parallels that of the standard sonority hierarchy. The implicational syllabicity hierarchy delimits the set of possible grammars based on the sonority hierarchy. Accordingly, this hierarchy predicts that it is impossible for a language to have syllabic consonants without also having vowels.

1.1 The Problem of the German Gap: Syllabicity of Consonants and the Sonority Heirarchy

This study is concerned primarily with the acquisition of nuclear-/r/ as it is found in both English and German. As it is common for /r/ to occupy its own rank (between vowels and /l/) on the sonority hierarchy (e.g. Selkirk 1984; Parker 2002), the following gap in the syllabicity of /r/ in German presents a problem for the universal implicational hierarchy of syllabic segments discussed above. Consider the following chart:

(1.5) Syllabic Consonants (German vs. English):

LANGUAGE	/r/	/l/	/N/
German	**NO**	YES	YES
English	**YES**	YES	YES

It would appear that, while English abides by the cross-linguistically attested pattern between syllabicity and sonority, German apparently has a gap. The standard approach to German syllable structure is to assert that both /l/ and nasals are candidates for heading syllable nuclei, but /r/ is not (Benware 1986: 69-70; Hall, C. 1992: 71). This is in violation of Zec's implicational relationship, which predicts that the presence of a syllabic segment of lesser sonority implies the presence of syllabic segments of greater sonority. This may indicate a problem with Zec's implicational relationship. It could also indicate, however, that our current understanding of the phonological sonority of /r/ is not satisfactory.

It is conceivable that the solution to this problem lies in the idiosyncrasies of language specific, phonetic sonority hierarchies. In the case of German, which putatively violates Zec's generalization, [ʁ] (and most other allophones: see section 2.2) would rank above nasals in sonority, while [ɐ], would be classed as a vowel. Thus, the fact that German /ʁ/ never occurs as a syllabic rhotic falls out from the ranking of the allophones (see (1.6)):

(1.6) A Coarse Proposed Phonetic Sonority Hierarchy for German:

Potentially Syllabic
✓ ⊘ ⊘ ✓ ✓
V + [ɐ] > [ʀ], [ʁ] > [l] > nasals > Obstruent allophones of /ʁ/ > obstruents

✓ = can be syllabic
⊘ = cannot be syllabic

Dark-schwa is an allophonic manifestation of the German phoneme, /ʁ/ (see section 2.2). It is comparable to English [ɹ̩] in that it is an occurrence of a phonemic /r/ in the nuclear position of a syllable. While the rhotic status of this sound is dubious, analyzing it as part of the rhotic group in German allows Zec's implicational relationship cohere with the syllabicity facts of German. The question that arises from this discussion is: despite the fact that German speakers ostensibly lack an overt syllabic rhotic, can German second language learners of English acquire its syllabic rhotic, [ɹ̩]?

This thesis will present evidence of learners of both languages substituting nuclear-/r/ with a non-rhotic vowel. To begin, however, an exploration into the possible rankings for /r/ in the universal sonority hierarchy, as well as in English and German is given, followed by a discussion of the phonetic and phonological issues surrounding the L2 study.

1.2 Where is /r/ in the Sonority Hierarchy?

It is common for /r/ to find its way into the liquid tier of the sonority hierarchy (Clements 1990; Gnanadesikan 1997), while others recognize the need for a finer-grained distinction between /r/ and /l/ (Selkirk 1984; Parker 2002). The latter position, however, is frequently based on arguments from English (Zec 2003, Parker 2002: 84). Parker's sonority hierarchy, which is formulated on the basis of relative intensity, is presented here as an exemplar of the type that places /r/ in its own class:

(1.7) Parker's Universal Sonority Heirarchy (Phonological): (Parker 2002; 240)

low vowels	16
mid vowels (except /ə/)	15
high vowels (except /ɨ/)	14
/ə/[2]	13
/ɨ/	12
glides	**11**
/r/	**10**
laterals	**9**
flaps	8
trills	7
nasals	6
/h/	5
voiced fricatives	4
voiced stops and affricates / voiceless fricatives	3
voiceless fricatives / voiced stops and affricates	2
voiceless stops and affricates	1

The greater part of the English evidence for this ranking is distributional; an overwhelming number of words in English employ syllabic /r/; syllabic /l/, and syllabic nasals are excluded from the head position of feet in English (i.e. they cannot bear stress). Incidentally, this metrical restriction is accounted for in terms of the sonority

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[2] As it turns out [ɹ] enjoys a broader distribution than even schwa in English as it can occupy stressed syllables, but schwa cannot.

scale. Specifically, it is argued that /r/ is uniquely aligned with the rest of English vowels. /r/ is the only non-vowel that can occupy the head of a foot. The other syllabic consonants of English (/l/ and nasals) are relegated to the unstressed position[3].

Rhoticity constitutes, at best, a nebulous natural class. While there are numerous phonological arguments to suggest that these sounds do form a natural class (see Ladefoged 1996), it is difficult to tie them into a cohesive phonetic family (Lindau 1985; Ladefoged 1996). Rhotics occupy a diverse spectrum of both place and manner of articultation. It is possible to identify rhotics as semi-vocalic approximants ([ɹ], [ɻ], [ʁ̞], [ʋ]); and often they pattern with vowels, as is arguably the case in English and German (Barry, 1997: 41; Gordon, 2004: 288). They also manifest as fricatives ([ʁ], [x], [χ], [ɣ]), trills ([r], [ʀ]), flaps, and taps ([ɾ], [ɽ]) (Ladefoged 1996; Lindau 1985; Barry, 1997; Catford 2001). The phonetic variation exhibited by /r/ cross-linguistically poses a significant challenge to those wishing to construct a universal sonority hierarchy.

German is rife with /r/-variation, where nearly the entire array of manners of articulation of rhotics can be found. In onsets, fricative, trill, and approximant productions occur in free variation (Barry 1997: 41; Ladefoged 1996: 233; Weise 2000: 171). This leads to the impression that German /ʁ/ is phonetically consonantal. However, in most standard dialects of German (Keller 1961; Russ 1990) /ʁ/ in a syllable rhyme is commonly vocalized, yielding what many described as [ɐ], dark-schwa (to be discussed in more phonetic detail later on). What is important to note here

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[3] One might speculate that the distribution of /l/ is becoming more like that of /ɹ/ in English: words such as *pull, bull, Mulder* can be pronounced with either [l] or [l̩]. This is not suprising given that /l/ has, in some dialects (e.g. New York) vocalized to [o] or [ɔ] and thus shares a strong affinity with vowels (Gick 2000; Gordon 2004: 289)

is that /ʁ/ in German exhibits considerable allophonic variation precluding it from being given a single sonority category on a scale specific to German[4].

Fortunately, English /ɹ/ does not share the same variation as German /ʁ/ does, although it occasionally is produced as a voiceless fricative or approximant in words such as [tʃɹ̥u:] 'true' or [kɹ̥ʌtʃ] 'crutch'. The two key varieties of English /ɹ/ are similar enough that placing them in the sonority hierarchy seems like a simple enough task. Articulatorily, the distinction between onset-/ɹ/ and nuclear-/ɹ/ is rather subtle and does not yield a tremendous difference in the acoustic structure (Catford 2001: 173; Stone 1996: 3735). Still it is worth noting that /ɹ/ in onsets can be viewed as the more consonantal variant given that there is a greater degree of stricture in the oral cavity during its production when compared with its nuclear cousin, [ɹ̩]. Specifically, in a three-dimensional imaging study (using MRI), Stone characterizes this 'consonantal-r' as having greater medial molar contact than [ɹ̩] (Stone, 1996: 3733-4). Uldall (1958) identifies the non-syllabic variant of /ɹ/ as 'tongue tip', standing in contrast to the 'molar-r' or 'bunched-r'. The latter articulations exhibit an elevated tongue dorsum, with little apical elevation (Kantner and West 1941: 158) compared to the former, which has a greater degree of apical elevation. Acoustically, the formant structure of /ɹ/, especially when compared with its natural class counter-part, /l/ (Ladeforged 2001: 54-5), seems to share more in common with vowels and glides than with consonants (Lindau 1985: 163). Notably, the greater occlusiveness of [l] is evident in spectrographic representations as a considerable attenuation of vocal tract excitation

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[4] Parker (2002: 127) generates a sonority hierarchy specific to Spanish to use as a basis for correlation with acoustic measurements. This hierarchy draws a distinction between flapped-r and trilled-r, which Parker claims is phonologically necessary in Spanish. Spanish, however, contrasts these sounds; in German, it must be emphasized that all the /ʁ/ variants are allophones, which means that the phoneme /ʁ/ covers a vast range of possible sonority grades.

when compared to neighbouring vowels. As mentioned above, /r/ typically ranks higher than /l/ in sonority, but lower than the vowels (Parker 2002: 76). The ranking of English /ɹ/ in most versions of the phonological sonority hierarchy represent the conditions described above adequately. However, none of the hierarchies assessed in Parker's study attempt to assess the placement of [ɹ̩]. In this study, [ɹ̩] is argued to be classed as a vowel in the English sonority hierarchy.

It is also worthy of note that there are a number of r-vocalizing dialects in English known as the non-rhotic dialects. While an extensive list could be compiled for all the international varieties of English that are non-rhotic (see Wells 1982) it is sufficient to note the general tendency of r-vocalization in English. Typically, /ɹ/ is lost post-vocalically or vocalized as schwa when there are no succeeding vowels as in the pronunciation of *here* [hiə] by New Yorkers who speak the non-rhotic variety of New York English (Gordon 2004: 288). Other important non-rhotic dialects are found in east and north England and most accents of Wales as well (Wells, 1982: 220). Wells (1982: 218) has used the term 'r-dropping' to characterize these dialects, where apparently the /ɹ/ is also simply lost (c.f. *fearing* [fiəɹɪŋ] vs. *feared* [fiəd]: Wells 1982: Vol 1. 219).

1.3 Phonological Aspects of [ɐ̩] compared to [ɹ̩]:

This study is primarily concerned with lower level phonetic acquisition, but examining the phonological structure of [ɐ̩] compared to [ɹ̩] will facilitate understanding of the differences that exist between these sounds. Furthermore, phonological structure can have an impact on the learning task and it must be understood what the learner is faced with on this level.

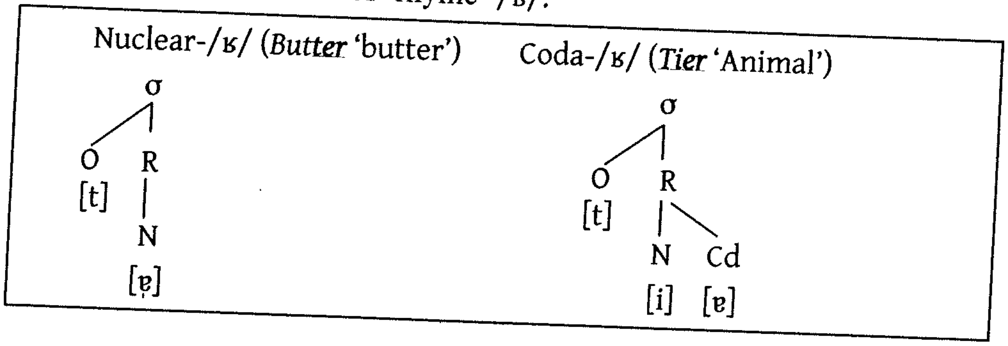
The core focus of this study is on a particular allophone of German /ʁ/, which occurs frequently in the language. Hall (2000) notes that this sound, referred to as dark-schwa [ɐ], is the Standarddeuschen (standard German) pronunciation of <-er> in a word such as ‘Kinder’ [kɪndɐ]. Note that dark-schwa is contrastive with regular schwa [ə] (as in *bitte* [bɪtə] ‘request’ vs. *bitter* [bɪtɐ] ‘bitter’), which also enjoys a wide distribution in German (Hall, 1992: 102). The two sounds bear a heavy contrastive burden and are apparently distinguished in all dialects of German (Hall 1992: 102). Despite the abundance of minimal-pairs, there is considerable evidence to support the view that dark-schwa, [ɐ], is not a phoneme in German. Benware (1986: 46) provides three morphophonemic arguments for rejecting the analysis of [ɐ] as a phoneme in German:

1) [ɐ] and [-əʁ] alternate in the comparative:
   c.f. größer [gʁø:sɐ] vs. größerer [gʁø:səʁɐ] (‘big’ vs. ‘bigger’)
2) [ɐ] and [-əʁ] alternate in the agentive:
   c.f. Lehrer [le:ʁɐ] vs. Lehrerin [le:ʁəʁɪn] (‘teacher’: masc. vs. fem.)
3) [ɐ] and [-əʁ] alternate in lexical morphemes:
   c.f. Hammer [hamɐ] vs. hämmere [hɛməʁɐ] (‘hammer’ vs. hammerer’)

The above examples demonstrate that while dark-schwa figures prominently in <-er> contexts, morphonemic alteration reveals an underlying [əʁ]. As is argued by Benware, positing another phoneme [ɐ] does not explain the variation observed. It also means the introduction of yet another German vowel phoneme. Finally, it is completely transparent how [ɐ] arises from /əʁ/; phonetically dark-schwa is essentially a merger between schwa and /ʁ/, or a by-product of coarticulation. Phonologically, it is a matter of schwa deletion and r-vocalization, which yields /ɐ/ (Benware 1986: 46).

Hall, C. (1992: 100), Hall, T. (2000: 71), and Bithell (1952: 124) also assert that [ɐ] is an allophone of /ʀ/ and provide a derivational rule of ʀ-Vokalisierung (ʀ-Vocalization) to explain how dark-schwa fits into German phonology (See also Barry 1995: 228; Meinhold 1989; Kohler 1990). Given these arguments, it will be assumed that [ɐ] is the phonetic output of /ʁ/ in any rhyme[5].

(1.8) syllable structure of 'rhyme' /ʁ/:



Ultimately, /ʁ/ as a phoneme manifests in an incredible variety of ways, including as an alveolar trill [r], uvular trill [ʀ], voiced velar fricative [ɣ], uvular fricative or approximant [ʁ], and as dark-schwa (Benware, 1986: 44; Moulton 1962: 35). Given the productivity of morphophonemic variation between [ɐ] and [-əʁ], as demonstrated immediately above, it will be of consequence for a learner to be able to identify this pattern and employ it. Thus, it will be necessary for them to establish /-əʁ/ as the underlying form of all <er> orthographic sequences. The mapping of allophones unto phonemes can be considered the phonological learning task for English speakers learning German; however, this issue will not be taken up by the study, as the primary focus of this study is the L2 acoustic output, not necessarily phonological knowledge.

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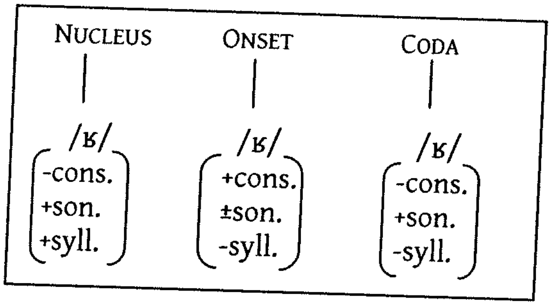
[5] A special notation will be adopted to separate the two types of [ɐ] possible: as the dark-schwa of interest in this study occurs in the nucleus of a syllable, it will be redundantly marked with the syllabic diacritic, i.e. as [ɐ̩], so that confusion with its off-glide counterpart, which originates from coda-/ʀ/ vocalization.

Phonologically, the allophones of German /ʁ/ are predominantly marked [+consonantal] ([+kons.] in Hall, T. 2000: 117). Both [ʁ] and [ɣ] are specified [-sonorant], which contrasts with the trills ([ʀ] and [r]) that have a [+sonorant] specification. All of these consonantal /ʁ/ sounds are subsumed under the [Dorsal] place node. Dark-schwa on the other hand is necessarily [-consonantal] and [+sonorant] due to its vocalic nature (Hall, T. 2000: 131). The sound is also constrained to rhyme position within the syllable, making it possible to provide featural specification in the form of syllable structure:

(1.9) German /ʁ/:



The following specification describes the state-of-affairs for German's rhotics in vocalizing dialects. Syllabification of /ʁ/ in the nucleus or coda can be thought of as *decoupling* the consonantal uvular gesture from the vocalic dorsal gesture. Gick (2000: 1) describes the same type of consonantal-vocalic decoupling occurring between [l] and [o], and [ɹ] and [ə]. Dialects of English that have vocalized these sounds exemplify how the consonantal articulation can be lost leaving a vestigial vocalic gesture (schwa for /ɹ/, [ɔ] for /l/; *cart* [kɑət] and *pill* [pɪɔ], respectively). The conceptualization of consonantal vocalization as an articulatory decoupling allows us to characterize dark-schwa as the "articulatory sibling" of uvular-r (Barry 1997: 41). Articulatorily, the relationship between the vocalic manifestation and the consonantal one can be thought of as a continuum of tongue gestures involving a greater or lesser degree of approximation of the tongue to the articulatory surface.

Considering the allophonic variation of German /ʁ/, it is not surprising that phonologically it possesses both a [+] and [-] specification for the feature [consonantal] in various syllable positions. English /ɹ/, on the other hand, typically manifests as a sonorant, whether it is in a rhyme or onset. This is likely attributable to the key distinction in place between English /ɹ/, a coronal segment, and German /ʁ/, a dorsal segment. The tremendous variety of coronal sounds cross-linguistically, relative to that of dorsals, is arguably due to the disparity in physiological control afforded to each region of the tongue (Dobrovolsky 1996). There is greater innervation (in the form of mechanoreceptors) in the tongue tip and, consequently, more neuromuscular control to be had over this region (Perrier et al. 1996: 56). This greater control over the coronal region of the tongue provides a physiological explanation for the consistency of English /ɹ/ in various syllable positions and segmental environments. In contrast, this explanation predicts that German /ʁ/ will be susceptible to the influence of its syllable and segmental environment because the dorsal section of the tongue is not as controllable motorically as the coronal section. Independent evidence for these physiological observations can be obtained by comparing the behavior German /ʁ/ with that of German, [CORONAL] /l/. German /l/ does not undergo velarization in codas; rather the coronal articulation is preserved (Wängler 1967: 153-4; Hall 2000: 40-1). This of course stands in contrast with English /l/, which does velarize (Hall 2000: 40-1);

however, Revised Articulator Theory (Halle 2000 et seq.) asserts that all vowels are specified [DORSAL], thus all coda segments are under pressure to assimilate to [DORSAL] (Howe 2004), which helps to explain velarization of English /l/.

Furthermore, onsets and codas are very different environments on the basis of the articulatory pressures they place on segments. Vennemann (1988: 13) has demonstrated through robust evidence found in historical phonological changes, that onsets are ideally composed of a single strong consonant (e.g. a voiceless plosive) as is formalized in the Head Law:

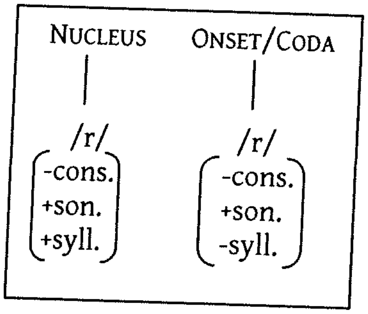
(1.10) The Head Law (Vennmann 1988: 13):

> A syllable head is the more preferred: (a) the closer the number of speech sounds in the head is to one, (b) the greater the Consonantal Strength value of its onset, and (c) the more sharply the Consonantal Strength drops from the onset toward the Consonantal Strength of the following syllable nucleus.

The Head Law outlines the historical preponderance of onset strengthening (i.e. diminishing in sonority). The other formalization relevant to this discussion is the coda law, which essentially is the converse of the head law: the weaker (more sonorous) the coda, the more optimal it is. While these laws have a diachronic application, they can be used to motivate why onset productions of /ʁ/ do not vocalize to the extent they do in the syllable rhyme. Thus, as predicted by the Head Law, German /ʁ/ in the onset is frequently realized as a strong (lower sonority) segment, in the form of a fricative or trill, depending on other segments that may be present. Conversely, the preferred coda production is one that is weak, such as the vocalized form of /ʁ/.

For the purposes of this study, English /ɹ/ will be considered specified as [-consonantal] (Parker 2002: 84; Zec 2003: 7). The chart below underscores the phonological features of English /ɹ/ in various syllable contexts:

(1.11) English /ɹ/



As far as the issue of learnability is concerned, for both groups (English and German), acquisition of the featural specification of nuclear /r/ is identical. Accordingly, it is predicted that positive transfer of the L1 phonological structure will occur and consequently facilitate the acquisition of the target phonological structure. The distinction that exists between English and German onset and coda-/r/ may prove to be a significant factor in the overall phonological acquisition of /r/. This thesis, however, does not address this issue.

2.0 Phonetic Issues: The Nature of the Input for Learners

As will be discussed in section 2.3, the acoustic nature of the target L2 segments is assumed to be integral to its acquisition. The acoustic quality and salient phonetic features of the [ɹ] and [ɐ] will be discussed in this section. Following this will be an assessment of potential substitution candidates for [ɹ] and [ɐ] based on phonetic similarity.

2.1 The acoustic attributes of English [ɹ̩]: Input for the German learner of English

To preface this discussion, it is important to observe that English [ɹ̩] is an unusual sound. It is both cross-linguistically rare (Ladefoged 1996: 313) and yet is employed frequently in American English (Ladefoged, 2005: 29). A similar sound is found in standard Mandarin Chinese (Duanmu 2000), but does not enjoy as wide a distribution as English [ɹ̩]. Its articulation is also considered among the hardest of English sounds to acquire by children (McGowan 2003: 871). It is also the only sound in English that could be considered a rhotic vowel, as opposed to a rhoticized or r-colored vowel, as can be observed in the words *air* [ʔɛ˞ɹ], or *horse* [hɔ˞ɹs]. For these vowels (Ladefoged 1996: 313), the post-vocalic /ɹ/ affects both their duration (by lengthening) and their formant structure (by causing F2 and F3 lowering). However, spectrography shows that they constitute a continuously varying articulation from pure vocalic to rhotic, compared with the homogenous spectrographic quality of [ɹ̩] production (Stevens 1999: 534-5; Ladefoged 2005: 30-1).

The most distinguishing acoustic feature of /ɹ/ in General American English is the lowering of the third formant (Ladefoged 1996: 313; Delattre 1971). While third formant lowering is most commonly attributed to the lengthening of the vocal tract through lip rounding, which is a concomitant articulation found in English /ɹ/ in general, there are other articulatory-acoustic relationships at work here. Constrictions at the palate and lower pharynx are also know to yield third formant lowering (Ladefoged 1996: 313; Stevens 1999: 151). In particular, it is important to note that English /ɹ/ can exhibit all three of these articulations to some extent. Lip rounding is a common secondary articulation for /ɹ/, although this can vary between speakers and amongst syllable positions (Ladefoged 1996: 234; Archibald, personal correspondence). With regards to palate region constrictions, Tongue-Tip-/r/ can be viewed as a palatoalveolar or a minor retroflex gesture (Barry 1997). The tongue bunching that occurs in Bunched-/r/ and Molar-/r/ involves constriction in the region of the palate (Ladefoged 1996: 234). Finally, pharyngeal constriction has also been observed to co-occur with /ɹ/ articulations (Delattre 1971: 150-1; Ladefoged 1996, Gick 2000). Given this combination of gestures for /ɹ/, it is not surprising that the third formant is lower to the extent that it is. Third formant lowering, however, is not the only acoustic product of these gestures. The acoustic effect of the /ɹ/ gesture also produces second and third formant convergence (Manning 2004:). The standard formant values that /ɹ/ possesses can be seen in (2.1):

(2.1) /r/ Formants: Stone (1996: 3735)

/r/	F1	F2	F3
Cons. [ɹ]	489	1230	1688
Syll. [ɹ̩]	488	1430	1934

The syllabic variant of /ɹ/ in English is subtly distinguished from its consonantal counterpart. Acoustically it exhibits higher frequencies for its second and third formants in the order of a ~250 Hz increase compared to the values of F2 and F3 for consonantal [ɹ]. The lower frequencies of these formants found in consonantal /ɹ/ are likely indicative of the greater oral and pharyngeal constriction (Manning 2004: 871).

Acoustically, schwa is treated as a vowel with a "uniform vocal tract cross-sectional area" (Stevens 1999: 284), in other words, no one point along the vocal tract receives more or less constriction. This vocal tract setting theoretically yields equidistant formant structure. Stevens (1999: 574) reports that schwa readily conforms to the articulatory pressures of its immediate environment and thus exhibits acoustic variability. Steven's identifies F2 as the most mutable of schwa's formants, although F3 also responds to coarticulatory pressures (such as consonantal gestures involving the tongue). For male and female speakers, Schwa's formant values exhibit the following ranges:

(2.2) Approximate Acoustic Domains (in Hertz) for Schwa Formants (As reported by Stevens 1999: 575):

Sex of Speaker:	F1	F2	F3
Female	410 – 494	1071 – 1785	2624 - 2513
Male	423 - 488	912 - 1491	2474 – 2908

2.2 The acoustic attributes of German [ɐ]: Input for English learners of German

As preface to the discussion of German /ʁ/, it is imperative to note the tremendous amount of cross-dialectal variation observed in the production of /əʁ/ sequences. Hall (1992: 102) presents the basic situation in a simple dichotomy between northern and southern varieties:

(2.3) Simple Dichotomy of Dialectal Variation of *<-e>* vs. *<-er>*:

	<-e>	*<-er>*
North	[-ə]	[-ɐ]
South	[-e]	[-ə]

Overall, the variation of rhyme-/ʀ/ in German dialects forms a continuum of pronunciations from total vocalization to the preservation of /ʀ/ as a coda (Keller, 1961; Russ, 1990). Vocalized forms of /ʀ/ include [ɐ], [ə], [ɑ], and [ɜ] in East Low German, Central Franconian, Hessian, Thuringian (Russ 1990: 120, 165, 229, 273); all of these vowels are roughly low and central to varying extents. Rhoticized vowels are also cited as possible in West Low German, and Palatinate/Pfälzische (Russ 1990: 75, 250). Apparently, central and southern Bavarian have syllabic uvulars (although manner of articulation has not been specified). Those dialects observed to have retained more than a mere vestige of the uvular (or alveolar) articulation of /ʀ/ (such as [əʁ]) are Upper Saxon (Obersaschsisch), Low Alemannic, Swabian, High Alemannic (Zurich and Barn) (Russ 1990: 369, 348, 318, 304).

With the preceding discussion in mind, a rough characterization of dark-schwa, in acoustic terms, is given. As was observed for English /ɹ/, the most important acoustic dimensions for dark-schwa, will be the first, second, and third formants. Barry (1997) provides values for the first two formants of dark schwa; unfortunately, he does not supply the third formant. Measurements of the third formant for this sound have been obtained from Ladefoged (2005) and Moisik (2006).

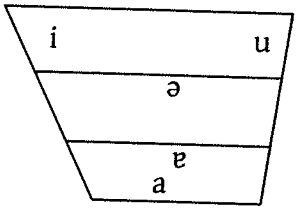
(2.4) Table of Formant Values for [ɐ̩]:

Sound:	[ɐ̩] (Barry 1997)	[ɐ̩] (Ladefoged 2005)	[ɐ̩] (Moisik 2006)	[ɐ] (Moisik 2006)
Sample Size:	n = 90; 1 n.s.	n = 1; 1 non-n.s.	n = 30; 1 n.s.	n = 10; 1 n.s.
F1 (Hz)	622	639	643	664
F2 (Hz)	1187	1186	1513	1397
F3 (Hz)	-	2648	2328	2386

The table displays mean formant values for [ɐ̩] in the first three columns, and non-syllabic [ɐ] (e.g. *Tier* [tiɐ] 'animal') in the final column for comparison. The data provided by Barry (1995) constitute a larger sample than those in the other columns. Thus, the values for the third formant should not be considered fully reliable measurements. Data from Moisik (2006) do come from a native speaker of German, while data from Ladefoged are assumed to be accurate by virtue of Ladefoged's training[6]. Due to the lack of agreement for F3 values, it is assumed to possess an F3 roughly in the 2350 – 2600 Hz range.

German schwa is assumed for the purposes of this thesis to exhibit similar acoustic attributes to that of English schwa. However, given that dark-schwa is a competing reduced vowel in German, schwa itself may be displaced in the vowel space somewhat.

(2.5) German Vowel Space: The relative location of [ə] compared to [ɐ]



Hall (1992: 98-100) claims that dark-schwa is lower in the vowel space than schwa (see 2.5); the acoustic implications of this are that dark-schwa will exhibit a higher F1 than schwa, as dark-schwa is articulated with the tongue body lower in the oral cavity. Consequently, this lower positioning also increases the volume of the front cavity, generating a lower F2 than that of schwa. As dark-schwa is a low vowel, there is also the potential for pharyngeal constriction to occur (Stevens 1999: 274), more so than for schwa. The perturbation model of acoustic resonance (see Stevens 1999) predicts mid-to-upper pharyngeal constrictions to yield a lowered F3 (Stevens 1999: 151). Therefore, dark-schwa is expected to have a lower F3 than schwa.

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[6] This data is introduced with the knowledge that Peter Ladefoged was not a native speaker of German. Despite this, it is worth noting that his first and second formant values for dark-schwa match exactly those given by Barry (1995).

2.3 Flege's Speech Learning Model

Perception of L2 input is known to have an impact on L2 acquisition. The *speech learning model* (SLM) put forth by Flege, et al. (1992a, 1992b, 1995, 2003a, 2003b, et. seq.) rests on this basic assumption. In this model, it is by virtue of input filtering through L1 perceptual categories that accents in L2 speech production exist. Such filtering is a function of the degree of fit, acoustically speaking, of an L2 phone to that of an L1 phone. The SLM dichotomizes foreign language sounds as being either *similar* or *new* when compared with the L1 inventory of phonemes. The consequence of this comparison leads to an equivalence classification; sounds judged *similar* are assigned to a previously existing L1 phonetic category, while those that are *new* trigger the creation of a new phonetic category. In the SLM this is known as the equivalence classification of "diaphones" (Flege, 1995: 241), or the linking of L1 and L2 sounds. The problem of L2 learning is succinctly captured as the "inappropriate use of previously acquired structures" (Flege, 1992: 565). For the purpose of this study, the basic tenets of the SLM will be adopted. These are summarized below:

1) As the L2 is acquired, its phonological space is mapped onto the L1.
2) Mapping is a perceptual process that serves to relate L2 sounds to L1 sounds based on acoustic properties.
3) Sounds that fail to map onto an L1 phonetic category will be classed as *new*.
4) Sounds that successfully map onto an L1 phonetic category, either by being perceived as identical or comparable will be classed as *similar*[7].
5) Once sufficient phonetic input is received *new* sounds will be readily acquired.
6) The acquisition of similar sounds is impeded by its competitor L1 sound.

(From Flege 1995: 239)

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[7] For Flege, while some sounds might be identical between L1 and L2, most possess some form of phonetic distinction to obviate the need for an *identical* classification (Flege 1992: 572).

The distinction between *similar* and *new* categories results in a distinction of the relative difficulty of acquisition[8]. Pre-existing categories that filter the L2 input are said to *impede* the acquisition of the target sound because the process of filtering the input winnows out subtle but significant distinctive phonetic attributes. *Impede* in this context should be understood as indicating difficulty relative to the acquisition of other sounds in the language that have been categorized as *new*.

Generally, acquisitional difficulty does not mean that there is an absolute time span or effort level required of the learner. It does suggest that there will be a broadly quantifiable distinction in the amount of time and effort required between *similar* and *new* sounds. While *new* sounds ought to be produced with relative ease by even novice learners, *similar* sounds are predicted to present difficulties for even the most advanced learners[9]. When the predictions concerning equivalence classification for the target sound in English and German are discussed, the issue of facilitation verses impediment will be raised again.

On a final note, Bohn and Flege (1997) assert that the identification of an L2 target sound as *new*, for the purposes of prediction of equivalence classification, should only be made when the L2 sound occupies an acoustic space that is unoccupied by other L1 phones. Flege (1989) reports an important implication of this assertion; languages with

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[8] It is assumed here that equivalence classification causes difficulty of acquisition; the goal of the analyst is to identify where perceptual equivalence may occur between the native and the target language, then predict, based on the type of classification, whether the sound will be easy or difficult to acquire.

[9] It is not always the case the *new* sounds facilitate acquisition; consider the discussion of the acquisition of clicks by Best et al (1988). Rochet (1995: 392) argues that clicks in this context constitute new sounds by virtue of being 'non-linguistic' sounds; otherwise, it is unexplained why clicks are difficult to acquire if they are indeed *new* in the Flegian sense.

a large vowel inventory are unlikely to possess any "uncommitted" acoustic space. As a result, the vowel space of such languages is likely to preclude the formation of many, if any at all, *new* categories.

2.4 Flege's Study of Italian learners of English: Italian Perception of [ɹ̩]

As will become significant in section 3.2 of this study, [ɹ̩] can form diaphonic pairings with the front vowels. Flege (2003a, 2003b) investigated the perception and phonetic classification of [ɹ̩] by Italian university students. Their typical response to the perception task was to classify [ɹ̩] as an instance of Italian /e/, /ɛ/, or /ɪ/ - all front unrounded vowels[10]. While they choose Italian /e/ most frequently, they also ranked it as a poor instance of an Italian vowel compared to other English vowel stimuli (e.g. [u] or [i]). Thus, Flege argues that the Italians identified [ɹ̩] as a new sound. Accordingly, the SLM predicts that perception and production of the sound would be facilitated and be produced accurately by novice learners. Production tests (Flege 2003a: 23-5) showed that [ɹ̩] was indeed produced accurately by early learners of L2 English as judged by native English speakers. Accuracy diminished significantly as the age of acquisition increased (from early to late) but Flege notes that acceptable productions were still found in the late learners.

Flege concludes, based on the evidence garnered from the Italian study, that acoustic properties, which are non-distinctive in the L1, will not necessarily be filtered out of the

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[10] It should be noted that Italian lacks front rounded vowels. Additionally, Standard Italian /r/, an apico-alveolar trill, is excluded from syllable nuclei; thus, it is an unlikely candidate for equivalence classification with English [ɹ̩].

L2 input by learners. Specifically, F2-F3 convergence and F3 lowering are still phonetically identified by learners, despite being non-distinctive for Italian vowels, enough so that a new phonetic category for vocalic rhoticity in L2 English can be established. Furthermore, Italians identified [ɹ̩] as a front vowel, most frequently [e]. This will be used as evidence to support the type of equivalence classification predicted to be employed by German learners of English. It underscores the fact that, despite the height of the third formant, [ɹ̩] is perceptually similar to the front vowels.

2.5 The Role of Perceptual Vowel Space in Target Substitution:

In a study closely related to the one at hand, Rochet (1995) examines the origin of a differential substitution for French /y/ by English and Brasilian Portugese speakers, both of which have only /i/ and /u/. The English group was observed to supply [u] for the target French sound, while the Brasilians instead produced [i]. Two tasks were administered to assess the perception of the target sound.

In the first task, English and Portugese speakers imitated French monosyllables containing one of three vowels: [i], [y], or [u]. Native French speakers then evaluated the imitation task; they indicated that the Brasilian speakers and English speakers could produce the sound accurately about 50% of the time. Faulty productions, however, were identified as /i/-like for the Brasilians and /u/-like for the English speakers.

The second task was a presentation of synthetic stimuli of the high vowel continuum, where F2 was manipulated across a range of frequencies. All groups of speakers were asked to divide the stimuli according to their native high vowel categories (/i/ and /u/

for English and Portugese; /i/, /y/, and /u/ for French). The French speakers identified an F2 between 1300 Hz and 1900 Hz as /y/. English speakers identified F2s in excess of 2000 Hz as /i/, and F2s below 1800 Hz as /u/. The Brasilian Portugese speakers categorically selected /i/ when F2s were at or above 1700 Hz and /u/ when F2s dipped below 1300 Hz. Thus, the acoustic domain of Brasilian Portugese /i/ more closely overlapped French /y/, compared with English /i/. In contrast, English /u/ matched the F2 domain of French /y/ more closely than Portugese /u/.

The problem of the differential substitution between Portugese and English learners of French has not been successfully accounted for in any other theory, including those that ground their analysis in distinctive phonological features (Brown 2000: 8; Rochet 1995: 394). Both English and Portugese possess the same contrast between front and back high vowels, thus it is unclear why the substitution should differ. As the SLM proposes, perception plays a critical factor in determining the L2 output. Rochet's study serves to illustrate the role that the interaction amongst acoustics, perception, and phonological space plays in interlingual production of L2 sounds. It identifies the efficacy of perceptual vowel space as a predictor of L2 output. If a speaker's L1 lacks an L2 contrast, the perceptual boundaries will not match those of native speakers of the L2. Thus, from language to language, perceptual vowel space is a function of contrast. This is in addition, of course, to the factors that give rise to cross-linguistic acoustic variation of the 'same' vowel (see Hinkl 2000). In French, the acoustic values of perceptual boundaries for vowels parallel the actual phonetic realization of these sounds; for example, [y] has a perceptual space for F2 between 1500 – 1900 Hz; acoustically, F2 for [y] runs the gamut from 1675 to 1850/1900 Hz: Rochet 1995: 385). Given this considerable overlap, it will be taken as evidence that perceptual boundaries may be inferred by consulting the acoustic structure of the target sound. Knowing the acoustic range of an L1 phonetic vowel category will aid in the identification of possible target phones to be assimilated into that category by L2 learners.

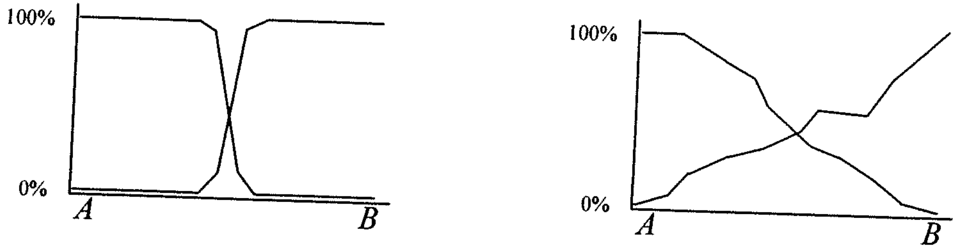
2.6 A Suitable Measure for Equivalence Classification: Various Approaches

In order to make predictions about whether target phones will be classed by L2 learners of a language as *new* or *similar*, a suitable means of assessing equivalence must be devised. One of the earlier models used to assess foreign accent, known as Contrastive Analysis (CA), posited that differences between languages are what constitute trouble spots for learners (Flege 1992: 566). The mechanism for assessing the extent of variation between languages was a simple process of comparing the phonemic inventory of the L1 with that of the L2. In application, the model failed to predict which sounds would be difficult; it also failed to identify whether problems originated on motoric or perceptual grounds. A more recent model, the Perceptual Assimilation Model (PAM; Best 1993), asserts that the phonological system influenced speech perception via assimilating L2 sounds to articulatory properties of the L1. Provided that distinct L2 categories are not assimilated into those of the L1, the model predicts that the learner will discriminate between them. Brown (2000) accuses this model of lacking explicit formalization of how and why the perceptual mapping occurs, rather it simply states that it does. She also criticizes the SLM for the same "failure to adequately formalize the perceptual mapping process" (2000: 9). While there is no intention to supply a formalization of this process in this thesis, it is important to consider how predictions of equivalence classification can be made.

For the SLM, Flege (1992: 571-2) proposes two methods of testing equivalence. The first relies on the IPA as a tool to predict sounds might fall into *similar* or *new* categories. Equivalence is based upon matching transcription used for the languages in question. Transcription, however, is not ideal for this task given the variability that exists from linguist to linguist and the nebulous correspondence between acoustic properties and the symbols representing the sounds. Transcription based systems of equivalence classification are therefore prone to making erroneous predictions. For example, English /θ/ is not used in French transcription, thus it might be predicted to be classed as a new sound for French learners of English. This sound, however, is perceived as *similar* to either /f/ or /s/ depending on context (Rochet 1995: 388).

The second method uses native speakers to adjudicate equivalence via perceptual tests. These tests necessarily rely mainly on orthography as a means of identifying foreign sounds. Native speakers listen to foreign sounds and then assign a native grapheme that best represents what they heard (Flege 1992, 1995:240). Again, perceptual tests are not without their drawbacks. Rochet (1995) addresses the issue of trivial as opposed to true categorical classification of sounds. Subjects asked to divide an acoustic continuum are constrained by the number of categories assigned to them by the experimenter. If given access to more categories, it is possible that speakers could successfully identify the extra category. This kind of error can be avoided by assessing the type of crossover line that results from graphically plotting perceptual classification:

(2.6) Schematic Graphs of Categorical and Non-Categorical Perception:



Categorical Perception:
- steep (monotonic) slopes
- indicates committed vowel space

Non-Categorical Perception:
- shallow (nonmonotonic) slopes
- may indicate uncommitted vowel space

Rochet notes that shallow and nonmonotonic slopes (linear acclivity or declivity) can be used to identify arbitrary classification of vowel space. True categorical perception is indicated by the monotonicity (steepness) of the crossover boundary lines. Rochet reports that lack of monotonicity (or departure from it) can be used as an indicator that part of the acoustic space is uncommitted.

Given the lack of a truly robust equivalence classification metric, predictions of similarity and newness, for this study, will be made on the comparison of acoustic data, given its accessibility. As acoustic data is continuous, we must be careful to keep a certain level of consistency between predictions. Thus, it is assumed that the greater the acoustic overlap between sounds, the greater the *similarity* between sounds. The primary domain of comparison will be amongst the values of the first three formants, although duration and intensity will be considered. It is also assumed that the closer the values match between L1 and L2 phones, we can predict with greater confidence that the sounds will be identified as *similar*. Grounds for a *new* classification will rest upon the sound being relatively less identifiable with any of the acoustic measurements from all likely candidates for a match.

2.7 The Sonority Hierarchy and L2: Possible and Impossible Grammars

This section discusses the possible and impossible interlingual grammars that will be imposed on learners by dint of the universal sonority hierarchy and that of the learner's L1. A coarse version of Parker's (2002: 240) universal sonority hierarchy is assumed for this discussion; this hierarchy, along with the English and German hierarchies (see section 1.2), are presented below:

(2.7) Parker's Hierarchy (Coarse)

Vowels > /r/ > /l/ >Nasals > Obstruents

(2.8) English Sonority Hierarchy (Coarse)

Vowels + [ɹ̩] > [ɹ] > /l/ > Nasals > Obstruents

(2.9) German Sonority Hierarchy (Coarse)

V + [ɐ] > [ʀ], [ʁ] > [l] > nasals > Obstruent allophones of /ʁ/ > obstruents

It is proposed that, as English and German both permit segments of equal or greater sonority than nasals to be syllabic, the only segments to be precluded from being used interlingually are syllabic obstruent allophones of German /ʁ/. In the case of English and German, the universal sonority hierarchy allows for the prediction that /r/ is a possible syllabic segment (as it has greater sonority than nasals). The language specific hierarchies show that the only segments affiliated with rhotics that are lower in sonority than nasals, are the *obstruent* allophones of German /ʁ/.

On the assumption that German's uvular trill and approximant allophones of /ʁ/ rank higher in sonority than at least German's nasals (Benware 1986: 57; Hall 2000: 118), these articulations cannot be ruled out as impossible by virtue of the sonority hierarchies. However, there is independent evidence for asserting that the uvular approximant may be impossible. This sound is articulatorily comparable to the traditional class of glides (mainly /j/ and /w/). Glides are prohibited from occupying syllable nuclei in any form other than their corresponding vowel (e.g. *syllabic-[j] vs. [i][11]; *syllabic-[w] vs. [u])). Thus, it is reasonable to conclude that the same constraint will apply to German's uvular approximant.

Finally, there is no reason to believe that [ɹ̩], [ə], or [ɐ] will be excluded from the learners pronunciation based on the sonority hierarchy, thus they have been included as possible substitute productions for nuclear-/r/ by either group of learners. In the case of the German learners of English, while German may lack a true syllabic rhotic, the sonority hierarchy does not exclude [ɹ̩] as an articulatory possibility. This is because it is more sonorous than nasals, which is where the syllabicity system bifurcates the phonemic inventory of German into non-syllabic, and potentially syllabic segments. A chart of the possible and impossible interlingual grammars is presented in (2.10):

(2.10) Grammatical constraints on nuclear /r/ production because of the Sonority Hierarchy

CONTEXT:	IMPOSSIBLE:	POSSIBLE
L1-Eng → L2-Germ	Obstruent Allophones of German /ʁ/ (e.g. [χ])	[ʀ̩], [ʁ̩]?, [ɹ̩], [ə], or [ɐ]
L1-Germ → L2-Eng	Obstruent Allophones of German /ʁ/ (e.g. [χ])	[ʀ̩], [ʁ̩]?, [ɹ̩], [ə], or [ɐ]

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[11] In English, *piano* is pronounced as [pj̥æ̃no] or [pijæ̃no] but *[pj̩æ̃no] is impossible.

3.0 The Study: Preliminaries

The following study is a bi-directional investigation of German and English phonetic acquisition of [ɹ̩] and [ɐ̩] respectively. The reason for a bi-directional study is so that a comparative perspective on the phonetic and phonological nature of rhoticity and semi-vocalic segments may be obtained. One goal of the investigation is to resolve the issue of the syllabicity gap in German discussed in section 1.1. It is posited that the evidence obtained from this thesis supports analyzing the English nuclear rhotic as belonging to the vowel class. It is also argued that, despite the fact that German lacks a true syllabic-rhotic, German learners of English can acquire [ɹ̩]. In addition, the SLM learning model is employed to make predictions about the specific phonetic production behavior of the two groups of learners based on acoustic equivalence classification of the target phones with native phones. This study provides evidence for both the model's efficacy in predicting learners' interlingual behavior and a potential inaccuracy concerning the difficulty of acquisition predicted by an equivalence classification of *similar*.

3.1 Hypotheses: Concerning the acquisition of nuclear /r/ in English and German

In section 1.2, an overview of the phonological structure of /r/ in both English and German was presented. While German and English showed variation in the structure of their onset and coda /r/s, their nuclear /r/s were identical. Section 1.1 addressed the location of /r/ on the sonority scale. German /ʁ/ can be located in a number of different ranks on the phonetic hierarchy; it can occupy the approximant, fricative, and vowel rank. English /ɹ/ exhibits considerably less variation and typically is ranked more sonorous than /l/, but less sonorous than the vowels. While it is acknowledged that the bigger picture of how acquisition of /r/ will play out amongst the learners of these languages is a complex issue, the primary focus of this study is on the *nuclear environment.* The syllable nucleus is a point of phonological common ground between these two languages as rhotics in these locations are specified as [-consonantal]. Thus, this structure is conducive to positive transfer between the languages.

The target nuclear rhotics in both languages share acoustic similarities with sounds in both L1s. As will be investigated in section 3.2 and 3.3, the degree of vowel space overlap between these languages will be identified. These two factors are hypothesized to impede the learning process for both groups. The central hypotheses of this investigation are thus stated:

H1: Positive phonological transfer of L1 structure of nuclear rhotics in both languages will facilitate the acquisition of the phonological structure.

H2: Acquiring accurate phonetic production of nuclear rhotics will be inhibited in both languages because of the high potential for equivalence classification of the target phone into a phonetically similar L1 category.

The two hypotheses represent the competing grammatical pressures acting on learners. The phonological structures are roughly identical in both languages and thus learners can generalize the L1 structure to that of the L2. This is predicted to facilitate the acquisition of the syllable structure of nuclear /r/ for both groups of learners. The phonetic component of the learning task, however, is predicted to inhibit the acquisition of L2 target production. This is attributable to an equivalence classification of *similar* for the target sound by both groups (discussed in the subsequent sections). Thus, the prediction made by this study is that empirical evidence can be obtained to demonstrate that learners are producing non-native-like articulations (either syllabic rhotics or some form of vowel substitute like [ə]) for the target L2 sound. However, these learners will not resort to the type of repair strategies employed when the phonological structure is considerably different, such as epenthesis (e.g. if the Germans produced *butter* as [bʌɾəɹ] instead of [bʌɾɹ̩]) or deletion.

(3.1) Summary of the learning task hypotheses and implications:

Learning Type:	Influence of the L1 Grammar:	Production:
Phonological	facilitates	no syllable or segmental repair strategies
Phonetic	inhibits	contrasts may not be produced faithfully; L1 phonetic forms used for L2 target

The next section explicates the motivation for a similar equivalence classification as specified in H2. It also details the specific productions predicted to be employed by L2 learners.

3.2 Predictions: German learners of English

The first prediction concerning German learners of English is a claim about the set of German phones that will be classified as similar to English [ɹ̩]. By implication, the second prediction asserts whether the learning of the sound will be impeded or not, i.e. whether the learners will classify [ɹ̩] as *similar* or *new* relative to their L1 vowel space.

As was learned from Flege's Italian study (section 2.4), the front vowel [e] (among others) was identified as the most perceptually similar Italian vowel to English [ɹ̩]. While this study does not directly inform us about the perception of [ɹ̩] by native speakers of German, it does indicate a potential relationship between the front vowels and [ɹ̩]. The sole difference compared to Italian is that a finer grained distinction can be made in German due to the presence of front rounded vowels. Further evidence of the relationship between front rounded vowels and [ɹ̩] comes from a moribund dialect of French spoken in Pennsylvania known as Frenchville French. There is a phonological merger occurring between front rounded /ø/ and /œ/ into a new /ɹ̩/ phoneme (Bullock 2004: 101). Acoustically, front rounded vowels exhibit lowered second and third formants because of lip rounding (Stevens 1999: 290-2). This makes them ideal candidates for equivalence classification with [ɹ̩] given similar acoustic make-up. The following table presents the first three formant values for a range of German vowels, which share acoustic properties with [ɹ̩]:

(3.2) German Vowel Formants vs. [ɹ̩]:

English Vowel	F1	F2	F3	
[ɹ̩]	488	1430	1934	-
German Vowel	F1	F2	F3	Candidate Ranking
[yː]	301	1569	**1934**	1st
[øː]	393	**1388**	2045	2nd
[ʏ]	**428**	1340	2137	3rd
[œ]	559	1353	2277	4th
[ə] [12]	395	**1455**	2400-2600	5th
[ɐ] [13]	622	1187	2400-2600	6th

(Barry 1995; Strange et al. 2004; Stone 1996)

In bold are the frequencies most closely shared with [ɹ̩] relative to the other candidates. In addition to the gamut of front rounded vowels in German, both reduced vowels have been included. This is on the assumption that reduced vowels in German might also constitute reasonable perceptual counterparts for [ɹ̩] given the phonetic and phonological relationship that exists between [ə] and [ɹ̩] in English (see section 2.1)

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[12] F3 measurements based on preliminary data collected for this study.

[13] F1 and F2 supplied by Barry 1995; F3 based on Moisik 2005 and measurements of [ɐ] productions by Peter Ladefoged (2005).

Unlike the Italians in Flege's study, the Germans will be faced with a greater degree of acoustic overlap between their front rounded vowels and [ɹ̩]. It is predicted therefore that [ɹ̩] will be classed as a *similar* sound. Furthermore, production of the sound will likely be executed using a vowel that falls below the high front rounded German vowels (/y/ and /ʏ/), and above the mid front rounded ones. Based on chart (3.2) the sound will likely fall between [yː] and [øː], or simply be one of these vowels. There is also the possibility that duration will be an important factor; both [yː] and [øː] are distinctively long in German compared with [ʏ] and [œ], whereas [ɹ̩] can vary in length[14]. At this point, duration is considered too context sensitive to be a reliable heuristic tool for perceptual candidate selection.

(3.3) Summary of Predictions: German learners of English

1) The optimal perceptual candidate/match for [ɹ̩] is: [yː] or [øː]

2) Equivalence classification for [ɹ̩] will be: *similar*
This entails that acquisition of accurate production will be impeded as in accordance with the SLM.

3.3 Predictions: English learners of German

Perceptual classification of dark-schwa in English seems to be more straightforward given the ubiquitous presence of ordinary schwa in English. If English learners do place dark-schwa in schwa's phonetic category, then it is likely that acquisition of the fine phonetic distinction that exists between dark-schwa and schwa will not be acquired. Consequently, it is predicted that learners will not show a significant difference between their productions of German schwa and dark-schwa, and furthermore, these productions are predicted to closely match their English productions of schwa.

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[14] for example the [ɹ̩] in *bird* would be longer than that in *Burt* as voiced consonants typically length tautosyllabic vowels in English

There is, however, the potential for orthography to have an influence on novice learners. Without enough phonetic input to lexicalize German phonology correctly, learners may resort to English phonemic awareness when pronouncing unfamiliar (or perhaps even recently acquired) words. This is because there is considerable overlap between the orthography of cognates in English and German; for example, compare German <Hammer> [hamɐ], with English <hammer> [hæmɹ̩]. Recent German loans into English also reflect the orthographic correspondence between German <-er> and English <-er>. English schwa would have been an ideal phonetic replacement for the <-er> in the German loan *weiner*, which would match the dark-schwa pronunciation in German. Instead, perhaps because most English speakers have never heard the a native German speaker pronounce these names, orthographic intuition prevailed and we employ [ɹ̩] for the <-er>. This is true of numerous other German loans, such as 'hamburger', and 'frankfurter'. In addition to this, the innumerable anglicized forms of German and Austrian composers, scientists, artists and the like with <er> in their written name are pronounced with [ɹ̩] instead of schwa. Consider the English pronunciations of <Schoenberg>, <Schubert>, <Webern>, and <Mahler> to name a few composers.

We now turn to the candidate chart for English learners of German. The vowels that have been selected as possible perceptual filters for dark-schwa constitute both the set of reduced vowels in English (including [ɨ] in words such as the verb *decent* [dɨsɛnt]) and members of the set of unrounded back vowels, such as [ʌ] and [ɑ]. Both [ʌ] and [ɑ] are produced low in the oral cavity, which means F1 values are high and F2 values are relatively low. As no significant lip rounding is usually present for these sounds, the third formant is distinctly higher than it is for [ɹ]. Comparison of these sounds with dark-schwa reveals that they are similar enough acoustically that they are predicted to be possible perceptual sinks for dark-schwa input. English schwa undoubtedly has the most in common with dark-schwa so it consequently is predicted to be the strongest candidate for perceptual classification of dark-schwa.

(3.4) English Vowel Formants vs.[ɐ]:

German Vowel	F1	F2	F3	-
[ɐ]	622	1187	2400-2600	-
English Vowel	**F1**	**F2**	**F3**	**Candidate Ranking**
[ə][15]	**619**	1804	**2820**	1st
[ɑ]	957	1477	**2802**	2nd
[ʌ]	704	1485	2930	3rd
[ɹ̩]	488	**1430**	1934	4th

(Stone 1996)

As this chart only indicates formant structure, the competition between [ʌ] and [ɑ] might not be accurately portrayed. It is important to remember that duration is a distinguishing factor of dark-schwa as well. Thus, while [ɑ]'s formant structure is a more like dark-schwa's than [ʌ]'s formant structure, [ʌ] is typically, of shorter duration than [ɑ] and consequently may be a better candidate for substitution of a reduced vowel. Both Moulton (1962: 35) and Hall (1992: 100) make note of the perceptual similarity of *Standard British* [ʌ] to dark-schwa; therefore, it might be assumed that *American* [ʌ] is a reasonable match for dark-schwa as well.

Unless orthographic transfer is causing interference with dark-schwa production, it is predicted that the use of [ɹ] will be less likely than the others vowels on purely acoustic grounds.

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[15] Formant measurements obtained from list utterances of schwa of native speaker of English recorded in the pilot study.

(3.5) Summary of Predictions: English learners of German

1) The optimal perceptual candidate/match for [ɐ] is: [ə]

2) Equivalence classification for [ɐ] will be: *similar*

This entails that acquisition of accurate production will be impeded as in accordance with the SLM. Also, no contrast is predicted to be produced by the learners.

3.4 Design and Methodology

The goal of this study is to assess the L1 and L2 production of German speakers of English and English speakers of German with regards to nuclear-/r/. German and English schwa production is also assessed. The author assembled two word lists and followed similar token acquisition guidelines for both languages. The most salient difference between the token sets is that English nuclear-/r/ is capable of being stressed; German dark-schwa, however, cannot be stressed. Schwa in both languages occurs in unstressed syllables and so similar guidelines were observed while tokens for schwa were collected. The guidelines for token collection were as follows:

1) Words of varying length were obtained and categorized into monosyllable, bisyllable and polysyllable groups.
2) Monosyllabic words were selected to exhaust (as completely as possible) the range of phonotactically permissible environments for the target sound.
3) Polysyllabic words that contained iterative targets were sought after.
   e.g. *murderer* ; *Zauberer* 'magician'
4) [for English] A balance was struck between collecting stressed and unstressed targets in token words.
   e.g. *cleaver* vs. *clergy*
5) While no frequency controls were in place, most words collected were judged to be relatively common. However, some words were chosen for their obscurity (e.g. tergiversate) to identify whether orthography could cue the target.
6) Loci for English schwa were controlled so that [ɨ] productions could be compared with true schwa productions.
   e.g. *d*[ɨ]*stroy* vs. *Canad*[ə]

In addition to the token lists, a number of sentences were created to control for list intonation (via comparison of sentence utterance with list utterance). Sentences ranged from transitive to intransitive with few to many adjuncts. A variety of intonation contexts (such as interrogatives and imperatives) were also created to provide further data on the effect of changes in pitch (F0).

The researcher briefly instructed the consultants on how the data was to be elicited and on how to read the list so as best to avoid list intonation. The consultants were asked to read the list three times so that they became familiarized with the process in the hopes of allaying any stress that might have interfered with linguistic naturalness. At the end of the token set, the researcher asked the consultants to provide a brief description of their experience with the L2 language (in English) along with a sample of spontaneous speech in German.

The data was collected using an audio-technica AT3035 cardioid condenser microphone and digitized using a UA-25 Edirol USB digital interface for PC. Cool Edit Pro 2 was used to record and store the digitized audio at a 16-bit resolution and a 44.1kHz sample rate. PRAAT was used both for spectrographic analysis and for the generation of spectral and spectrographic images presented in this thesis.

3.5 Analysis of Data

The following case studies are investigations into the target production by learners from both groups. For the English learners of German a within consultant statistical analysis (two-tailed t-tests; $\alpha = 0.05$) will be presented to determine if the production of the target (dark-schwa) is significantly different from schwa, i.e. to see if they contrast phonetically. Similar statistical analyses are conducted for the German speakers as well to determine if the dark-schwa/schwa contrast is observed. A within group analysis was also conducted for the German data of [ɹ̩] between the list, sentence and spontaneous utterances to identify if production was consistent from one level of formality to the next. Non-statistical comparisons are then made for [ɹ̩] between the German and English groups to determine if the acoustic structure was observably similar or distinct. Overall comparisons will be made to the formant structure of equivalence candidates explored in section 3.2, and 3.3. Finally, the presentation format will be as follows: English L2 learners, followed by German L2 learners, from novice to experienced. To further illustrate the data, the reader is advised to consult Appendix-A, which contains composite spectra of crucial data points for each case study.

German learners of English: Data Analysis of Consultant-G_1

Consultant-G_1 has had a total of twelve years of exposure to English, which includes periods of residence in English speaking Canada. The subject claims to have had six years of intense immersion (working in an English academic environment). Originally, the subject hails from a small town neighboring Hamburg, which places him technically in the North Lower Saxon (Nordniedersächsich, Holsteinisch, Plattdeutsch) dialect group. Subjectively, this consultant comes across as a highly articulate and confident English speaker with a noticeable but unobtrusive German accent.

(Table 3.1) Consultant-G_1's German Production Data: Schwa vs. Dark Schwa

Environment	Token List			Sentence	
	[ɐ]	[ɐ̩]	[ə]	[ɐ]	[ə]
F1	562 (95)	588 (49)	519 (66)	542 (86)	467 (91)
F2	1283 (145)	1261 (75)	1388 (58)	1198 (203)	1389 (187)
F3	2295 (226)	2247 (112)	2464 (80)	2158 (215)	2262 (170)

*note: standard deviations are shown in parentheses

While the extent of overlap between these similar sounds is considerable, there are demonstrably significant differences between schwa and dark-schwa for this speaker. The values of F1 for sentence [ɐ] and [ə] were not significantly different at $p < 0.416$ ($df = 24$). However, the F1 of token-list productions were: $p < 0.001$ ($df = 32$). Sentence F2s had a $p < 0.021$ ($df = 24$). List F2s also came out to be significantly different: $p < 0.0001$ ($df = 32$). Token F3 values between schwa and dark-schwa differed at $p < 0.0001$ ($df = 32$). Finally, F3 values for sentential utterances came out to be non-significant at $P < 0.189$ ($df = 24$). Note that values for non-syllabic dark-schwa are presented for the purposes of comparison to syllabic dark-schwa.

These results indicate that the consultant was indeed contrasting the two sounds as expected in the token context. This contrast was mildly neutralized to some extent in sentential utterances.

(Table 3.2) Consultant-G_1's English Production: Nuclear-/r/ and Schwa

Environment	Token List		Sentence		Spontaneous	
	[ɹ̩]	[ə]	[ɹ̩]	[ə]	[ɹ̩]	[ə]
F1	487 (44)	559 (100)	481 (45)	-	519 (25)	470 (63)
F2	1304 (64)	1377 (137)	1352 (106)	-	1283 (39)	1335 (121)
F3	1812 (127)	2418 (144)	1924 (215)	-	1999 (99)	1928 (162)
F3-F2	484 (85)	1056 (184)	560 (161)	-	721 (108)	594 (150)

*note: standard deviations are shown in parentheses

Consultant-G_1's English progressively loses the F3-F2 convergence pattern, characteristic of [ɹ̩], as the formality of the task decreases (from List to Spontaneous). The third formant height changes as well on the basis of task formality. As formality decreases, the third formant value elevates. This seems to indicate that the speaker, is most capable of producing [ɹ̩] in formal contexts, but loses the articulation when other articulatory pressures are faced (such as long term utterance planning). The substitute for [ɹ̩] sound appears to be assuming the formant structure of a front rounded vowel, as was predicted in section 3.2. The first formant (from 487 Hz to 519 Hz) indicates a mid-level articulation akin to [e]. A decrease in second formant frequency shows a tendency towards an ever-increasing anterior resonating cavity – suggesting that the tongue is progressively descending (from context to context). Finally, the third formant value appears in the mid-to-low range (from 1812 Hz to ~2000 Hz). F3 and F2 for [ɹ̩] seem to suggest the formant structure of [øː]. It should be kept in mind that the speaker is producing [ɹ̩] in limited contexts, only in less formal occasions producing deviant productions of the sound. It is likely what is being observed is a hybrid sound of both normal German front rounded vowel productions and [ɹ̩].

German learners of English: Data Analysis of Consultant-G_2

Consultant-G_2 has resided in an English speaking country (Canada) for ten years. She was first exposed to English in grade school and, by subjective judgment, is highly fluent in the language, albeit stilted sounding at times. She hails from the city Zelle, which is due southwest of Dresden in the Saxony region likely placing her in the East Low German dialect group.

(Table 3.3) Consultant-G_2's German Production Data: Schwa vs. Dark Schwa

Environment	Token List			Sentence		Spontaneous	
	[ɐ]	[ɐ̩]	[ə]	[ɐ]	[ə]	[ɐ]	[ə]
F1	631 (207)	671 (73)	625 (47)	698 (86)	587 (65)	684 (86)	535 (65)
F2	1662 (207)	1689 (181)	1722 (121)	1552 (170)	1848 (229)	1534 (196)	1748 (145)
F3	2669 (134)	2757 (162)	2849 (111)	2757 (142)	2893 (186)	2987 (137)	2968 (162)

*note: standard deviations are shown in parentheses

Regarding the contrast between [ɐ̩] and [ə], the token list items show no significant differences in any of the three formants analyzed. However, the first formant came close to differing at $P < 0.058$ (df = 32). Sentential items, on the other hand, were statistically different, where a of $P < 0.0001$ (df = 32) was obtained for both F1 and F2. The spontaneous items only showed a significant difference in F1 and F2, where $P < 0.0140$ (df = 8).

These results indicate that for the most part dark-schwa and schwa for this speaker do contrast by virtue of the first formant. The speaker does show a great degree of variability though. German dialectology predicts that both of these speakers will vocalize /ʁ/ in post-vocalic environments (Keller 1961: 310; Russ 1990: 120). The speakers do not deviate from this prediction and the minimal variation between them is likely do to individual differences.

(Table 3.4) Consultant-G_2's English Production: Nuclear-/r/ and Schwa

Environment	Token List		Sentence	Spontaneous
	[ɹ̩]	[ə]	[ɹ̩]	[ɹ̩]
F1	547 (70)	637 (47)	598 (72)	578 (86)
F2	1748 (152)	1781 (169)	1727 (151)	1784 (194)
F3	2351 (197)	2854 (231)	2565 (335)	2586 (194)
F3-F2	596 (139)	1066 (252)	739 (185)	802 (266)

Consultant-G_2 behaves in a similar fashion to Consultant-G_1 with regard to the gradual loss of F3-F2 convergence as task formality decreases. F3 and F2 values for [ɹ̩] are also remarkably high indicating that the sound is not being faithfully produced. She is, however, successfully contrasting [ɹ̩] and [ə] in token utterances based on an F1 ($P < 0.0040$; df = 40) and an F3 ($P < 0.0001$; df = 40), though not on F2 ($P < 0.630$).

The formant structure of Consultant-G_2's [ɹ̩]s are comparable to, yet critically distinct from, her German dark-schwas and schwas. The first formant of [ɹ] (547 to 598 Hz) lies in roughly the same range as that of German [ə] (535 to 625 Hz). It seems that [ɹ] more closely matches [ə] in F2, which runs in the range of 1722 to 1848 Hz. It was noted in section 2.1 that schwa exhibits the most variability in F2 structure. Crucially, however, the third formant is ~400 Hz lower for [ɹ̩] than her German schwa and ~300 Hz lower than dark-schwa. It is proposed that once again some form of front rounded vowel is being substituted for the English target, [ɹ̩]. Most plausible is German [œ], whose F3 is the highest amongst the front rounded vowels in German: [œ] has an F1 of 599 Hz, an F2 of 1353 Hz, and an F3 of 2277 Hz. Thus, while Consultant-G_2's [ɹ̩] values for F2 and F3 are higher than those of [œ], it should be noted that the same is true for her reduced German vowels. For example, the formant chart in section 3.2 indicates that both schwa and dark-schwa are produced with F1, F2 and F3 values all ranging 100 Hz to 300 Hz lower than the subject produces them. The fact that she is a female with a high fundamental frequency (~200 Hz) explains the higher formant values of this speaker's [œ] and dark-schwa productions (Borden 2003: 90). It is concluded then that [œ] is the substitution target for her infelicitous productions of [ɹ̩].

English learners of German: Data Analysis of Consultant-E_1

Consultant-E_1 represents an extreme end of the English learners of German spectrum; this subject claims to have no knowledge of German. She was selected to test the hypothesis that orthography may impose an influence on the production of novice German learners. She was first instructed to attempt to pronounce the German token list. Then the subject was told to listen carefully to a subset of the token list as produced by a native speaker of German. After a brief pause, she again attempted to say the German words. This process was repeated one more time. The following chart illustrates the results of this staged learning task:

(Table 3.5) Consultant-E$_1$'s English Production: Nuclear-/r/ and German Dark-Schwa

Environment	English	Initial attempt at German	German Trial 1	German Trial 2
	[ɹ]	[ɐ]	[ɐ]	[ɐ]
F1	462 (48)	449 (70)	453 (85)	521 (41)
F2	1431 (104)	1445 (101)	1593 (102)	1650 (105)
F3	1717 (78)	1727 (99)	1926 (108)	2094 (134)
F3-F2	284 (53)	206 (34)	306 (28)	427 (42)

Initial attempts at producing dark-schwa indicate that English [ɹ] was used (F1: $p < 0.490$; F2: $p < 0.6800$; F3: $p < 0.7250$ ($df = 38$)). This suggests that orthographic transfer has occurred. However, it should be noted that all formant values and the F3-F2 gap increase after each 'learning' session. The formant values (particularly F1) in *German Trial 2* indicate that the tongue is being lowered for German <er> but not enough to allow for classification of the sound as [ɑ] or [ʌ], whose F1s are in excess of +700Hz. The author has subjectively classified the sounds produced in *German Trial 2* as a rhoticized lax mid-open front vowel, [ɛ˞]. In any case this new production is significantly different from the initial attempt at German [ɐ] (F1: $p < 0.0060$; F2: 0.0001; F3: $p < 0.0001$). The sound is evidently not an accurate [ɐ]; comparing consultant- E$_1$'s production (a female) to that of Consultant-G$_2$ (also a female): consultant- E$_1$'s dark-schwa has an F1 that is about 200 Hz lower and an F3 that is about 700 Hz lower than the native values. As the consultant did not evidently attain a true production of dark-schwa, but did manage to change her production of the target, despite being ignorant to the nature of the learning task, indicates that she was capable of overcoming the influence of orthographic transfer of <er>.

English learners of German: Data Analysis of Consultant-E_2

Consultant-E_2 is a native to Western Canada; she has spent two years studying academic German. For a period of six weeks she sojourned in Kastel (Germany), where she experienced full immersion in German with a host family. She has classified herself as a novice German learner. We begin with a brief look at her English [ɹ̩] data to get a bearing on her L1.

(Table 3.6) Consultant-E_2's English Production: Nuclear-/r/ and Schwa

Environment	Token List		Sentence	Spontaneous
	[ɹ̩]	[ə]	[ɹ̩]	[ɹ̩]
F1	444 (53)	618 (179)	448 (56)	420 (0)
F2	1465 (92)	1804 (206)	1547 (161)	1284 (0)
F3	1781 (114)	2819 (255)	1876 (236)	1736 (0)
F3-F2	325 (73)	978 (98)	312 (91)	427 (0)

*note: standard deviations are shown in parentheses

This speaker demonstrates the standard [ɹ̩] pattern. However, the F3-F2 convergence pattern has subtly diminished in her spontaneous productions. The consultant also employs a typical schwa with formants roughly equidistant from each other and a considerable amount of variability.

Table 3.7 Consultant-E_2's German Production Data: Schwa vs. Dark Schwa

Environment	Token List			Sentence		Spontaneous	
	[ɐ]	[ɐ̩]	[ə]	[ɐ]	[ə]	[ɐ]	[ə]
F1	540 (65)	482 (50)	665 (60)	564 (60)	628 (145)	676 (79)	531 (133)
F2	1547 (112)	1582 (169)	1659 (93)	1545 (177)	1784 (140)	1535 (105)	1663 (170)
F3	2041 (406)	2500 (113)	2781 (88)	2412 (157)	2646 (128)	2451 (137)	2464 (144)

*note: standard deviations are shown in parentheses

This learner shows evidence of making a contrast between [ɐ̩] and [ə] in the more formal list elicitation task. For the token list, both F1 and F3 differ significantly at the level of $p < 0.0001$ ($df = 26$); F2 does not show a contrast with $p < 0.1350$ ($df = 26$). While F1 does not contrast statistically for the sentential elicitation ($p < 0.1220$; $df = 24$), both F2 ($p < 0.0020$; $df = 24$) and F3 ($p < 0.001$; $df = 24$) do. Finally, spontaneous [ɐ̩] and [ə] formant values fail to contrast significantly (F1: $p < 0.0870$; $df = 10$; F2: $p < 0.1480$; $df = 10$), except F3 ($p < 0.0001$; $df = 10$). Thus, it is concluded that this consultant has acquired a phonetic contrast between schwa and dark-schwa, but does not maintain it in informal contexts.

A comparison of formant values between Consultant-G_2 (female German native) and Consultant-E_2 (female German learner) reveals that Consultant-E_2's F3 formant structure for both schwa and dark-schwa is typified by lower frequency values for all formants to the order of 100 Hz to 300 Hz. Conversely, the F3 values (for schwa and dark-schwa) of Consultant-G_2 are roughly 100 Hz to 300 Hz higher than those of Consultant-G_1 (a male German native). Thus, these differences could be a product of the Consultant-E_2's low fundamental frequency ~175 Hz, compared with Consultant-G_2's, which is ~ 230 Hz. One deviation worth noting is the relative heights of the first formant for schwa and dark-schwa. True German dark-schwa should have a first formant that is lower than German schwa. This pattern can be attributed to tongue height; generally, the lower the tongue in the oral cavity, the higher the first formant. Dark-schwa is characterized as being lower in height than schwa (Hall 1992: 98-100). Consultant-E_2, however, appears to have reversed the pattern; her schwa has higher formants than dark-schwa for both sentence and list contexts. The reason for this pattern reversal stands to be explained. There is no indication based on the value for F1 of dark-schwa in these interlingual productions that [ʌ] or [ɑ] are being substituted for the German dark-schwa target. The F1 of the schwa productions is sufficiently high to indicate that [ʌ] may be being substituted. The formant values presented in section 3.3 (F1: ~700Hz, F2: ~1500Hz, F3: ~2900Hz) do match those observed in table 3.7.

English learners of German: Data Analysis of Consultant-E_3

The final consultant, a native to Canada, has received over 200 hours of formal instruction in German. In addition to this she spent seven months in Germany, employed by a German company and enjoyed daily contact there with the language. She is the most advanced of the L2 German speakers, but it should be kept in mind that she is still a relatively novice speaker at that. Once again, we begin with a brief overview of the speaker's production of her native language, and then turn to her German production.

Table 3.8 Consultant-E_3's English Production: Nuclear-/r/ and Schwa

Environment	Token List		Sentence		Spontaneous
	[ɹ̩]	[ə]	[ɹ̩]	[ə]	[ɹ̩]
F1	441 (59)	685 (109)	497 (80)	532 (91)	482 (44)
F2	1573 (81)	1665 (76)	1610 (117)	1666 (193)	1654 (95)
F3	1932 (117)	3084 (202)	1966 (126)	2989 (141)	1993 (117)
F3-F2	355 (62)	1422 (207)	343 (91)	1356 (218)	327 (44)

*note: standard deviations are shown in parentheses

A cursory glance at this speaker's [ɹ̩] reveals it to possess the same characteristic qualities that have been observed throughout this thesis. Perhaps more interesting is the high F3 of both schwa groups. It lands 200 Hz to 300 Hz higher than those observed for Consultant-E_2.

Table 3.9 Consultant-E_3's German Production Data: Schwa vs. Dark Schwa

Environment	Token List			Sentence		Spontaneous	
	[ɐ]	[ɐ̩]	[ə]	[ɐ]	[ə]	[ɐ]	[ə]
F1	549 (102)	702 (73)	564 (55)	681 (114)	495 (77)	602 (88)	574 (130)
F2	1563 (194)	1716 (132)	1801 (94)	1637 (151)	1982 (173)	1579 (106)	1758 (260)
F3	2991 (173)	3009 (117)	2892 (128)	2985 (197)	2975 (129)	2972 (135)	2833 (121)

*note: standard deviations are shown in parentheses

Beginning with the speaker's token list utterances, there is evidence of a contrast between schwa and dark-schwa. Both F1 and F3 show significant differences (at $p < 0.0001$ and $p < 0.0140$; $df = 33$); F2 narrowly fails to show significance ($p < 0.0730$; $df = 33$). The sentential groups are statistically different in terms of both F1 and F2 (for both $p < 0.0001$; $df = 28$); however, with a $p < 0.8860$ ($df = 28$), F3 fails to be significantly different between the two phones. Finally, spontaneous productions fail to differ at a statistically significant level (F1: $p < 0.6710$; F2: $p < 0.1420$; F3: $p < 0.0900$; $df = 10$).

The statistical analysis evinces that once again this L2 German consultant has managed to contrast schwa and dark-schwa. The learner also produces the formants in accordance with the pattern observed for natives (i.e. dark-schwa has higher formant frequencies than schwa). Spontaneous productions of the sounds could not be shown to contrast significantly; this could be due to a small sample size. Finally, it seems that again [ʌ] may be the phonetic realization of dark-schwa for this speaker given the correspondence between the formant structures observed for this sound (see section 3.3) and those presented in table 3.9. The best match is found between the F1 of the learners dark-schwa and that of [ʌ] (~700Hz).

3.7 Discussion: Observations and Implications of the Acoustic Study

With respects to the English learners of German, it would seem that they acquired a phonetic contrast between dark-schwa and schwa. However, for Consultant-E_2 the expected formant values between the two vowels were unexpectedly reversed. Nevertheless, these results arguably run contrary to H2 (see section 3.1) the hypothesis founded on the claims of the SLM that *similar* diaphones represent an impediment to learning. If it is accepted that the English learners of German did indeed contrast the two schwas, then it is questionable whether they were impeded at all by equivalence classification. On the contrary, given that both of these learners had considerably limited experience with German, it is remarkable that the contrast was produced. In other words, the novice German learners were not hindered in their development of the native contrast by the presence of an existing L1 competitor (schwa) for equivalence classification and L2 target substitution. As this finding challenges the learning process proposed by the SLM, it would be an ideal topic to pursue in future research. It should be noted that while a contrast was observed to be made between the two German reduced vowels, it is likely that these productions do not approximate the German targets perfectly. It is very possible that dark-schwa was produced as [ʌ] by the learners. Finally, with respects to H1, there was no evidence for phonological repair strategies; rather, there was positive evidence that both the syllable structure and the segmental structure of German are faithfully produced. Whether the underlying representation for [ɐ] was acquired (i.e. /-əʁ/), however, cannot be answered with the data collected here.

The German learners of English, on the other hand, indeed appeared to be impeded by the diaphone relationship between English [ɹ̩] and the front rounded vowels in German. Both learners examined were highly fluent in the spoken language, yet failed to show evidence of a truly native-like production of [ɹ̩]. Thus, there is evidence to support H2, and consequently the SLM. It was noted that, for both consultants, task formality appeared to improve the production, but as formality decreased, so did the accuracy of the production. As discussed in section 2.7, [ɹ̩] productions were evidently not impossible for the German learners, despite their difficulty. This constitutes evidence to support the claim that syllabic rhotics are learnable by Germans, despite the lack of one in their L1. With regards to H1, the syllable structure was preserved and the substitution pattern indicated that a front rounded vowel was a suitable replacement for [ɹ̩]. This supports the view of [ɹ̩] as [-consonantal] as discussed in section 1.2.

Concerning the theoretical question posed in this thesis- the ranking of /r/ in the sonority hierarchy- the following observations can be made:

1) The German learners substituted a front rounded vowel for nuclear-/ɹ/
2) The English learners produced a contrast between nuclear-/ʁ/ and German [ə].

The first observation constitutes evidence that German learners of English perceive English [ɹ̩] as a vowel. It is conceivable that the learners might have re-syllabified the /r/ into the syllable coda, producing [Vɹ] (for example *bird* pronounced as [bɪɹd]). It would appear, however, that the German learners of English tolerated rhotic segments in syllable nuclei. The fact that the Germans substituted a vowel for it is evidence that the speakers perceive the segment as homogenous and attempted to remain faithful to this perception during production of the sound by substituting an equally homogenous sound. The German phonetic vowel space does not allow much room for [ɹ̩] to be given a distinct category and is thus absorbed, via equivalence classification, into that of a mid front rounded vowel. This evidence helps to support the classification of [ɹ̩] as a *vowel* in the English sonority hierarchy.

The second observation has more dubious implications for the sonority hierarchy than the first. English speakers did not show evidence of rhoticizing dark-schwa productions or substituting dark-schwa with [ɹ̩]. This indicates that learners perceive dark-schwa as a non-rhotic by learners, which explains its treatment as non-rhotic during interlingual production. This challenges the view that dark-schwa fills the /r/-gap in German's syllabic class. Thus, if dark-schwa is not considered a member of the rhotic class, then the problem of the syllabicity gap remains. This does not ultimately effect the placement of dark-schwa within the German sonority hierarchy though, as it is undoubtedly a vowel.

A brief summary table of the findings of this study is now presented:

Table 3.10 Summary of Findings:

Learner Group:	H1: Phonological Transfer	H2: Phonetic Impedance	The Sonority Heirarchy
EngL1 → GerL2	observation: phonological structure appears to be unchanged; no evidence of syllable or segmental alteration based on incongruent phonological structure conclusion: cannot reject phonological structure proposed in section 1.2; transfer of phonological structure has likely occurred; *H1 is sustained*	observation: contrast between schwa and dark-schwa acquired conclusion: pre-existing *similar* L1 category did not impede acquisition *contrary to H2*	observation: reduced vowel contrast can be acquired; no rhoticity detected conclusion: dark-schwa is not treated as a rhotic; raises the question of whether dark-schwa fills the rhotic gap in the system of syllabic segments in German.
Ger L1 → EngL2	observation: syllable structure appears to be unmodified; segmental repair is explicable in the phonetic domain conclusion: cannot reject phonological structure proposed in section 1.2; transfer of phonological structure has likely occurred; *H1 is sustained*	observation: advanced learners showed evidence substituting front rounded vowel for [ɹ̩]; formal productions were more native-like than informal conclusion: similar sound equivalence classification appears to have impeded acquisition; *support for H2*	observation: [ɹ̩] is produced as a vowel conclusion: indicates that [ɹ̩] is reinterpretable as a vowel; evidence to place rhotics in with glides and vowels in the English sonority hierarchy.

4.0 Conclusion: The Acquisition of Nuclear-/r/

This thesis has been an exploration in to the issues surrounding the acquisition of /r/ as it occurs in nuclear contexts in English and German. The main impetus for investigating such an issue was to confront the question of whether German has a gap in their system of syllabic segments. A gap in the German system could have potentially negative phonological and typological implications. This issue arises from the placement of /r/ in the sonority hierarchy. If /r/ is classed as having greater sonority than /l/ or nasals, then German ought to have a syllabic /r/ because both /l/ and nasals can be syllabic. A comparative L2 study of the productions of /r/ in nuclear contexts by German learners of English and English learners of German was conducted to determine if interlingual forms could shed light on this problem. The sonority hierarchy allowed for the prediction that English [ɹ̩] would be a possible articulation for Germans to acquire, despite lacking a corresponding syllabic rhotic in their language. Conversely, it was predicted that English speakers might employ [ɹ̩] as a substitute for dark-schwa.

It would seem that /r/ was an acceptable vowel to the German learners of English because they substituted a homogenous and phonetically similar segment for the sound, and even managed to closely approximate. As predicted by Flege's Speech Learning Model, an equivalence classification of *similar* between the diaphones [ɹ̩] and the mid-range front rounded vowels in German led to difficulty in acquiring the phonetic production of the sound. This was indicated by the persistence of production errors involving front rounded vowel substitutes, despite the learner's considerable experience with English. This data lends support to the view that English [ɹ̩] ranks as a vowel in the English sonority hierarchy.

The English learners of German did not show evidence of substituting [ɹ̩] for dark-schwa in German. This data supported the claim that dark-schwa lacks overt rhoticity, and thus is, at best, a degenerate member of the group of rhotic segments in German. Consequently, if dark-schwa is not analyzable as a rhotic, then the problem of the syllabicity gap in German still remains. Furthermore, the German L2 data has implications for the acquisition of phonetic structure in an L2 context. The consultants were both *novice* learners of German, yet managed to produce a contrast between dark-schwa and schwa targets. This ran contrary to the stipulations of the SLM, whereby a diaphone relationship of *similar* is predicted to impede acquisition. This finding could be construed as counter evidence to the SLM, indicating that it requires revision.

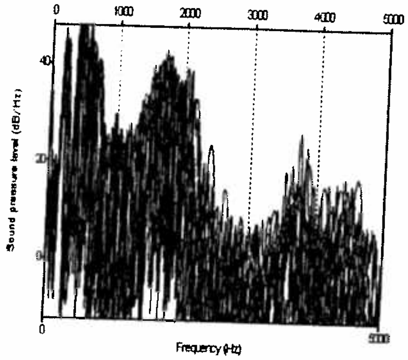
This study provides the impetus for a number of related studies concerning the acquisition of nuclear rhotics. Future research on native German perception of the non-native contrast made between schwa and dark-schwa by English learners of German is required to support the finding that an equivalence classification of *similar* does not necessarily lead to acquisitional difficulty. With regards to the German learners of English, to further test the accuracy of the claim that Germans substituted a front rounded vowel for [ɹ̩], these target productions could be spliced into German words and tested for how well they match their native German counter parts. Positive identification of these sounds as front rounded vowels would support the argument that German speakers are using them as [ɹ̩] substitutes. It would also be useful to investigate whether English learners of German can acquire the morphophonemic variation between [-ɐ] and [-əʁɐ] in word pairs such as größer [gʁø:sɐ] vs. größerer [gʁø:səʁɐ] ('big' vs. 'bigger').

Finis

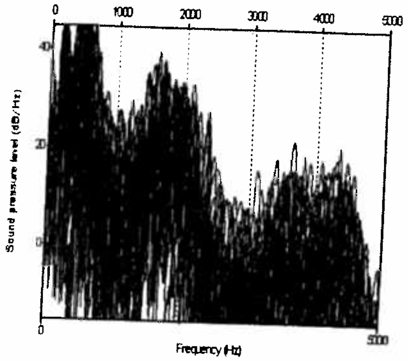
I Appendix A: Composite Spectra and Spectrographic Representation

Consultant-E3: English Learner of German (Novice)

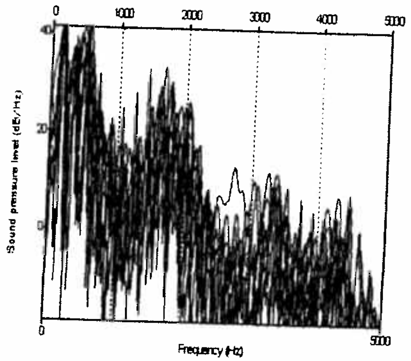
English Production: [ɹ̩]



[ɹ̩] - list



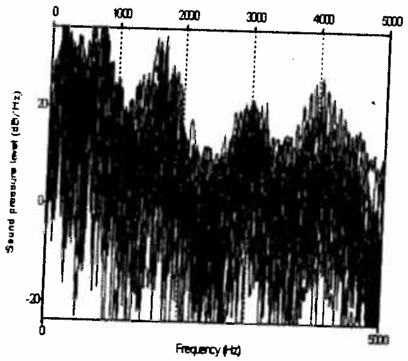
[ɹ̩] - sentence



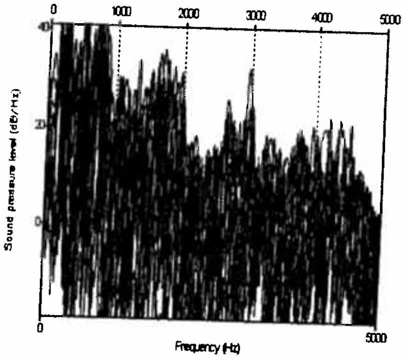
[ɹ̩] - spontaneous

Native [ɹ̩] is produced consistently in all contexts; F3 is typically below 2000 Hz and merged with F2.

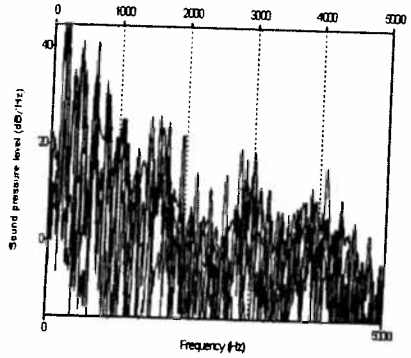
German Production: [ɐ̯] compared to [ə]



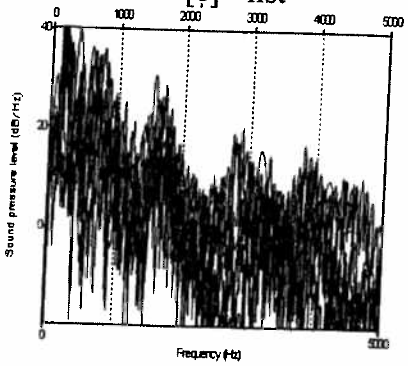
[ɐ̯] - list



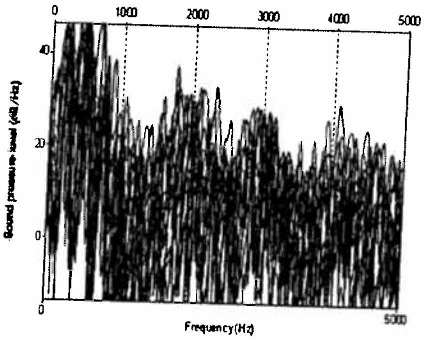
[ɐ̯] - sentence



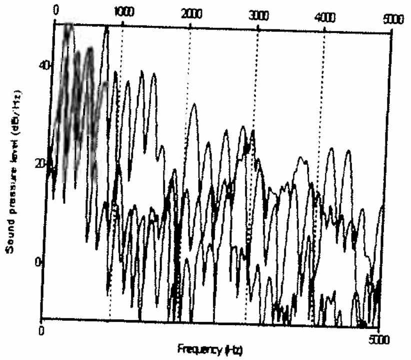
[ɐ̯] - spontaneous



[ə] - list



[ə] - sentence

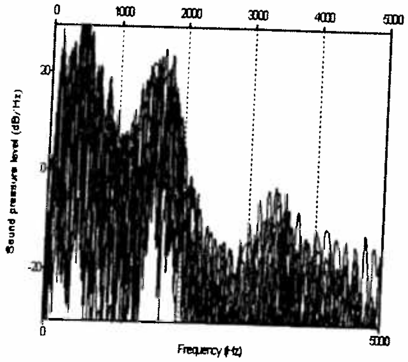


[ə] - spontaneous

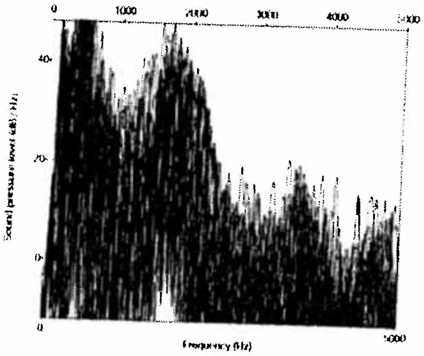
List productions do not provide strong visual evidence for a contrast between the two reduced vowels in German. In the sentence productions the contrast between F1 and F2 of each vowel is more apparent. Given the small data pool for spontaneous productions of schwa, a satisfying comparison cannot be made.

Consultant-E$_2$: English Learner of German (Novice)

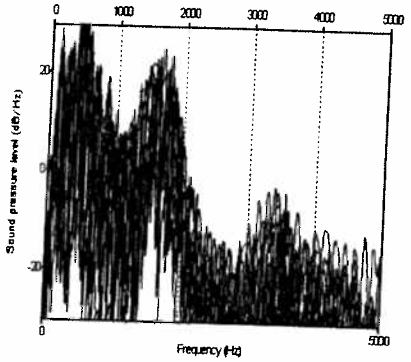
English Production: [ɹ̩]



[ɹ̩] - list



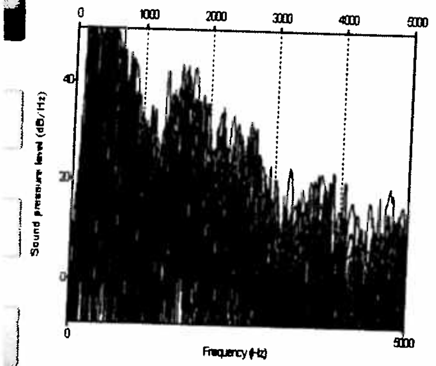
[ɹ̩] - sentence



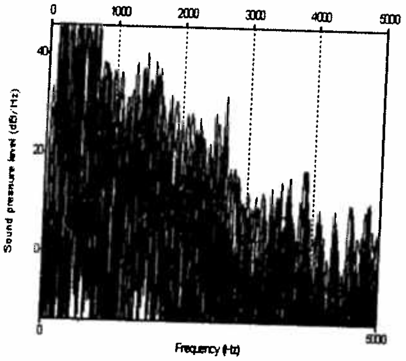
[ɹ̩] - spontaneous

Native [ɹ̩] is produced consistently in all contexts; F3 is typically below 2000 Hz and merged with F2.

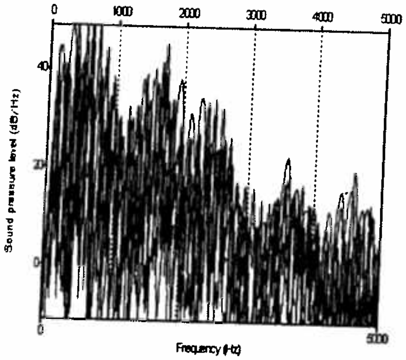
German Production: [ɐ̩] compared to [ə]



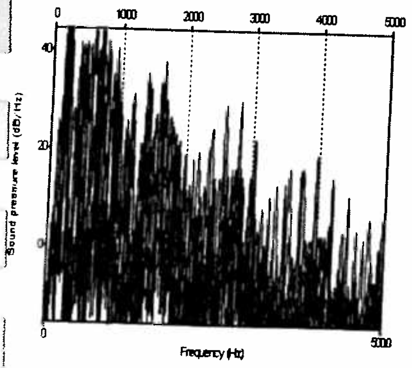
[ɐ̩] - list



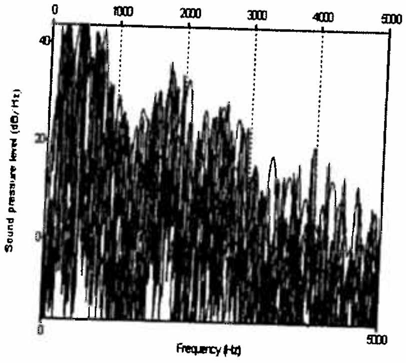
[ɐ̩] - sentence



[ɐ̩] - spontaneous



[ə] - list

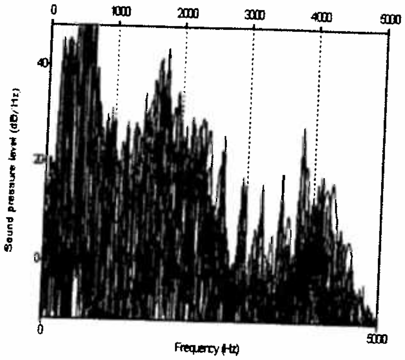


[ə] - sentence

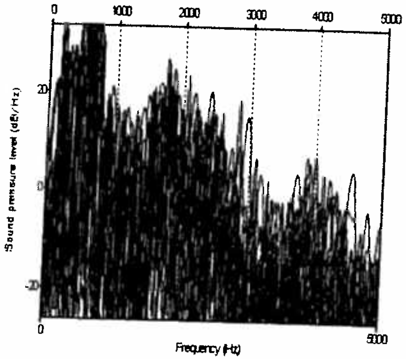
Evidence of increased formant frequencies for schwa in all formants compared to dark-schwa. Suggests that speaker has the vowels confused, but a contrast is still made.

Consultant-G$_2$: German Learner of English (Advanced: Dresden)

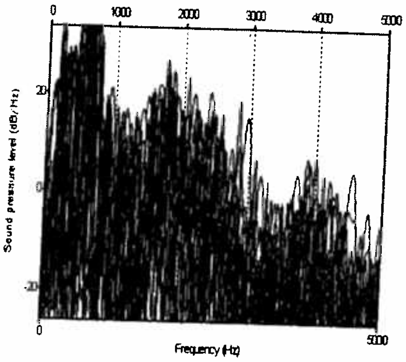
English Production: [ɹ̣]



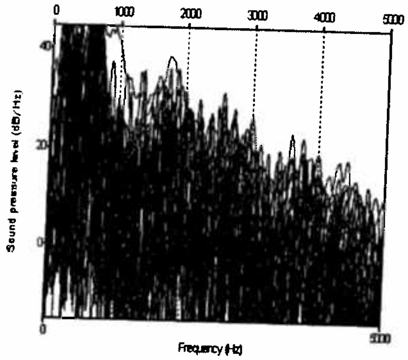
[ɹ̣] – list
monosyllable



[ɹ̣] – list
bisyllables



[ɹ̣] – sentence

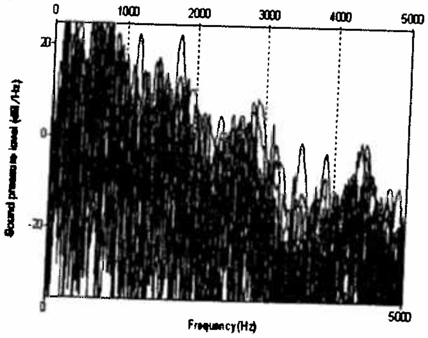


[ɹ̣] - spontaneous

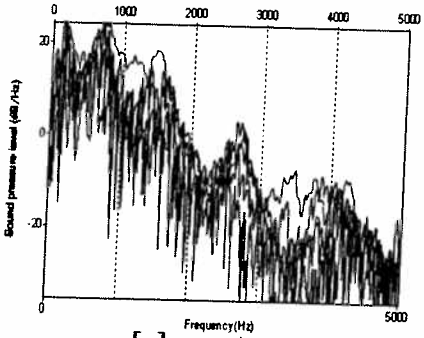
The strongest instance of semi-native production of [ɹ̣] is exemplified by monosyllabic list productions. Even this composite spectra shows a considerably high F3 and a fair degree of distance between F2 and F3, especially when compared to the native English spectra. Sentence and bisyllabic words are produced with an even more pronounced separation between F2 and F3 as well as a raise in F3 frequency. Finally, spontaneous productions indicate a high degree of variation and separation between F2 and F3.

German Production: [ɐ] compared to [ə]

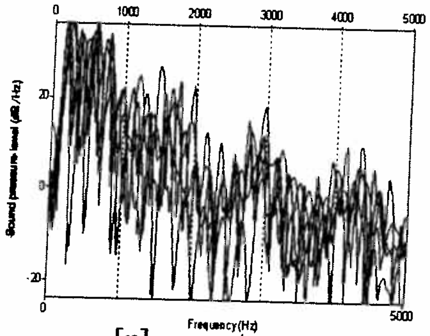
[ɐ] contrasts with [ə] in F1 (higher) and F2 (lower); this is evident in list and sentence productions.



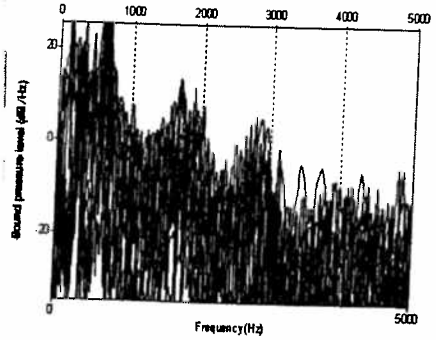
[ɐ̣] - list



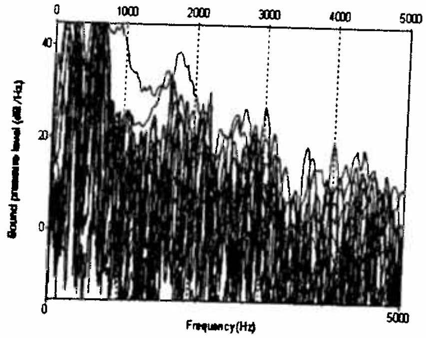
[ɐ̣] - sentence



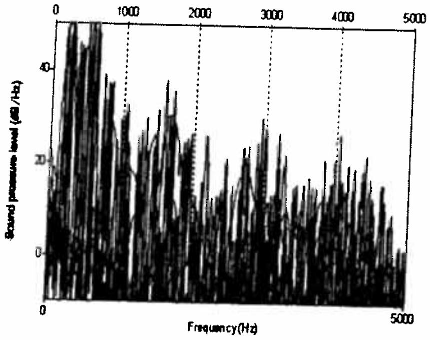
[ɐ̣] - spontaneous



[ə] - list



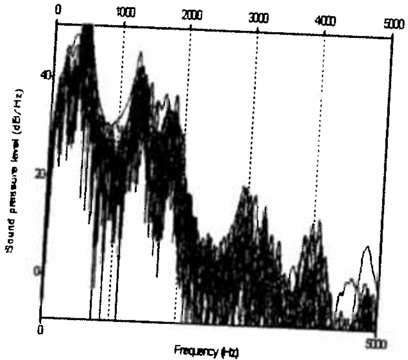
[ə] - sentence



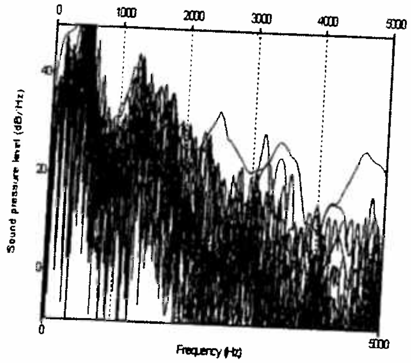
[ə] - spontaneous

Consultant-G_1: German Learner of English (Advanced: Hamburg)

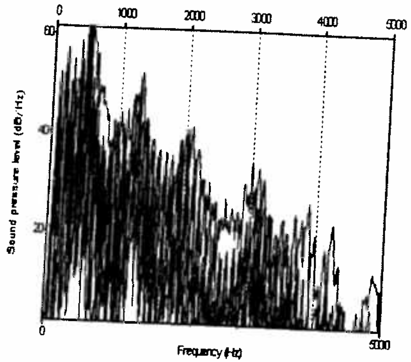
English Production: [ɹ̩]



[ɹ̩] - list



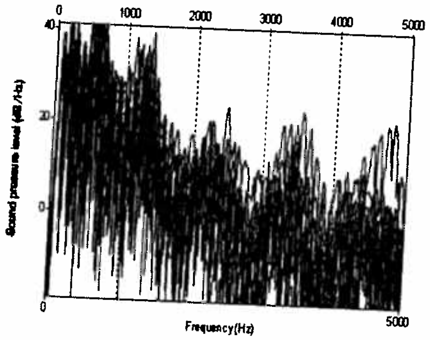
[ɹ̩] - sentence



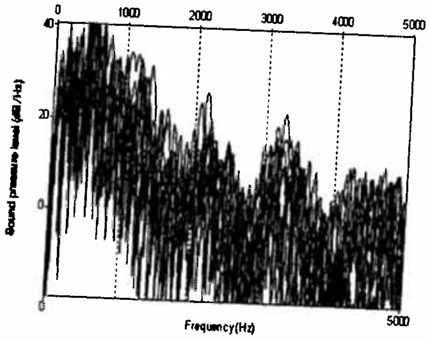
[ɹ̩] - spontaneous

The list production shows a lowered third formant, but weak F2-F3 approximation. The speaker is highly consistent during list production. Sentence production indicates greater inconsistency and a tendency toward a high F3 and greater F2-F3 separation. Finally, spontaneous productions indicate more a prototypical front rounded vowel than English [ɹ̩].

German Production: [ɐ] compared to [ə]

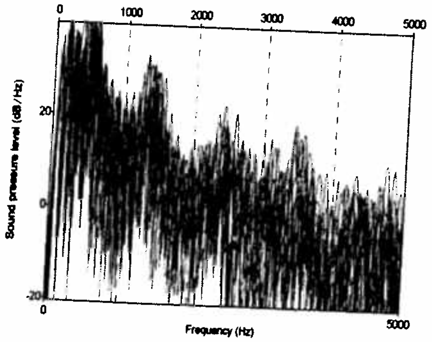


[ɐ̩] - list

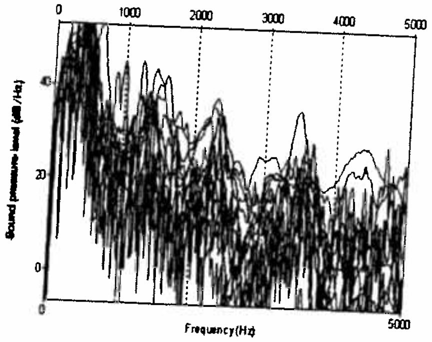


[ɐ̩] - sentence

A contrast is evident in F1 and F2 between the two vowels; dark-schwa is seen with a higher F1 and a lower F2. F3 is inconsistent amongst the various contexts indicating environmental influence.



[ə] - list



[ə] - sentence

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