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Phonetic and phonological variability in the L1 and L2 of late bilinguals: The case of /r/ and /l/

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Deutsche Zusammenfassung

Bis heute hat eine Vielzahl von Studien zum Spracherwerb im Erwachsenenalter gezeigt, dass sich die phonetischen Merkmale der Muttersprache (L1) und Zweitsprache (L2) gegenseitig beeinflussen. Durch den Einfluss der L1 auf die Lautbildung in der L2 weichen insbesondere späte L2-Lerner von der L1 Norm ab. Modelle zum Erwerb von Lautmerkmalen in einer Zweitsprache wie zum Beispiel das *Speech Learning Model* (SLM) von Flege (2007) erklären den starken Einfluss der L1 im Spracherwerb im Erwachsenenalter anhand einer Eingliederung des Lautsystems der L2 in den bereits bestehenden phonetischen Raum der L1. Die dadurch entstandene Verknüpfung zwischen der L1 und der L2 führten nicht nur zum Einfluss der L1 auf die L2, sondern wie durch das SLM vorgesagt und durch neuere Studien gezeigt (z.B. DeLeeuw, Mennen & Scobbie, 2004; Chang, 2012), auch zu Veränderungen der L1 Lautkategorien. Diese nähern sich hierbei an die Ziellaute der L2 an, ein Prozess der als *Spracherosion* bezeichnet wird.

Über das genaue Fortschreiten und die Gesetzmäßigkeiten des Einflusses der L2 auf die L1 ist jedoch wenig bekannt. In der bisherigen Forschung wurden Veränderungen in der L1 durch Transfer von der L2 in die L1 erklärt; jedoch zeigt sich bei genauerer Betrachtung vorheriger Ergebnisse, dass die L2 allein nicht ausreicht, um die beobachteten Veränderungen vollständig zu erklären.

In meiner Dissertation befasse ich mich mit Prozessen der Spracherosion, welche sich nicht nur in den konkreten phonetischen Realisierungen von Lauten der L1 später bilingualer Sprecher äußern, sondern auch in den Verteilungsmustern von konkreten positionsspezifischen Lautvarianten. Die Forschung zur Spracherosion in der L1 beschränkte sich bislang auf eine kleine Anzahl von phonetischen Merkmalen, insbesondere VOT (z.B. Flege, 1987), und erklärte Veränderungen vollständig über die Merkmaleigenschaften der L2. Im Gegensatz hierzu ist der Beitrag anderer Faktoren jenseits des L2-Transfers zur Spracherosion weitestgehend unerforscht. Daher ist aktuell wenig bekannt, ob zweisprachige Realisierungen einer L1-Lautkategorie in verschiedenen phonetischen Kontexten (z. B. Position innerhalb einer Silbe) ebenfalls von Erosionserscheinungen betroffen sein können. Ebenfalls ist der Grund für solche Veränderungen unbekannt.

In meiner Dissertation schließe ich diese Lücke, indem ich untersuche, wie Veränderungsprozesse der Spracherosion in den Verteilungs- und phonetischen Merkmalen wirken. Zu diesem Zweck untersuche ich Veränderungen phonetischer Merkmale sowie der

Verteilungsmuster von L1-Rhotizität und /l/-Allophonen bei späten Amerikanisch-Deutschen Bilingualen.

Zu diesem Zweck präsentiere ich mein Ergebnis einer Produktionsstudie von zwölf L2-dominanten Amerikanisch-Deutsch-Spätsprachlern sowie einer einsprachigen Kontrollgruppe zur jeweiligen Sprache. Die Proband*innen führten eine Vielzahl von Produktionsaufgaben, die darauf abzielten, die (Nicht-) Rhotizität und /l/-Allophonie in beiden Sprachen (Englisch und Deutsch) zu evaluieren. Diese habe ich in dieser Arbeit auditiv analysiert (nur /r/) und akustisch (/r/ und /l/) ausgewertet. Obwohl der Verlust von Rhotischen und Lateralen in der L1 bereits untersucht wurde (z. B. de Leeuw, 2008; Ulbrich & Ordin, 2014), blieb der Effekt von linguistischen und nicht-linguistischen Variablen auf den Erstsprachverlust bisher unerforscht.

Das Ergebnis der auditorischen Analyse von postvokalischen /r/ zeigt, dass die späten Bilingualen von monolingualen Sprechern beider Sprachen abweichen. Im Englischen realisierten die Bilingualen das postvokalische /r/ häufiger in der L2-ähnlichen (vokalisierten) Variante und zeigten Reste von konsonantischen Realisierungen in der eigentlich nicht-rhotischen L2. Während der Verlust der Rhotizität in der L1 der Bilingualen (Englisch) von kontextuellen Beschränkungen (z. B. Art des vorrhotischen Vokals und der morphophonologischen Struktur der Silbe) geprägt war und differentielle Verteilungen über die Kontexte hinweg zeigte, waren die Bilingualen in ihrer L2 (Deutsch) nicht empfänglich für kontextuelle Variation, wie es auch in monolingualen Sprechern des Deutschen erwartet wird. Die akustischen Analysen zeigen, dass rhotische Produktionen der zweisprachigen Sprecher im Englischen und Deutschen sich deutlich von denen der monolingualen Kontrollgruppen unterscheiden: Hier wichen die späten Bilingualen vor allem in der Produktion antizipatorischer Rhotizität ab und produzierten die vorrhotischen Vokale mit weniger rhotischer Färbung.

Ich interpretiere meine Ergebnisse als Beleg, dass die bilingualen Sprecher in zwei getrennten phonologischen Grammatiken für ihre Sprache arbeiten, die jeweils der L1-Norm entsprechen, jedoch einen höheren Grad an Variabilität zeigen. Diese Variabilität entsteht jedoch nicht durch sprachübergreifenden Transfer, sondern ist beeinflusst von den grammatischen Gegebenheiten der L1. Die phonetische Analyse zeigte im Gegensatz dazu, dass die bilingualen in einem einzigen phonetischen Raum agieren, welchen sich beide Sprachen teilen und wodurch phonetische Wechselwirkungen zwischen beiden Sprachen entstehen. Somit werden die Veränderungen im Zuge der Spracherosion von der L2 induziert, aber nicht von ihr gesteuert. Die Änderungen der L1 zeigt Sprachveränderungen auf, denen die Grammatik der L1 zugrunde liegt, und sind weiterhin geprägt von allgemeinen Gesetzen der Phonetik und des Sprachwandels.

Die Ergebnisse der Lateral-Analyse zeigen, dass genau wie in postvokalischen /r/ die zweisprachigen Sprecher nicht mit monolingualen Sprechern konvergent sind. Besonders in Bezug auf die Velarisierung von wortfinalen /l/ in beiden Sprachen unterscheidet sich die bilinguale Gruppe deutlich von Monolingualen. Die festgestellten Änderungen unterlagen hier positionsbedingten Beschränkungen und waren im wortinitialen /l/ deutlich stärker ausgeprägt als im wortfinalen /l/. Weiterhin zeigten die Bilingualen eine stark ausgeprägte Allophonie in beiden Sprachen.

Die Ergebnisse der Untersuchungen zu Lateralen liefern jedoch keinen Beleg für einen gleichmäßigen Erosionsprozess, und waren stattdessen stark geprägt von der L1 sowie von universellen Gesetzmäßigkeiten der Lautbildung. Insofern zeigt meine Dissertation, dass Spracherosion nicht einheitlich auf einen Sprecher wirkt, sondern dass Spracherosion einem historischen Prozess des Lautwandels ähnelt, welcher universellen phonetischen und phonologischen Gesetzen folgt.

Die Ergebnisse meiner Studie erkläre ich mithilfe von phonologischen Constraint-Grammatiken (insbesondere Optimality Theory und Harmonic Grammar), den ich Dynamic Constraints nenne. In diesem Ansatz modifiziere ich einen Algorhithmus, wodurch linguistische und nicht-linguistische Faktoren das Gewicht von Constraints und die zufällige Streuung von Gewichten beeinflussen können. Hierdurch ergibt sich die Möglichkeit, mit Dynamic Constraints bisherige Forschungsergebnisse im Bereich der Psycholinguistik mit Kenntnissen aus der historischen und sozialen Sprachforschung zu verbinden und einen Einblick in die Sprachsysteme von Bilingualen zu gewinnen.

English Abstract

A large body of research has shown that a late bilingual's L1 and L2 phonetic categories influence each other, yielding deviations from monolingual norms in the phonetics of both languages. Existing models of L2 sound acquisition (e.g., the *Speech Learning Model;* Flege, 1995, 2007) predict unified phonetic spaces which accommodate both L1 and L2 sound categories. Such connections between an L1 and an L2 are believed to lead to persistent non-nativelikeness in the L2, but also to divergence from the monolingual norm in the L1, as shown in numerous studies (e.g., Bergmann et al., 2016). In this dissertation, I focus on the differences in the sound patterns of a bilingual's languages which do not only emerge in the precise phonetic realizations of L1 sounds but also in language-specific distributional patterns that determine the realization of these sound categories in different phonetic contexts. Previous work in L1 attrition is limited to a small set of phonetic properties (especially VOT, e.g., Flege, 1987), variables beyond L2 transfer which are known to give rise to variable realizations have been neglected. Thus, little is known as to whether bilinguals' realizations of an L1 sound category in different phonetic contexts (e.g., position within a syllable) are subject to change in L1 attrition, and whether such changes arise due to long-term exposure to different distributional patterns of an equivalent L2 category.

In this dissertation I address these gaps by exploring L1 attrition in the distributional and phonetic characteristics of liquids to shed light on the contribution of the L2 and the role of general phonetic and phonological variables to the processes that drive change in an L1. I investigate changes to phonetic properties and distributional patterns of rhoticity and /l/-allophony in the L1 of American-German late bilinguals, a language constellation which offers an instructive test case to investigate the causes of L1 attrition as well as the source from which changes due to L1 attrition emerge. Furthermore, changes to liquids can also shed light on the processes which drive sound change, gradience and variability due to various positional and phonetic factors (e.g., preceding vowel, syllable structure) in liquids across many native varieties of English. In particular, I explore the variable realization and distributional patterns of two sounds known to be subject to a considerable degree of gradience and variability, namely English /r/ and /l/, in American English-German late bilinguals.

To that end, I present the results of a production study of 12 L2-dominant American English-German late bilinguals as well as a monolingual control group for each language. The speakers performed a variety of production tasks which were aimed to elicit the realization of (non)-rhoticity and /l/-(non-)allophony in both languages of the late bilinguals, English and German which were analyzed auditorily (/r/ only) and acoustically (/r/ and /l/). Although L1 attrition of rhotics and laterals has been investigated previously (e.g., de Leeuw, 2008; Ulbrich & Ordin, 2014), the effect of contextual variables on L1 attrition and whether such variables also shape L1 attrition remains unexplored.

The results of the auditory analyses of postvocalic /r/ revealed that the late bilinguals showed non-convergence with monolingual (non-)rhoticity in both of their languages by vocalizing postvocalic /r/ more frequently in their L1 (English) and failing to entirely suppress rhoticity in their L2 (German) leading up to a higher degree of rhoticity in their L2. While the loss of rhoticity in the bilingual's English was distributed along a spectrum of contextual constraints (e.g., type of pre-rhotic vowel and morpho-phonological environment) known to affect rhoticity in other English varieties, the non-targetlike productions of non-rhoticity (i.e., non-vocalized postvocalic /r/) in their L2, German, were not sensitive to the same contextual constraints. The acoustic analyses of the bilinguals' rhotic productions in English and German differed from the monolinguals in the acoustic correlates of rhoticity in pre-rhotic vowels where they showed reduced anticipatory F3-lowering (i.e., less /r/-colored vowels).

I take my results to indicate that the bilinguals operate in two separate phonological grammars which approximate the respective L1 norm but show an increase of variability along constraints already present in each grammar. In contrast, the bilinguals' phonetic system seem shared between the two grammars. This leads to persistent L1-L2-interactions as the two grammars operate within the same phonetic space. Thus, the changes in L1 attrition are induced but not governed by the L2: Change to the L1 reflects constraints underlying the L1 as well as more general laws of phonetics and universal trajectories of language change.

The lateral results revealed that just like in postvocalic /r/, the bilinguals showed non-convergence with the monolingual norm regarding the velarization of coda /l/ in both their languages. The changes to English laterals were sensitive to their positional context and more substantial for word-initial laterals than word-final laterals. Similarly, their German laterals were non-convergent with the monolinguals in two ways. Firstly, the bilinguals differed with regard to the acoustic specifications of their laterals, and secondly, the bilinguals failed to suppress the lateral allophony from their L1, leading to a non-targetlike allophonic pattern in their L2 laterals.

I interpret the lateral results to lack evidence that the L1 allophonic rule was affected by the presence of an L2; nevertheless, L1 change emerged in the phonetic specifications of laterals. Furthermore, the bilinguals did not establish a nativelike allophonic pattern in their L2, leading to non-convergence in the allophonic distribution as well as the phonetic realization of German laterals.

In this way, this dissertation provides evidence for L1 attrition in the distributional and the phonetic properties of liquids in the L1 of late bilinguals. In particular, the study presented in this dissertation provides evidence that L1 attrition is induced by the presence of a similar sound pattern in the L2. The pathway of attrition follows constraints not only underlyingly present in the L1 but also part of the universal laws of phonetics known to shape sound change. To explain these results, I draw from existing constraint grammars in phonological theory (such as Optimality Theory and Harmonic Grammar) to develop my Dynamic Constraints approach which allows the effects of external variables (e.g., L2 acquisition and its effect on the mind), and internal variables such as an increased likelihood of variability due to articulatory differences can be modeled using scaling factors which can interact with each other, the noise within the grammars, and the constraint weight itself. In this way, the model links previous findings on L1 attrition and its connections to diachronic and synchronic variability, offering insights into the links between the individual languages in a bilingual's mind.

Meiner Mutter…

…und meinem Vater.

'... no oath or bond is laid on you to go further than you will. For you do not yet know the strength of your hearts, and you cannot foresee what each may meet upon the road.'

'Faithless is he that says farewell when the road ***darkens****,' said Gimli.*

Maybe,' said Elrond, 'but let him not vow to walk in the dark, who has not seen the nightfall.'

'Yet sworn word may strengthen quaking heart,' said Gimli.

'Or break it,' said Elrond.

(FR 2.III.281)

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List of abbreviations

AAE	African American English
AE	American English
AoA	Age of Acquisition
AoDC	Age of Decreased Contact
ATH	Activation Threshold Hypothesis
C	Consonant
CLI	Crosslinguistic Influence
COWAT	Controlled Oral Word Association Test
CP	Critical Period
CPH	Critical Period Hypothesis
DMM	Dynamic Model of Multilingualism
DST	Dynamic Systems Theory
EA	European American English
F	FAITHFULNESS constraint(s)
GLMM	Generalized linear mixed-effects model
HG	Harmonic Grammar
IH	Interface Hypothesis
L1	First language
L2	Second language
LMM	Linear mixed-effects model
LoR	Length of Residence
M	MARKEDNESS constraint(s)
ME	Middle English
NflE	Newfoundland English
NHG	Noisy Harmonic Grammar
nz_b	bilingual noise factor
OE	Old English
OT	Optimality Theory
PrG	Proto-Germanic
RP	Received Pronunciation
sdc	speed and direction of change
SLA	Second language acquisition
SLM	Speech Learning Model

UG	Universal Grammar
V	Vowel
VOT	Voice Onset Time

Chapter 1

Introduction: Phonetic and phonological variation

1.1 Aims and objectives

While much research has investigated the mechanisms and forces that drive the development of a phonological system in the acquisition of a second language (L2), other facets of phonological learning and development (e.g., third language [L3] acquisition and first language [L1] attrition) have been largely neglected. Indeed, the dominant position of research on L2 phonological acquisition as compared to research on other types of language development introduces a bias which limits the scope of research on bilingualism in general. For instance, while much research has investigated transfer from the L1 to the L2, little is known about the other forms of interplay between the L1 and the L2 and mutual influence of the linguistic systems therein. This lack of research falls out from the assumption that an L1 stabilizes and is static by the time the speaker reaches adulthood which led to a neglect of questions regarding bidirectional influence such as whether an L2 can influence mature L1 grammars.

Recently, studies showed that even a mature L1 grammar remains adaptive throughout adulthood in monolinguals and bilinguals alike; while changes to the grammars of the former are referred to as *language change*, changes to the grammars of the latter are referred to as L1 attrition. It is precisely this type of change in the L1 across the lifespan that offers an instructive test case to explore various open questions on the architecture of the bilingual mind. For example, the effect of L2 acquisition on the L1 offers insights into the adaptability of a speaker's L1 and can enrich existing approaches to L2 acquisition by revealing interfaces between the L1 and the L2. So far, little is known about the processes that trigger changes in the L1, and previous studies on L1 attrition suffer from various limitations, for example, that

L1 attrition is a direct consequence of L2 acquisition rooted in transfer from the L2. This notion does not find strong empirical support as previous studies revealed that although some changes seem to result from direct structural interference of the L2, other changes cannot readily be explained by L2 properties alone. Also, previous studies often rely on the equivalence of phonetic properties in the L1 and the L2 and fail to test structural variables which may modulate a feature's susceptibility to change. Therefore, further research is necessary to reveal the causes and constraints that guide the progression of L1 attrition.

Here, taking typological, diachronic and synchronic observations of variability across languages into account offers a promising avenue which can enrich research on L1 attrition with perspectives beyond the influence of an L2. For example, it has been argued that the structural patterns observed in L1 attrition reflect the patterns also observable in language change (e.g., Schmid & de Bot, 2004). Crucially, diachronic change and the structural changes therein have also been linked to synchronic variation, for example by Labov (1978) who argues that "the forces which operated to produce the historical record are the same as those which can be seen operating today" (Labov, 1978, p. 281). Similarly, McMahon (2000) claims that "we can use the linguistic present to explain the linguistic past" (p. 230) and that "the connection should work both ways: that is, the linguistic past should ideally also help us understand and model the present" (McMahon, 2000, p. 230).

As bilinguals have been shown to drive change in language time and again, it stands to reason that the connection between historical change and synchronic variation also extends to the interaction of two or more languages (of which L1 attrition is one incarnation) in bilingual individuals. In this perspective, change in the phonetic and phonological system of bilinguals is viewed as an expression of the same grammar-internal and -external forces that also guide changes in monolinguals. In this way, the changes observed in bilinguals and monolinguals differ from each other in quantity of change, not in quality, as well as the rate at which the development proceeds. In this way, L1 attrition is not only "a condensed form of change processes in the language itself" as de Bot and Weltens (1991, p. 36) argue, but presumably mirrors synchronic variability in phonetics and phonology observed in monolinguals. As such, tying L2 acquisition and the interplay of a bilinguals' languages to empirical and theoretical accounts of phonetic and phonological variability leading up to language change in synchronic and diachronic grammars offers a promising perspective on L1 attrition.

This dissertation addresses these gaps by investigating phonetic and phonological L1 attrition in late American English-German bilinguals. More precisely, I investigate L1 attrition of liquids, a class of sounds known for their synchronic and diachronic variability within and across languages, and which differ in their positional distribution in the two languages under investigation. While American English (henceforth ‘AE’) is rhotic, German (henceforth ‘GE’) is non-rhotic; and while AE exhibits /l/-allophony with non-velarized (‘clear’) /l/ in word-initial position and velarized (‘dark’) /l/ in word-final position, /l/-allophony is absent in German where clear /l/ occurs across the board. That is to say, GE has /r/-allophony while AE does not, and while AE has /l/-allophony, GE does not. In this way, the language combination of the late bilinguals, L1 American English and L2 German, offers an instructive constellation to test for various directions of change under L1 attrition. For instance, the differences regarding the allophonic distribution of liquids in the L1 and the L2 allow for a direct comparison of the patterns acquired in the L2 to changes to an allophonic pattern under L1 attrition. Liquid allophones in German and English thereby offer interesting insights into the question of whether (non-)allophony in a specific L1-L2 pairing can accelerate or inhibit acquisition and attrition.

Moreover, since /r/ and /l/ are distributed along a fine-grained acoustic spectrum induced by positional differences that fall out as consequences of the universal phonetic specifications of liquids, the case of L1 attrition in late American English-German bilinguals can help shed light on the ways an L2 shapes the phonetic and distributional changes under L1 attrition, the role of universal constraints and whether either of the two takes precedence over the other. In this way, L1 attrition of liquids offers a variety of insights into these previously unaddressed questions and allows the causes and the nature of the emerging variability in a bilingual’s L1 grammar to be explored in depth.

In this dissertation, I will show that the changes observed in L1 attrition follow universal constraints imposed by the timeless laws of phonetics and phonology which also give rise to the trajectories of diachronic change and synchronic variability and that similar constraints re-emerge in the L1 of the late bilingual speakers. To capture the interaction of such multifaceted sources contributing to each individual pattern of change, I offer a holistic approach to L1 attrition in phonetics and phonology which I call the Dynamic Constraints Model. In this approach, I demonstrate that the unification of theoretical tools from L1 attrition research and phonological theory results in a promising explanatory approach which brings various previously only loosely linked strands of research together.

1.2 Preliminaries: Variability and change across the lifespan of monolinguals and bilinguals

The stability and invariance of mature L1 grammars – that is, the grammar of a speaker beyond a particular age, typically at 12 years of age (Abrahamsson & Hyltenstam, 2009; Bialystok & Hakuta, 1999; Birdsong, 1999; DeKeyser, 2000; Flege, Yeni-Komshian, & Liu, 1999; Johnson & Newport, 1989; Moyer, 2004) is the most widespread assumptions in research in L2 acquisition. The assumption is rooted in the implications of the *Critical Period Hypothesis* ('CPH') which attempts to account for the failure of many L2 learners – especially late learners – in the attainment of native-like proficiency in an L2.

The assumption of invariance in mature L1 systems is also implicit in other linguistic subfields. In sociolinguistic research, for example, the 'apparent-time' construct (e.g., Bailey, Wikle, Tillery, & Sand, 1991) relies on the assumption that the speech of an individual speaker faithfully reflects the language of the speech community at the time the speakers acquired their L1. Consequently, apparent-time constructs rely on operationalizing the age of speakers to reflect successive stages on the timescale for diachronic language change and using inter-generational comparisons to trace the structural changes in a language. This approach leads to a linear view of language change in which change is expected to progress with young speakers who are argued to drive change, while older speakers are assumed to contribute very little to language change (with some exceptions, see Bermúdez-Otero & Trousdale, 2012**)**. Conversely, recent sociolinguistic and psycholinguistic studies demonstrate that mature grammars maintain some degree of flexibility and indicate that any speaker, regardless of their age, may participate in changes currently progressing in their speech community at any time and to varying degrees.

In sociolinguistic research, *panel studies* for which speakers are repeatedly interviewed for several years or decades **(**e.g., Bowie, 2005; Sankoff & Blondeau, 2007; Buchstaller & Wagner, 2018) show that even older monolingual speakers seem to participate in changes often assumed to be restricted to younger speakers. Sankoff and Blondeau (2007), for example, investigate rhotics in Montreal French, where a change from the conservative variant [ɹ] towards the progressive variant [r] is currently underway. In their panel-study, Sankoff and Blondeau (2007) compared the usage frequency of the two rhotic variants by 32 adult speakers across two interviews conducted in 1971 and 1984, respectively. Their results showed that nine of their 32 speakers had dramatically decreased their use of the conservative variant [ɹ] and increased their use of the innovative variant [r]. Although only one-third of the adult speakers participated in the on-going change over the course of 13 years, the results should not be interpreted to indicate that a mature grammar is less likely to change.

A considerable number of studies mirror the results reported by Sankoff and Blondeau (2007). Harrington (2006; 2007), for instance, reports similar findings with regard to phonetic changes of the British English vowel system currently undergoing a sound change. In his study of acoustic changes to the Queen's pronunciation throughout several decades of her life, Harrington provides compelling evidence that pervasive phonetic change can take place in a presumably static adult L1 phonetic system.

The studies highlighted so far raise a number of questions, for example, if and how lifespan change to an L1 is constrained by any grammar-internal and grammar-external variables which may also play a role in determining the likelihood of change in mature grammars. Nahkola and Saanilahti address this question with a particularly interesting case of L1 attrition in bilinguals. They found that

> "categorical linguistic features are inclined to remain categorical in the idiolect. If a speaker, as a child, "learns" a feature with little or no variation in it, no major changes are likely to take place during the speaker's lifetime. In other words, new changes rarely commence in an idiolect later in life. If, however, a speaker adopts a feature as a variable one, with two or more truly competing variants, it is possible that the balance of the variants will shift during the speaker's lifetime. The more equal the proportions of the rivaling variants are, the more likely it is that one of the variants will gain dominancy during the speaker's lifetime." (Nahkola & Saanilahti, 2004, p. 75)

In this way, Nahkola and Saanilahti link synchronic variability to diachronic (or, in this case, lifespan) language change. Importantly, their argument is highly reminiscent of suggestions that liken L1 attrition to community changes observed diachronically. Schmid and de Bot (2004), for example, point out "that the evolution of a linguistic system over a long time in a language community and over a short time in an individual might follow some of the same or similar principles" (p. 211). In a similar vein, Ahlsén (2012) argues that "[f]rom typological as well as, for example, psycholinguistic or sociolinguistic perspectives, interesting parallels can be found between attrition of a language in an individual and attrition of a language in the whole community" (§1). Although these ideas have not been addressed explicitly, a small number of studies provide tentative empirical support for the connection between a change in a speech community and L1 attrition (e.g., Geelen & de Bot, 1986; Boyd & Andersson, 1991**)**. Geelen and de Bot (1986), for example, investigated the acquisition and attrition of dialects of the same language and showed that the acquisition of a new dialect seems to trigger changes to the native dialect. The changes observed in the dialect learners, Geelen and de Bot argue, mirror changes also observed in the native dialect community, indicating that the changing native dialect of their bidialectal speakers follows pre-existent trajectories of change rather than patterns induced by a second dialect.

In a similar study, Boyd and Andersson (1991) compared the use of morphosyntactic structures in the L1 of Finnish-Swedish bilinguals to that of monolingual Finnish native speakers. In particular, Boyd and Andersson (1991) investigated possessive constructions in the L1 (Finnish) of Finnish-Swedish bilinguals living in Sweden. In Finnish, possessives are marked with the non-obligatory suffix {-*ni*} which is not obligatory and can be dropped, although dropping is mainly restricted to spoken Finnish. Thus, Finnish possessive constructions like the example in (1) vary between constructions with an overt possessive marker in (1a), and constructions without an overt possessive marker in (1b).

(1) Possessive constructions in Finnish (Boyd & Andersson, 1991, p. 21).

(1a) Minun kirja-ni	my book
(1b) Minun kirja-∅	my book

The possessive marker {-*ni*} has been subject to an on-going change in Finnish, and its use has become more variable in recent years as the frequency of dropping has increased. In their study on L1 attrition of Finnish possessive markers, Boyd and Andersson (1991) revealed that the bilinguals exhibited a strong preference for the construction without overt possessive marker as shown in (1b). Most importantly, although monolingual speakers of Finnish also use dropping, Boyd and Andersson showed that the bilinguals surpassed even the most progressive monolingual Finnish speakers regarding the frequency of {-*ni*}-dropping. Boyd and Andersson argue that the acceleration of an ongoing L1 change rather than direct transfer from the L2 provide support for the assumption that language change and L1 attrition are two incarnations of a single process, and that the two are linked to the same underlying constraint which regulates both processes.

The connection between structures in the L2 and the changes observed in L1 attrition seems more indirect than expected in that L1 change in morphology and syntax are not readily accounted for by L2 transfer and instead, attrition seems to follow more general principles also observed elsewhere, for example in language change (e.g., Sorace, 2011). These findings contrast with much of the research on L1 attrition of phonetics and phonology, where potential similarities between L1 attrition and language change are often neglected. Indeed, most previous studies on phonetic and phonological L1 attrition adopt frameworks developed in studies on *second language acquisition* (henceforth 'SLA'; see also Chapter 3 of this dissertation).

There is some evidence that rather than L2 transfer, an L1 phonetic and phonological system undergoing language attrition reflects the variability already present in the grammar and may enhance on-going change in the L1. One such study is Yeh and Lin (2015), who investigated synchronic variation and individual language change in the tonal patterns of Hakka. In particular, they show that younger speakers substituted the low-level tone with the low-falling tone, a pattern likely induced by contact with Mandarin Chinese which lacks a low-level tone, and by the low perceptibility of low tones in general.[1] While this result has been interpreted as contact-induced change resulting from widespread Hakka-Mandarin bilingualism among young native speakers of Hakka, Yeh and Lin's detailed group comparisons reveal that contact alone cannot account for the change. In particular, they compared young daily Hakka users, young non-daily Hakka users, and old daily Hakka users. However, the frequency of use differed between young and old daily users in that the young users use Hakka less and Mandarin more frequently as compared to the old daily users. Yeh and Lin's results revealed no significant differences between the young daily Hakka users and the old daily Hakka users but found that both daily user groups differed from the young non-daily user group. Crucially, this pattern is an unlikely one in language contact, where the young daily users are expected to show gradience in usage frequency of the low-level tone as a function of the relatively increased contact with Mandarin as compared to the old daily users. Yeh and Lin interpret the similarity between the old daily users and the young daily users on the one hand, and the dissimilarity of the two groups to the young non-daily users on the other hand as evidence for language attrition in the young non-daily users. Importantly, the low-level tone is subject to variability in other dialects of Hakka as well and is undergoing a sound change which is also in progress in other languages (e.g., Cantonese and Taiwanese). Here, Yeh and Lin (2015) argue that the substitution of the tones observed in their study "gives rise to phonetic variants first, and gradually causes some sounds to change." (p. 200)

[1] The perceptual forces driving sound change are discussed extensively by Ohala (1981).

Taken together, the results of the studies reviewed so far provide evidence that the magnitude of variability (or the tendency to exhibit variability) in a linguistic feature increases the likelihood that it will be subject to language change not only diachronically and synchronically as observed in monolingual speech communities but also on the individual level in L1 attrition.

1.3 Outline

Chapter 2 presents the typological, phonetic, synchronic, and diachronic background on developments in /r/ and /l/. First, I focus on pointing out similarities and differences between the two laterals, followed by overviews over historical and contemporary variation and change to /r/ and /l/ in English, and analyze structural variables that arguably modulate the behavior of /r/ and /l/. These background chapters provide important typological, phonetic, and phonological perspectives which inform the model I develop later in this dissertation. In Chapter 3 I review the relevant research background to L1 attrition in phonetics and phonology. Here, I point out various shortcomings of previous studies and argue that empirical research does not provide sufficient evidence for the view that the L2 is the leading force in L1 attrition. In particular, I show that on the one hand some changes observed in previous studies cannot straightforwardly be explained by L2 influence while on the other hand some predicted changes are not observed. Thus, I argue that L1 attrition is not the mirror image of L2 acquisition but rooted in universal principles which guide the development of phonological systems in various domains. In Chapter 4, I turn towards the acquisition of allophones in a second language to show that allophones are particularly well-suited to explore the forces that determine the course of L1 attrition. Instead of attrition research, I draw from previous research in SLA to demonstrate that L2 learners acquire L2 allophones along a continuum which is shaped by a variety of structural and positional constraints characterized not exclusively by L1 transfer but by general principles of language development and change. Chapter 5 presents the aims and research questions of the study, followed by a description of the experimental procedure as well as the procedures of the analyses. Here, American English late learners of L2 German performed three production tasks aimed to elicit speech in three different degrees of formality. The dataset was operationalized by way of auditory judgment in the case of postvocalic /r/, and acoustically for both /r/ and /l/. Chapter 6 then presents the results of the analyses of postvocalic /r/, followed by the results of the lateral analyses in Chapter 7. In Chapter 8, I will discuss the implications of the findings from the perspective of one formulation of the *Dynamic Systems Theory* (henceforth '*DST'*), namely the *Dynamic Model of Multilingualism* (henceforth '*DMM*,' see Herdina & Jessner, 2002). I argue that the DMM offers an instructive framework which attempts to holistically incorporate various types of bilingualism including L1 attrition but relies too heavily on social and individual variables which leads to a neglect of grammar-internal variables known to give rise to variability and change. This results in a lack of predictive and explanatory power, weakening the DMM's premises. I turn towards phonological theory to fill these gaps and will briefly offer a background to constraint-based approaches before focusing on *Noisy Harmonic Grammar* (henceforth 'NHG'; Legendre, Miyata, & Smolensky, 1990; Boersma & Pater, 2008), with which I will develop my approach. I present a unified account of L1 attrition based on DST and NHG to account for the changes observed in the bilinguals, using what I will call *Dynamic Constraints Model*. Here, I argue that L1 constraints in attrition are not only modified by the influence of an L2, but also follow general laws of phonetics, and reflect the recurring patterns of synchronic variation and diachronic language change. Finally, Chapter 9 summarizes the insights from the study presented in this dissertation and points out future research avenues.

Chapter 2

Variability and change in sound patterns: The case of English rhotics and laterals

2.1 Rhotics and laterals as a natural class: Unity and variation

Rhotics and laterals, two highly variable sounds, are often unified as members of a single natural class, the liquids. Naturally, their high degree of variability raises challenges regarding their classification: For instance, rhotics and laterals exhibit inconsistent phonetic properties and are not only characterized by the phonetic properties they share but also by those both segments *lack*. Walsh Dickey (1997), for example, characterized them as 'non-nasal sonorant consonants,' indicating that a unifying feature of liquids is their *lack* of a feature rather than a *shared* feature. Indeed, Ballard and Starks (2005) go as far as calling "liquids […] a residual category consisting of the consonants left over after the classes of obstruents, nasals and glides have been phonetically defined" (p. 2). The notion that liquids cannot be unified based on phonetic justifications is not widely accepted as evidence against liquids as a unified class, even when disregarding that lack as a unifying feature. Instead, the unification has been justified on phonotactic grounds as well as similarities in phonological behavior and their phonological correspondences across languages. The unifying and dividing properties of rhotics and laterals offer valuable insights into the behavior of liquids across languages and inform the account of liquids under L1 attrition which I will develop later in this dissertation.

This chapter is not intended to provide a comprehensive overview of liquids but to provide insights into relevant phonetic specifications of /r/ and /l/ and to highlight selected patterns of variation and variability observed in liquids across languages which point to typological links between /r/ and /l/. After discussing similarities and differences between rhotics and laterals, I will turn to English rhotics and laterals individually from a phonetic, diachronic and synchronic perspective. To that end, I will show that the high degree of variability and the patterns of this variability which can be observed typologically are reflected by the variability of liquids in English. Crucially, these patterns of variability will inform the patterns observed in L1 attrition in the bilingual data in this dissertation. Moreover, the typological and language-specific insights form the foundation of one of the scaling factors included in the model I will develop in Chapter 8 to account for L1 attrition.

2.1.1 Cross-language distribution of liquids

Liquid segments are highly frequent across the world's languages, with 95.9% of all languages surveyed in Maddieson (1984) possessing at least one liquid segment, and 72.6% of all languages possessing more than one. Maddieson (1984, p. 83) finds that in languages with liquids, laterals are slightly more widespread than rhotics: 81.4% of the languages surveyed feature at least one lateral, while only 76% feature at least one rhotic segment. In a quantitative overview of all liquids across the languages surveyed, laterals are cross-linguistically more frequent than rhotics: 57% of all liquids in Maddieson (1984, p. 73) are lateral liquids.

Despite the weak cross-linguistic preference for laterals, rhotics are more frequent than laterals in languages with a single liquid segment (56.8% of all languages with a single liquid; see Maddieson, 1984). Maddieson (1984, p. 84) finds that languages with two liquids are highly likely to have one lateral and one rhotic segment (83.1% of all two-liquid languages; see also Gordon, 2016). On the other hand, if a language with two liquids has two liquids of the same type, two laterals are more frequent (13%) than two rhotics (2.3%). Languages with three liquids usually have two laterals and one rhotic (50%), although one lateral and two rhotics is also possible (37%). In a small number of languages with three liquids, all liquids are laterals (13%), whereas none of the languages with three liquids have only rhotics. Overall, it seems to be a robust cross-linguistic trend for languages with multiple liquids to have more laterals than rhotics, and to favor laterals over rhotics if all liquids are the same type (Maddieson, 1984, pp. 82–83; see also Gordon, 2016).

In summary, the cross-linguistic distribution of rhotics and laterals shows that liquids are highly frequent sounds which seem connected across languages. Laterals seem to be favored cross-linguistically, although languages with a single liquid seem to favor rhotics. This classification does not take into account allophonic variation in liquids in languages with a single rhotic segment such as Japanese, where /r/-like and /l/-like qualities alternate and relativize the high frequency of rhotics in single-liquid languages (for a brief discussion, see Maddieson, 1984, p. 83).

2.1.2 Cross-language articulatory properties of liquids

Regarding the manner of articulation, rhotics are typically realized either as trills or as taps, which cross-linguistically accounts for 85.8% of all rhotics (Maddieson, 1984); laterals, on the other hand, are most often realized as approximants. Although it has been suggested that the lack of a shared place feature (*place of articulation*, 'POA') across laterals, shown in Table 2.1 and rhotics, shown in Table 2.2, does not offer meaningful insights to help with the unification of both segments (e.g., Maddieson, 1984), some interesting tendencies emerge within and across both sounds. Table 2.1 and Table 2.2 show a statistical preference for laterals and rhotics to be coronal: Most liquids are dental or alveolar, followed by retroflex articulations, whereas other places of articulation are considerably less frequent.

Table 2.1: Distribution of POA across lateral variants (from Maddieson, 1984, p. 77).

	Dental	Dental/ Alveolar	Alveolar	Palato-alveolar	Retroflex	Palatal	Velar	Alveolar-velar
No secondary articulation	31	178	132	8	28	15	1	3
Palatalized	3	1	5	0	0	0	0	0
Velarized	0	7	3	0	0	1	0	0
Pharyngialized	0	1	1	0	0	0	0	0
Total	34	187	141	8	28	16	1	3
% of laterals	8.1%	44.7%	33.7%	1.9%	6.7%	3.8%	0.2%	0.7%

Table 2.2: Distribution of POA across rhotic variants (Maddieson, 1984, p. 81).

	Dental	Dental/ Alveolar	Alveolar	Palato-alveolar	Retroflex	Uvular
No secondary articulation	9	118	135	2	38	3
Palatalized	1	3	4	0	0	0
Velarized	0	1	1	0	0	0
Pharyngialized	0	0	1	0	0	0
Total	10	122	141	2	38	3
% of rhotics	3.2%	38.6%	44.6%	0.6%	12%	0.9%

The statistical tendency of liquids to be either dental or alveolar is not considered indicative of any phonetic similarity between the two segments, and thus rarely seen as justification for the unification of rhotics and laterals as liquids (Maddieson, 1984). When comparing liquids to sounds from other natural classes which do not exhibit such consistent statistical preferences, the cross-linguistic tendency provides at least some (albeit limited) justification for unifying rhotics and laterals into a single natural class and therefore treating them as counterparts in a single analysis (Ballard & Starks, 2005).

2.1.3 Cross-language phonological behavior of liquids

As briefly mentioned above, laterals and rhotics display some properties which suggest that the unification of both in a single natural class may be justified on other grounds rather than on phonetic properties. One such justification comes from phonotactic constraints, the distributional behavior of liquids, phonological processes which they are subject to as well as the processes they trigger (Ballard & Starks, 2005).

For instance, liquid allophony can be observed in some languages (e.g., Japanese, Korean, Toaripi[2]) which have a single liquid in their phonemic inventory. In these cases, the surface realization of the liquid varies between at least two realization types of which

[2] Toaripi is a language spoken in Trans New Guinea.

regularly one is r-like and the other is l-like.[3] This intimate connection by way of allophony has led to the assumption that liquid allophony "seems to provide some of the best phonological evidence for […] the existence of a class of liquids in these languages" (Proctor, 2009, p. 28).

In a similar vein, cross-linguistic insights into the shared phonotactic behavior of /r/ and /l/ provide additional evidence. One such example comes from English, where /r/ and /l/ are subject to similar constraints. The examples in (2) illustrate that /r/ and /l/ can take the second position within an onset cluster while nasals and obstruents cannot. Loan words where nasals and obstruents are in second consonant position are subject to consonant deletion which typically affects the first consonant of the cluster (Ballard & Starks, 2005).

(2) Licit and illicit onset clusters in English with liquids, nasals, and obstruents in second position (from Ballard & Starks, 2005, p. 3).

Licit:	Liquids	/pl-/, /pr-/	plant, prey
Illicit:	Nasals	*/pn-/	*pneumonia
Illicit:	Obstruents	*/ps-/	*psoriasis

These restrictions in complex onsets which block consonants including sonorants other than /r/ and /l/ from the position directly next to the nucleus suggests that /r/ and /l/ cannot be readily categorized as members of another class (i.e., sonorants[4]) or a subclass of the sonorants (e.g., nasals). Instead, liquids share properties exclusive to rhotics and laterals, and the presence of similar constraints for /r/ and /l/ (but not for others) suggests that they belong to the same class. Furthermore, the similarities between /r/ and /l/ regarding phonotactic behavior and the lack of similarities when compared to other consonants indicates that the class liquids belong to does not contain other consonants such as nasals as they are not

[3] The precise phonetic realization and the distinction between r-like and l-like is not clear cut, and strongly depends on language-specific properties. In Japanese, for example, research suggests that native speakers of Japanese perceive American English /l/ as a better exemplar of the single Japanese liquid as compared to American English /r/ (see Hattori and Iverson, 2009 for a discussion of the effects of this asymmetry).

[4] It is worth mentioning here that not all liquids can be phonetically classified as sonorants. Especially rhotics are often phonetically obstruents, for example in Scottish English where /r/ is an alveolar trill (e.g., Schützler, 2015).

affected by these constraints. While the similarities described above are highly suggestive of liquids as a justified class of sounds, /r/ and /l/ also display some crucial differences, which will be addressed in the remainder of this section.

/r/ and /l/ rank high in sonority and cluster together in several languages (including English) where they either share the same sonority rank or occupy ranks directly adjacent to each other. If the latter is the case, /r/ often outranks /l/ in being the more sonorous segment as also visible in the simplified version of the sonority hierarchy shown in (3).

(3) Sonority hierarchy (simplified illustration; from Selkirk, 1984).

Plosives > Fricatives > Nasals > Laterals > Rhotics > Vowels

In some languages, e.g., in English and German, /r/ and /l/ occupy different sonority ranks which impose different distributional restrictions on them. For example, the co-occurrence of /r/ and /l/ in German and English syllable codas is differentially restricted such that in complex codas containing both liquids, /r/ will be adjacent to the syllable nucleus whereas /l/ is blocked from this position. That means that syllable-internally, /rl/-clusters are permitted to appear in codas whereas */lr/-clusters are not. Thus, /r/ and /l/ may co-occur in English words like *snarl* and *hurl*, and in German words like *Kerl* (‘guy’) whereas other syllable-internal /r/-/l/ clusters are not permitted (Wiese, 2011).

When /r/ and /l/ do not co-occur in syllables, they are often affected by similar constraints in word-initial and word-final position. Proctor (2009) offers examples from French where consonants in word-final position are prohibited if the following word has a consonant in initial position. Rhotics and laterals are exempt from such constraints and surface in word-final position even if a consonant follows as the examples in (4) show.

(4) Constraints on word-final consonants in French (from Proctor, 2009, p. 21).

(/s/→Ø|#):	Les camarades	(‘the friends’)	→	[leØ.ka.ma. ʀad]
(/t/→Ø|#):	Petit camarades	(‘small friend’)	→	[peØ.ti.ka.ma. ʀad]
(/ʀ/→[ʀ]|#):	Cher camarades	(‘dear friend’)	→	[Seʀ.ka.ma. ʀad]
(/l/→[l]|#):	Nul camarades	(‘no friend’)	→	[nul.ka.ma. ʀad]

The interaction of /r/ and /l/ as a part of various phonological processes highlights their close phonological relationship. For example, both liquids are known to undergo dissimilation, a process causing two identical segments within a single unit (most commonly the word-level) to become less similar to each other. Liquid dissimilation thus affects sequences of either multiple /r/ or multiple /l/ such that rhotic sounds dissimilate in the presence of another rhotic sound in the same word, and laterals dissimilate in the presence of other laterals. The dissimilating segment is either deleted altogether or substituted by a different segment. While the outcome of dissimilation is language-specific and varies across languages, liquids are exceptional: Often, the result of liquid dissimilation is another liquid.

An example of dissimilation resulting in complete deletion of a liquid comes from American English, where /r/-dissimilation is found in several dialects (Hall, 2008; Hall, Vasquez, Damanhuri, Aguirre, & Tree, 2017). /r/ in unstressed syllables is affected most frequently so that dissimilation in words like *surprise* gives rise to surface forms like [səˈpraɪz] rather than [sɚˈpraɪz] (Hall, 2009). Dissimilation is however not restricted to unstressed syllables and can also affect /r/ in other phonetic contexts as well as /r/ in onsets, although the latter dissimilation type is rare (Hall, 2007; 2009).

An example of the second type of dissimilation where the dissimilated segment alternates with other phonetically similar segments comes from Latin. Here dissimilation affects /l/ in the suffix /-*alis*/ which dissimilates if the root of the word contains another /l/, leading to the alternation of /-*alis*/ and /-*aris*/ (Bennett, 2015). Dissimilation is blocked if a rhotic intervenes between the two laterals. The Latin dissimilation pattern is shown in (5).[5]

(5) /l/-dissimilation in Latin (from Bennett, 2015, p. 276).

(5a) L-dissimilation: suffix /-alis/ → [-aris] after /l/ in the root

/sol-alis/ → [sol-aris] - 'solar' *sola-lis

(5b) T-transparency: L-dissimilation after intervening coronals

/milit-alis/ → [militaris] - 'military' *milit-alis

(5c) R-blocking: no L-dissimilation with intervening /r/

/flor-alis/ → [flor-alis] - 'floral' *flor-aris

[5] Note that labials and velars also block dissimilation in Latin (Bennett, 2015, p. 276).

While liquids are not unique in their susceptibility to dissimilation, the interactions between /r/ and /l/ under dissimilation are unusual from a cross-linguistic perspective and highly suggestive of their relationship. Liquid dissimilation often operates within the same natural class such that rhotics dissimilate to laterals and vice versa. Other liquids typically have a blocking effect if they occur in an intermediate position between the dissimilation candidates. Thus, a lateral occurring between two rhotics blocks rhotics from dissimilating, and rhotics block lateral dissimilation in the same way.

Yidiny is a particularly interesting example as it exhibits extensive dissimilation. For instance, Yidiny features both /r/ and /l/-dissimilation by which /r/ dissimilates to /l/ and vice versa, yielding patterns such as those shown in (6); (6a) shows regular dissimilation of laterals, and (6b) shows the regular dissimilation pattern of rhotics.

(6) Liquid dissimilation in Yidiny (from Bennett, 2015, p. 269).

(6a) Lateral dissimilation:	L…-L → R…-L
(6b) Rhotic dissimilation:	R…-R → R…-L[6]

Finally, Yidiny provides an instructive example to shed light on the hierarchical ranking of lateral and rhotic dissimilation processes. Dissimilation in Yidiny also operates across more than two identical liquids, although here too dissimilation does not apply if /r/ and /l/ alternate regularly. Thus, sequences like $[R\ldots\text{-}L\ldots\text{-}R]_{word}$ and $[L\ldots\text{-}R\ldots\text{-}L]_{word}$ are licit.

Illicit sequences of liquids may emerge in Yidiny due to underlying forms in which /r/ and /l/ do not necessarily alternate regularly. Words in Yidiny can contain illicit sequences of liquids where dissimilation of an illicit sequence yields another illicit liquid sequence which usually triggers dissimilation. To illustrate, in an alternation of three liquids containing both /r/ and /l/ where the medial liquid is identical to another liquid either to its left or its right, both /r/- and /l/-dissimilation will yield an illicit sequence of either /r/ or /l/. The example in

[6] Note that this example suggests that R-dissimilation and L-dissimilation yield an identical order of rhotics and laterals, i.e., both yield [R…-L]. Although Bennett (2013) does not explicitly address this issue, he notes that overt R-R alternations do not occur in Yidiny. Moreover, his illustration of the two examples also shown in (7) suggests that the pattern shown in (7b) here is hypothetical.

Fehler! Verweisquelle konnte nicht gefunden werden. illustrates the two illicit dissimilation outcomes.

(7) Precedence of /r/-dissimilation over /l/-dissimilation in Yidiny (Bennett, 2013, pp. 402–403)

(7a) $[R\ldots\text{-}R\ldots\text{-}L]_{word}$ – dissimilates to the prohibited $[R\ldots\text{-}L\ldots\text{-}L]_{word}$ sequence.
(7b) $[R\ldots\text{-}L\ldots\text{-}L]_{word}$ – prohibited due to /l/-/l/-sequence, but no dissimilation due to $*R^2 > *L^2$

/r/-dissimilation outranks /l/-dissimilation: two rhotics are worse than two laterals, or $*R^2 > *L^2$.

Here, a hierarchical pattern emerges in that violations of constraints affecting laterals, shown in (7b), are less severe than those affecting rhotics, shown in (7a). The circular dissimilation pattern is blocked if dissimilation would produce an illicit sequence of rhotics, even if this results in an illicit sequence of laterals. Yidiny accepts illicit lateral sequences if this leads to an avoidance of illicit rhotic sequences, but is just one representative of a more general cross-linguistic tendency of the precedence of dissimilation from /r/ to /l/ as compared to dissimilation from /l/ to /r/ (Bennett, 2013, p. 613; see also Bennett, 2013, pp. 501–502 for a full typology of dissimilation types).

Beyond these synchronic patterns of dissimilation, /r/ and /l/ are also known to follow similar paths in diachronic and synchronic variability and change. For example, both are known to frequently undergo vocalization diachronically across various languages and reflect these diachronic changes in their synchronic variability which often involves vocalization. From a phonological perspective, this can be seen as a case of lenition by which the sonority of sounds increases. In particular, lenition progresses along a continuum where vocalization marks a stage of lenition which is observed in sounds moving towards complete deletion. As such, lenition can be understood as a type of weakening in which a segment becomes increasingly more sonorous or ‘vowel-like’ (Lass, 1984). Although /r/-vocalization is not canonically treated as lenition, it stands to reason that /r/-vocalization fulfills the characteristics of lenition. Indeed, the parallelism between /r/-vocalization and lenition, in general, is more apparent when we compare the differences in vocalization and weakening of /l/ and /r/. For instance, /r/ and /l/ do not vocalize to the same extent which may stem from the acoustical differences between rhotics and laterals causing an asymmetry in segmental strength. Proctor (2009) argues that "laterals tend to be more consonantal in their behavior, and rhotics more vocalic" (p. 44), and as such, higher frequencies of vocalization of /r/ arise from its more vocalic acoustic and auditory characteristics which /l/ lacks. The cross-linguistic frequency at which /r/ is avoided more frequently than /l/ is also reflected in the diachronic changes to English rhotics and laterals thoroughly explored in Chapters 2.3.2 and 2.4.2 respectively.

2.2 Separating rhotics from laterals

As we saw above, both rhotics and laterals exhibit similarities in various domains of their behavior, suggesting that they are subject to similar constraints; this may fall out from their association with the same natural class in different phonological systems across the languages of the world. What is most relevant for the current work is that liquids as a class are subject to high internal variation cross-linguistically as demonstrated by their multifaceted behavior as well as their involvement in various phonological processes. They also exhibit a considerable degree of variation in the domains of articulation and acoustics, diachronic developments, and typological distribution within and across languages. The magnitude of variation differs when we consider the sub-classes of laterals: Rhotics show a broader range of phonetic and phonological variation and change more readily than laterals, which is also reflected in their synchronic and diachronic behavior in English, as we will see in Chapter 2.3. In the remainder of this section, I will review the typological behavior of rhotics (Chapter 2.2.1) and laterals (Chapter 2.2.2) as independent categories to provide the background for the diachronic, sociolinguistic and psycholinguistic aspects of English rhotics.

2.2.1 What is (or isn't) a rhotic sound?

Rhotics are a group of segments which exhibit considerable acoustic and articulatory complexity and a high degree of variation. Just like liquids overall, the sub-category of rhotics evades a unified classification which succeeds to incorporate the different rhotics as members of the same class. As shown in Chapter 2.1.2, cross-linguistic observations reveal that rhotics may emerge as trills, taps, fricatives, and approximants, among others, and their place features span from dental to uvular. Their articulatory complexity also renders them prone to variation and change guided by grammar-internal (i.e., reduction of articulatory complexity) and grammar-external variables (e.g., reduction in language learning and language contact). The different realizations of /r/ in the IPA classification shown in Table 2.3 illustrate this class-internal variability.

Table 2.3: R-like IPA symbols for rhotic segments (from Wiese, 2000).

PoA[a] / MoA[b]	Alveolar	Retroflex	Uvular
Trill	r		ʀ
Tap or Flap	ɾ	ɽ	
Fricative			ʁ
Approximant	ɹ	ɻ	
Lateral flap	ɺ		

[a] Place of articulation; [b] Manner of articulation

Some (e.g., Ladefoged & Maddieson, 1996) go as far as to suggest that the only feature rhotics share beyond some historical connections among the individual sounds is their high likelihood to be represented by the letter <r> across languages. Conversely, Wiese (2003) argues that the seemingly unrelated group of segments referred to as ‘rhotics’ is indeed unified by several shared characteristics which are listed in (8).

(8) Characteristics shared by rhotic sounds (from Wiese, 2003, p. 26).

(8a) “The position in the phonotactic patterns of languages: r-sounds are vowel-adjacent elements in the syllable. The pattern is: CrVrC, for any language allowing consonantal clusters at all.

(8b) r-sounds, while nonsyllabic consonants in general, often have a syllabic variant, alternatively called a vocalicized r or a rhotacized vowel.

(8c) Within a language, rhotics of one type often alternate with rhotics of another type (synchronically or diachronically).

(8d) If rhotics alternate with each other in this way, the phonotactics of these r-sounds does not change.

(8e) Phonological constraints on /r/ and other generalizations such as those in 1 to 4 above can refer to /r/ without any reference to the more specific type of /r/ in question […].”

Importantly, Wiese's characteristics does not rely on acoustic similarities between rhotic segments, also stated explicitly in (8e), but relies on language-internal variability also observed cross-linguistically.[7] The high frequency of vocalization in coda-/r/ found cross-linguistically is one such example which supports that coda rhotics are subject to enhanced variability.[8] Ladefoged and Maddieson (1996) support some of Wiese's (2000) suggestions. For example, cross-linguistic evidence in Ladefoged and Maddieson (1996, p. 216) supports (8d) by revealing that rhotics are most frequently located adjacent to the syllable nucleus irrespective of their acoustic quality when they occur in complex onset or coda clusters.

As can be seen in (8), Wiese argues that their shared phonotactic and distributional properties unify rhotics as a class. This argument fails to explore the relationships between individual rhotic segments and leaves various questions unanswered. Wiese's criterion in (8d) raises questions regarding the connection of rhotics to each other. More precisely, it raises the question whether rhotics are connected by some single (acoustic or articulatory) characteristic or if the connection is more direct for some rhotics than for others. Crucially, the nature of the connection between rhotics may also provide insights into whether some rhotic segments are more likely to vary among each other synchronically and diachronically.

As mentioned before, rhotic segments do not share a sole property which unifies them on phonetic grounds. Lindau (1985) showed that several rhotic segments do not exhibit acoustic properties typically associated with rhotics, or a perceivable rhotic quality: A low third formant (*F3*), for example, which is often assumed the primary acoustic correlate of rhoticity in various languages (see also Chapter 2.3.1 of this dissertation for an acoustic profile of English /r/) may be absent. Instead, Lindau (1985) shows that even an increase in F3 frequency (i.e., as compared to the non-rhotic or neutral F3 value) induces the perception of rhotic quality in some types of rhotics. Furthermore, variation in the degree of obstruction introduced a gradient continuum from strongly consonantal realizations of rhotics (e.g., rhotics articulated with a high degree of friction such as fricatives) to (near-)vocalic (approximants and vocalic allophones of /r/).

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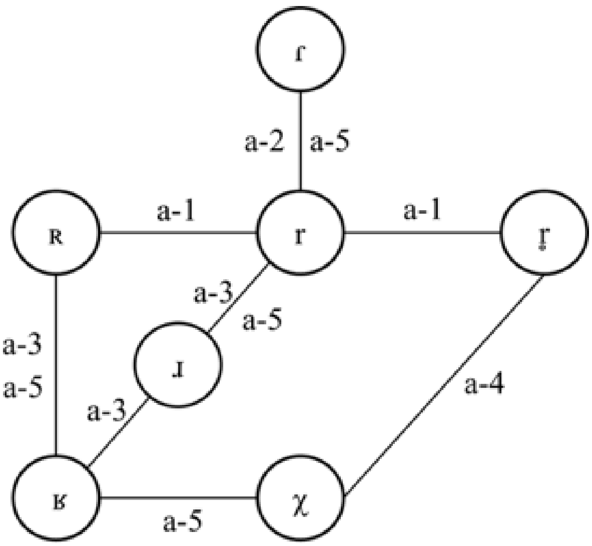
[7] Wiese's (2003) justifications to classify rhotics into a single class are highly reminiscent of those suggested for the classification of liquids in general. This may be interpreted as another piece of evidence (albeit anecdotal) for the inherent variability of liquids, and tentatively provide some support to the unity of liquids as well as the liquid subcategories rhotics and laterals.

[8] Onset-coda asymmetries in the application of phonological processes are not unique to liquids but reflect more general laws of phonetics and phonology; see Beckman (1998) for an in-depth exploration of positional asymmetries in phonology.

Lindau (1985) suggests that these issues can be done away with by resorting to approaches which rely on large-scale family resemblance rather than direct connections between each member of a class. A family resemblance model instead links rhotic segments indirectly along a feature chain. Lindau's feature chain of rhotics shown in

Figure 2.1 which illustrates that the relationship between a pair of rhotics does not necessarily resemble its relationship with other rhotics, or relationships between other rhotics with respect to the type of connection and the number of shared phonetic characteristics.



Shared characteristics	
a-1	Pulse pattern (trill)
a-2	Closure duration
a-3	Presence of formants (sonorant)
a-4	Presence of noise
a-5	Spectral energy distribution (place)

Figure 2.1: Lindau's family resemblances model for rhotics (from Lindau, 1985).

Lindau's model provides a comparatively comprehensive approach towards rhotics but lacks some segments which frequently associate with /r/. Recall that Wiese's (2003) list of shared characteristics of liquids shown in (8) included vocalized variants of /r/; these remain unaccounted for in Lindau's approach. Also, Lindau fails to address the acoustic and articulatory variability which emerges especially if less prototypical rhotic segments are considered. Magnuson (2007) addresses these gaps by offering a more extensive version of Lindau's model shown in Figure 2.2.

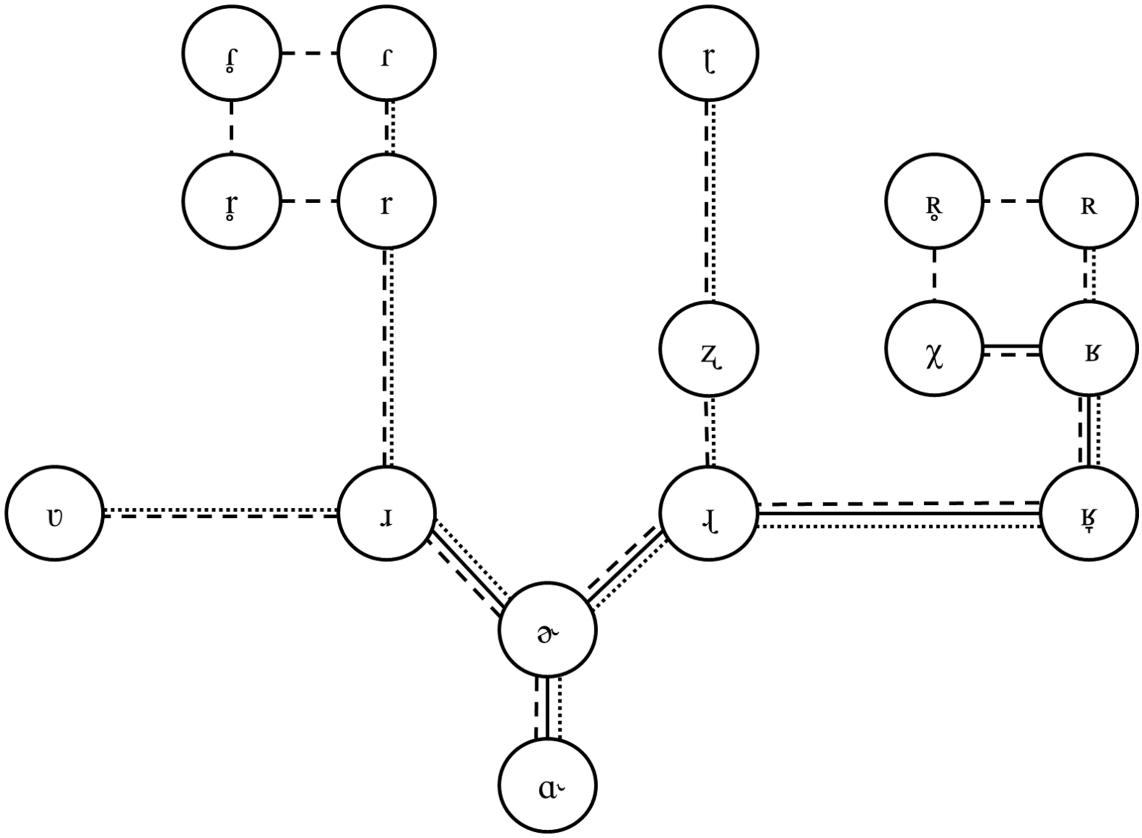


Figure 2.2: Magnuson's family resemblances model for rhotics (from Magnuson, 2007, p. 1195).

Unlike Lindau, Magnuson (2007) adds an articulatory dimension to his family resemblance model by distinguishing rhotics with oral components from rhotics with pharyngeal components. Crucially, this distinction also reflects differences in the acoustic properties already addressed by Lindau (1985) and helps account for the asymmetries observed in the role of F3. Magnuson (2007) argues that F3-lowering correlates with pharyngeal constriction in that constriction at the bottom of the pharynx yields lower F3 frequencies and will not be present in rhotics which lack pharyngeal constriction. Magnuson also includes vocalized variants of /r/ as well as rhoticized vowels, implicitly classifying them as possible allophonic variants of /r/.

Importantly, the arguments above also bear implications which can help account for the behavior of rhotics in the languages of bilinguals. Although this will be discussed in more detail in Chapter 4, some aspects are worth mentioning here. As the acquisition of an L2 involves the cross-language association of segments which links L2 sounds to L1 sounds if the learner perceives them as examples of an existing L1 category (Flege, 2007). Considering the vast phonetic differences between the different rhotic sounds, the establishment of cross-language links in the phonetic system of bilingual speakers does not seem straightforward and instead may depend on the types of rhotic sounds in the L1 and the L2 and their phonetic similarity. The extensive discussion of the justifications to unify rhotics into a single class provided in the chapters above highlights several characteristics which indicate that bilinguals may draw from some characteristic other than acoustic similarity and can be expected to associate the rhotics in their languages based on shared phonotactic principles. The heterogenic phonetic characteristics across the distinct types of rhotics also suggest asymmetries regarding their likelihood to change and can be expected to yield different results depending on variables such as the (perceived) phonetic proximity of the rhotics in a bilingual's languages.

2.2.2 What is (or isn't) a lateral sound?

In contrast to rhotics, laterals have received considerably less attention in sociolinguistic and diachronic research and have been neglected in typological perspectives. Nevertheless, laterals are known to be subject to considerable cross-linguistic variability. Yip (2011), for example, claims that the behavior of laterals "is more variable across languages than that of most other sounds" (p. 751). In comparison to the high degree of variability in rhotics, variability in laterals is comparatively moderate. As will be shown below in more detail, laterals are arguably more homogeneous regarding phonetic specifications which makes their sound class association less troublesome. Nevertheless, the distributional constraints and patterns of variability of laterals are highly reminiscent of the behavior of rhotics and allude to the close links between the two segmental groups.

For instance, just like rhotics, even phonetically diverse types of liquid sounds follow similar constraints regarding their distributional behavior which also seems to be active across languages. This behavior was extensively demonstrated in the previous chapters (esp. Chapter 2.1.3) and is also reflected in English where laterals in consonant clusters are typically located adjacent to the syllable nucleus, yielding licit onset clusters such as [kl], whereas onset clusters such as [*lk] are illicit (Yip, 2011, p. 735).

Yip (2011) shows that cross-linguistically, laterals alternate with various other segments. They have been shown to alternate with stops (e.g., in Palenquero Spanish and some Bantu languages), nasals (e.g., in Min dialects of Chinese) and rhotics (see also Chapter

2.1.3). Yip, however, argues that vocalization is among the most frequently observed phonological processes that affect laterals and is diachronically and cross-linguistically well-attested. The assumption also holds true for English laterals where /l/-vocalization is attested historically as well as synchronically. Historical /l/-vocalization can be demonstrated by comparing English to other Germanic languages which lack historical vocalization; for example, English (and also Dutch) show /l/-vocalization is words like '*old'* (also compare its Dutch cognate '*oud'*), whereas the Modern German cognate '*alt*' retained the non-vocalized variant (Yip, 2011, p. 740).

/l/-vocalization falls out from the articulatory architecture of laterals which includes a dorsal component – the 'vocalic' gesture – and an apical component – the 'consonantal' gesture (Sproat & Fujimura, 1993). The reduction or complete loss of the apical gesture, Sproat and Fujimura (1993) argue, results from phonological environments which disfavor a consonantal gesture and strengthens the vocalic one. The likelihood of loss of the consonantal gesture is higher in coda laterals as the preceding vowel attracts the vocalic gesture of /l/ which induces a timing delay between the vocalic and the consonantal gesture. This delay leads to a more vocalic quality in coda laterals which leaves them prone to vocalization. The likelihood of /l/-vocalization differs across lateral types and depends on its phonetic specifications. Johnson and Britain (2007), for instance, show that dark (or velarized) /l/ is more prone to vocalization which, they argue, indicates that the velarization of /l/ is an intermediate stage along a diachronic path of sound change towards vocalization or complete loss. In contrast, if the consonantal gesture precedes the vocalic gesture, as is the case in syllable onsets, the consonantal gesture in the lateral is more resistant to loss and strengthens the consonantal quality of the lateral (Recasens & Espinosa, 2005).

Unlike rhotics, variability in laterals is rarely categorical and instead exhibits phonetic gradience along a continuum of intermediate variants of /l/ (Recasens, 2012). Cross-linguistically, lateral approximants are often categorized binarily with regard to the degree of velarization, where the non-velarized variant [l] is usually referred to as *clear /l/* (sometimes also *light /l/*) and the velarized variant [ɫ] as *dark /l/* (Recasens, 2004). If the two variants are not contrastive, their distributional behavior may be determined either by intrinsic or extrinsic allophones, or both. Intrinsic allophones arise from variation due to co-articulatory patterns with adjacent segments whereas extrinsic allophones are phonologically conditioned and are usually sensitive to the front-back dimension of the surrounding vowels (Recasens, 2004). In this way, intrinsic allophony emerges merely as coarticulatory pattern shaped by the phonetic neighborhood of the lateral. In contrast, extrinsic allophones are sensitive to their positional distribution and may be relatively resistant to coarticulatory variability.

2.3 Rhotics in English

Rhotics have received considerable attention, and particularly English rhotics are well-researched from diachronic and synchronic perspectives. In this way, liquids offer an instructive test case for L1 attrition with regard to the estimation of the effect of typological, diachronic, and synchronic forces within and across languages and comparison to the contribution of an L2 to changes in the L1 of late bilinguals. As illustrated in Chapter 1, the phonetic and phonological behavior of monolingual speakers is not invariant across the lifespan, and the changes in mature monolingual grammars have been linked to patterns of language change over time across a speech community, which has also been argued to apply to L1 attrition (see Chapter 1.2). The results from studies on monolingual change across the lifespan indicate that the domains in which variability emerges in monolinguals are not just vulnerable to diachronic language change but also to change in L1 bilingual grammars. As discussed in Chapters 2.1 and 2.2, liquids are typologically diverse with regard to their phonetic characteristics, but often behave similarly in terms of the phonological processes they participate in, which can also enrich insights into the changes across the lifespan under the pressure of an emerging L2.

The following section is intended to zoom in on English postvocalic /r/ by drawing from previous work on grammar-internal and grammar-external variables that condition its variable realization in diachronic change and synchronic variability. This will provide the foundation which will help account for the changes in the L1 of late bilinguals observed in the study below.

2.3.1 Phonetics and phonology of rhoticity in (American) English

2.3.1.1 Categoricalness, gradience, and acoustics

Rhoticity – i.e., the presence of consonantal variants of /r/ in syllable codas – is one of the most pervasive phonetic and phonological characteristics of English and expresses a wide range of sociolinguistic differences. Sociolinguistic research often treats rhoticity as a categorical variable (e.g., Becker, 2014; Eberhardt & Downs, 2015; Nagy & Irwin, 2010), typically operationalized into *rhotic* and *non-rhotic*. However, as shown so far, /r/ is rarely categorical in its behavior and subject to considerable acoustical and articulatory differences; these also emerge in postvocalic position, suggesting that the *rhotic–non-rhotic*-continuum may be much more fine-grained than implied by the distinction between rhotic and non-rhotic, i.e., consonantal, and vocalized variants of postvocalic /r/.[9]

Let us first characterize the acoustic and articulatory properties of American English /r/. It belongs to the approximants, which are acoustically characterized by vowel-like formants rather than consonantal patterns of noise and friction produced by full or partial oral closure (see also Chapter 2.1 of this dissertation). In this sense, approximant /r/ is rather vowel-like both articulatorily as well as acoustically. Its vowel-like quality has been stressed previously, for example by Lutz (1994, p. 171), who describes English /r/ as "inherently weak based on [its] vowel-like character," indicating that vacillation between consonantal to vocalic properties is both natural and expected. McMahon (2009) also stresses this 'inherent' weakness by describing coda-/r/ as "a weak consonant in a weak position" (p. 99).

As all approximant /r/, American English /r/ is characterized by a steep drop of F3 as well as its lowering effect on the F3 of the surrounding segments especially if they precede /r/. The presence of /r/ often induces severe anticipatory lowering of F3 in the segments preceding /r/ and may extend to several of the preceding syllables (Kochetov & Neufeld, 2013). Anticipatory F3 lowering causes a low onset of the F3 of the pre-rhotic vowel as compared to non-pre-rhotic vowels followed by a mild but steady decrease of F3 throughout the vowel and induces the perceivable rhoticization characteristic of a pre-rhotic vowel, often referred to as */r/-coloring*. The lowering of F3 continues throughout the transitional phase from the vowel to the onset of consonantal /r/ proper where the characteristic fast and deep drop of F3 occurs (Hagiwara, 1995).

Generally, lower F3 values are linked to higher oral constriction during the articulation of /r/, although a perceivable rhotic quality is often assumed to emerge once F3 falls below the threshold of 2000 Hz (Hagiwara, 1995). Hagiwara (1995) sharply criticizes this approach and shows that especially for female speakers, F3 may exceed 2000 Hz while still being perceived as rhotic, while in some male speakers, it may drop well below 2000 Hz without resulting in perceivable rhoticity. Hagiwara (1995) argues that 2000 Hz should not be used as

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[9] I use the term 'consonantal /r/' to highlight differences between truly consonantal productions of /r/ and their vocalized counterparts, which will be treated separately due to their status as allophones of /r/ later in this chapter.

an indicator of perceivable rhoticity and suggests instead that the production of perceptible rhotic quality is linked to a speakers' *neutral* F3 formant value, which is defined as a speaker's mean F3 (in Hz) in non-rhotic vowels. More specifically, in his 1995 study, Hagiwara found that a perceivable rhotic quality emerges once a speaker's F3 drops below a threshold which is located at roughly 80% of their neutral F3 value. The discrepancy between previous studies and Hagiwara's findings can be accounted for by the degree of physical similarities among speakers. More precisely, the average Hertz-range produced by an individual is modulated by the length of the vocal tract, where longer vocal tracts lead to a lower mean range; vocal tract length, in turn, strongly correlates with body height. The relatively robust finding that rhoticity emerges when F3 drops below 2000 Hz can thus be accounted for by the considerable overlap in the physical height of the tested populations, and consequently similar vocal tract lengths among the speakers. Thus, most speakers' threshold seems to be located at around 2000 Hz due to physical similarities rather than a genuine and inherent property of rhotic segments. Hagiwara's results can be taken to indicate that perceivable rhoticity emerges as a proportional relationship between F3 in /r/ itself and F3 in neutral contexts, and potentially its relationship to other formants (e.g., F2, see Heselwood, 2009).

Approximant /r/ has also been argued to closely resemble SCHWA in terms of acoustics. McMahon (1994), for instance, suggests that English /r/ is closely related to SCHWA from an articulatory perspective in that the two sounds share many aspects of their gestural layout. One primary gestural difference, the anterior raising gesture in /r/, is vulnerable to weakening and loss which results in a substantial overlap with regard to the gestural configurations of /r/ and SCHWA respectively. McMahon's (1994) observation finds support in the articulatory study by Gick (1999) who confirms the similarities and furthermore shows that /l/ shares some articulatory properties with /r/ and SCHWA. Thus, SCHWA and approximant-/r/ are acoustically linked, suggesting that the diachronic and synchronic vacillation of postvocalic /r/ and its vocalized counterpart SCHWA is rooted in the phonetic properties of /r/, a critical point which we will revisit in Chapters 2.3.2 and 2.3.3.

2.3.1.2 Articulatory features of American English /r/

Variation in American English /r/ also involves articulatory specifications such as tongue configurations. Variation is primarily restricted to two primary tongue shapes, namely *retroflex*, shown in Figure 2.3 and *bunched*, shown in Figure 2.4, which express the speakers' social characteristics in some varieties of English (e.g., in Scottish English, see Lawson, Scobbie, & Stuart-Smith, 2011), while they escape speaker perception entirely in other dialects, for example in American English (Twist, Baker, Mielke, & Archangeli, 2007).

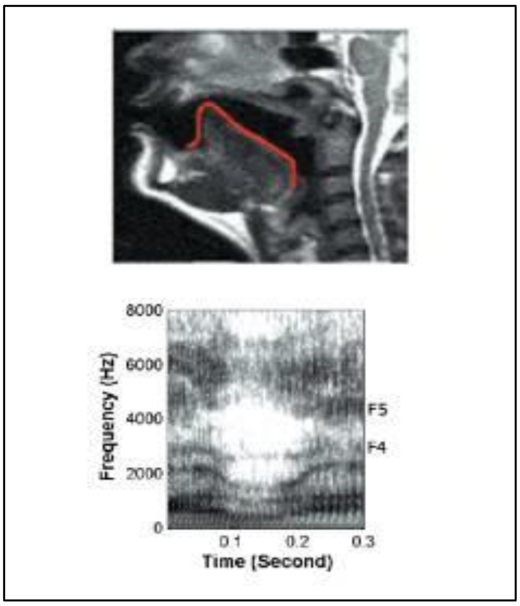

Figure 2.3: Tongue shape and acoustic profile of retroflex /r/ in American English rhotics (from Zhou et al., 2008).

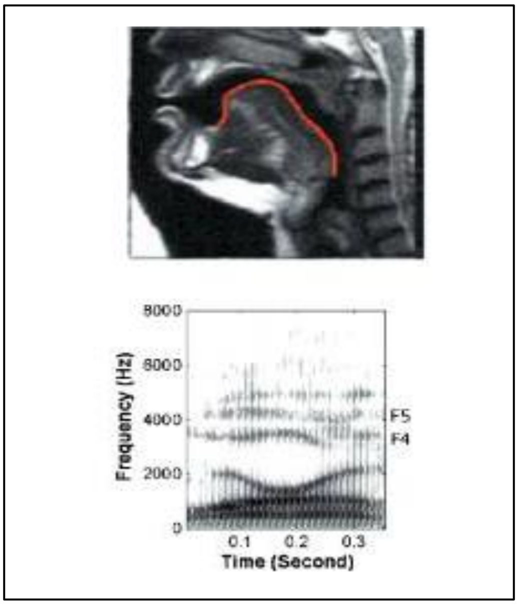

Figure 2.4: Tongue shape and acoustic profile of bunched /r/ in American English rhotics (from Zhou et al., 2008).

Like in other varieties, positional constraints modulate the distribution of tongue configurations in syllable onsets and codas for some AE speakers while others use one of the two shapes invariantly. An adaptation of Scobbie, Lawson, Nakai, Cleland, and Stuart-Smith's (2015) reanalysis of Mielke, Baker, and Archangeli's (2010) data on tongue shape variation in American English speakers are given in (9) which shows an overview of speaker numbers for each possible onset-coda configuration constellation.

The distribution shown in (9) reveals that most American English speakers do not have an onset-coda-alternation for tongue shapes, and instead invariantly use either bunched or retroflex in onsets and in codas. Only a small number of speakers show an onset-coda-alternation; in this case, the speakers use retroflex in onsets and bunched in codas, the opposite pattern with bunched onsets and retroflex codas is not attested.

(9) Distribution of speaker numbers across the different onset-coda-pairings for articulatory variants of American English /r/ (Scobbie et al., 2015).

Coda \ Onset		No. of speakers	
		Bunched	Retroflex
No. of speakers	Bunched	14	8
	Retroflex	-	5

A bunched tongue configuration across the board is more frequent than retroflex across the board: Scobbie et al.'s (2015) analysis in (9) shows that among the invariant speakers, 14 used the bunched tongue shape and only 5 used retroflex. Indeed, the use of the retroflex tongue shape in both onsets and codas was the least frequent constellation in the sample (excluding the unattested retroflex onset/bunched coda constellation). Although most speakers in the sample were invariant, the alternation pattern (bunched onset and retroflex coda) was more frequent than an invariant pattern among those speakers who used retroflex in at least one position. That is to say, retroflex was more likely to be confined to onsets, alternating with bunched in codas (8 speakers), as compared to an invariant pattern of retroflex in both onset and coda (5 speakers).

The differences in tongue configurations raise the question as to how variability in articulatory configurations impacts the acoustic quality of /r/ which may cause severe issues in an acoustical analysis if such variability affects the acoustic specifications under analysis, most importantly F3. Previous research robustly shows that at least in American English, variation regarding tongue shapes is neither socially meaningful nor perceivable to native speakers. In particular, Scobbie et al. (2015) argue that American English speakers do not seem to be aware of the articulatory difference between bunched and retroflex /r/ as “tongue shape or timing appears to lack social meaning” (sect. 4, §1). Scobbie et al.’s claim is supported by various other perception studies which show that native American English speakers do not perform well on the discrimination between bunched /r/ and retroflex /r/. This suggests that articulatory variants do not only lack social meaning in American English but that speakers are also entirely insensitive to such variation (Twist et al., 2007).

Even more importantly, research on the acoustic differences between bunched and retroflex /r/ demonstrates that tongue shape variation is primarily expressed by F4 and F5 while it does not acoustically interfere with the first three formants, an important fact as F2 and F3 are typically used to analyze rhoticity acoustically. For example, Zhou, Espy-Wilson, Tiede, and Boyce (2007) found that the effects of retroflection on the first three formants were negligible and that it affects the height of F4 and F5 as well as the relative distance between the two. Similarly, a series of studies on articulatory variation in English /r/ and its acoustical specifications demonstrate that F3 is robust against articulatory variation (Espy-Wilson & Boyce, 1999; Espy-Wilson, Boyce, Jackson, Narayanan, & Alwan, 2000; Zhou et al., 2008). That is to say, *bunched* and *retroflex* tongue shapes are indistinguishable with regard to their pattern in F1, F2, and F3 but differ in the interaction of F4 and F5.

2.3.2 Diachronic variability and change of English postvocalic /r/

Historically, Modern English /r/ derives from two sources, firstly what one may call ‘native /r/’, i.e., /r/ inherited from its ancestor languages, and secondly /r/ acquired through rhotacism, a sound change by which fricatives – usually /z/ – turn into /r/.[10] Minkova (2014) illustrates rhotacism in OE cognates, shown in (10), which differ (among other phonological changes) in the shift from Proto-Germanic /z/ to OE /r/.

(10) /z/ ~ /r/ alternations in Old English cognates (from Minkova, 2014, p. 66).

Proto Germanic *ris-	→	OE rīsan ‘to rise’ and OE rœran ‘to rear’
Proto Germanic *laiz- ‘to teach’	→	OE lār ‘lore’

Throughout its historical development, English /r/ was subject to several types of sound change and alternations, to various changes of the prevalent type of rhotic, as well as to /r/-vocalization and loss. Examples of such alternations in OE are metathesis as shown in (11a) and sporadic epenthesis in consonant clusters containing a rhotic as shown in (11b).

[10] Rhotacism occurred in several languages including West and North Germanic ones; German, for example, also acquired some of its /r/ through rhotacism.

(11) OE alternations involving /r/ (from Minkova, 2014, pp. 119–120).

(11a) Metathesis

brinnan ~ birnan - ‘to burn’

cers ~ cress - ‘cress’

(11b) Epenthesis

beorc ~ berec - ‘birch’

bebr ~ beber - ‘beaver’

Minkova (2014) argues that such historical variability results from the perceptual characteristics of /r/ which are rooted in the differences in sonority of /r/ and any adjacent sounds. She argues that /r/ is a segment with a transitional character in that /r/ clusters “mimic(s) the transition from an obstruent to a vowel” (p. 121). For example, she claims that [C/r/]-sequences are easily confusable with [CV/r/]-sequences, leading to epenthesis. She thus sees the perceptual properties of /r/ as the primary trigger of phonological processes around /r/, implying that /r/ may carry an inherent inclination to be subject to change including coda-vocalization.

Evidence of early reflexes of historical r-loss appear around 1300 where, as Lass (1997) argues, the emergence of forms such as *ass* (‘arse’), and *bass* (‘barse’), which show complete /r/ deletion, can be seen as indicative of the loss of coda-/r/ (Lass, 1997, p. 284). Occasional instances of early loss of postvocalic /r/ are also implied by the orthographic variability of words like *parcel* which is attested in two orthographical variants between *passel* and *parcel* (Lass, 1997, p. 285).

According to Lass (1997), early /r/-loss seems to have been confined to /r/ after stressed vowels; coronals after /r/ strongly enhanced the likelihood of /r/-loss. Lass moreover argues that such early instances of /r/-loss did not trigger the lengthening of the pre-rhotic vowel as was the case throughout much of the historical development of /r/, and points out that this may indicate that early /r/-loss was a sporadic lexical change rather than a systematic sound change.[11] He furthermore argues that this first sporadic /r/-loss was followed by a second, qualitatively different and more far-reaching wave of /r/-loss which slowly began in the 17th century and spread more quickly towards the end of the 18th century, which Lass considers "a point where we can begin to talk seriously about /r/-loss" (Lass, 1997, p. 287). The second wave also affected unstressed vowels and was not sensitive to the type of the following consonant. Furthermore, in contrast to the first /r/-loss which Lass calls a "trial run" (p. 284), the second /r/-loss induced lengthening of the pre-rhotic vowel. Crucially, Lass assumes the first and the second wave to be independent processes as the first wave lacked the systematicity of the second wave. Based on these observations, Lass (1997) offers a diachronic timeline which illustrates the historical loss of English /r/ and the development of modern non-rhoticity. His account rests on a clear separation of early /r/-loss, where /r/-loss was independent of other coinciding processes such as vowel lengthening, and late /r/-loss which involved vowel lengthening, as two distinct processes. The individual instances of change in Lass' (1997) account are listed in (13) and visualized in Figure 2.5 which illustrates the timeline of changes to English rhotics.

(12) Instances of historical loss of /r/ in English (from Lass, 1997, p. 287).

(12a) Precursor: Sporadic Loss, no lengthening c. 1300-1715.

(12b) Variable lengthening from c. 1680.

(12c) Weakening of /r/: c. 1640 onward.

(12d) Sporadic Loss + Stable Lengthening 1740-90.

(12e) Loss: after 1790, but still unstable or with traces c. 1874.

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[11] Naturally, the extent and structural properties of historical /r/-loss cannot be reconstructed extensively due to a lack of consistent and sufficiently reliable data. In any case, it can be assumed that the loss of /r/ was not a widespread phenomenon – see Lass, 1997, p. 284-289 for a discussion.

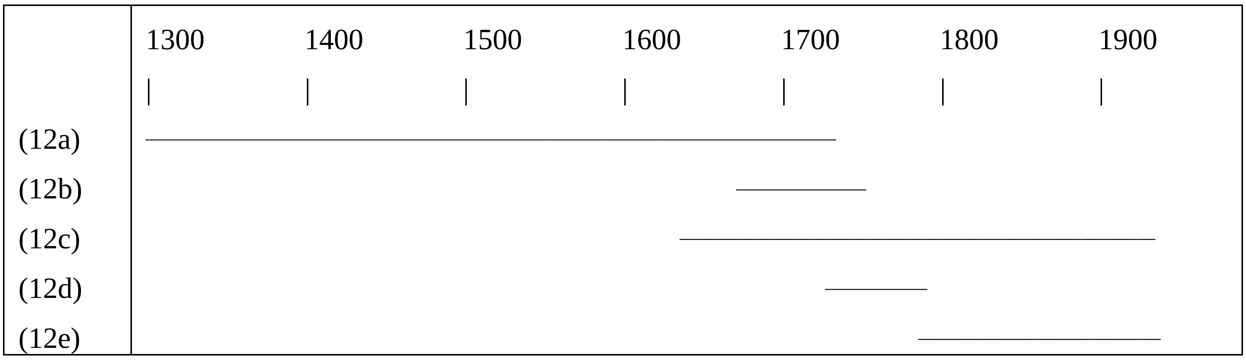

Figure 2.5: Timeline of changes to postvocalic /r/. Labels a) - e) on the left indicate the references of each bar to the change listed in (12) (from Lass, 1997, p. 287).

Figure 2.5 and (12) show that in this view, instances of historical /r/-loss are not incarnations of a single and ongoing phenomenon, but "actually the second [instance of /r/-loss] in the history of English" (Lass, 1997, p. 284) which he claims was qualitatively different as it seemed to have affected primarily long vowels. Lass sees the beginning of the late 17th century as the onset of "*another* development, this time the loss of final /r/ in unstressed syllables" (1997, p. 285, emphasis added). This /r/-loss was described, for instance, by phoneticians such as Ben Jonson, who remarks in his *English grammar* in 1640 that /r/ "sounded firme in the beginning of words, and more liquid in the middle, and ends" (p. 40). Similar reports come from Tucker (1773) and Walker (1791), who describe the weakening of /r/ in syllable-final position as well as the lengthening of the vowel preceding a weakened /r/.

That the historical instances of /r/-loss are unrelated as Lass (1997) suggests by splitting the development into individual processes is not universally accepted. Minkova (2014), for example, extensively criticizes several of Lass' suggestions and proposes that what Lass calls "successive stages" are indeed stages of the same process. For instance, while Lass considers the sporadic loss of /r/ in the 14th century the earliest precursor of modern non-rhoticity, Minkova places the roots of /r/-loss in OE. *Pace* Lass (1997), who sees the lack of systematic vowel lengthening in these earliest instances of /r/-loss as evidence of a different process, Minkova (2014) argues that "[i]t is likely […] that the earlier and the later cases of /-rC/ simplification represent a single historical process stretching over more than six centuries and affecting different dialects and different lexical items unevenly" (p. 124).

In particular, Minkova (2014) argues that the lack of vowel lengthening in 14th century /r/-loss provides only weak counterevidence because /r/-loss and lengthening of the pre-rhotic vowel are not in an absolute implicational relationship; instead, they merely coincide in subsequent episodes of /r/-loss. Moreover, she claims that lengthening was not absent in earlier /r/-loss. Here, Minkova (2014, p. 124) claims that diagraphs in historical spellings such as ME *board*, corresponding to OE *bord*, provide evidence of vowel lengthening as <oa> arguably indicates a lengthened vowel in comparison OE <o>. Similarly, she suggests that modern instances of loss do not always trigger lengthening as shown by words such as *gal* (from *girl*) or *cuss* (from *curse*), where the vowel remains short despite the loss of /r/. Minkova argues that such asymmetries show that early /r/-loss marks the beginning of a historical continuum which extends to the present and includes synchronic variability in the realization of coda-/r/. This variability is not just characterized by the absence and presence of /r/ in codas but by a variety of /r/-related phenomena such as "the occurrence of hyper-rhoticity, as in *warsh* for *wash*, *larst* for *last*, incipient derhoticisation in essentially rhotic varieties of English, and reversal to rhoticity in previously categorically non-rhotic accents" (Minkova, 2014, p. 124) which "[…] are clearly points on one historical continuum" (Minkova, 2014, p. 124).

More recent changes to coda-/r/ in American English provide further evidence for a continuum of change from rhoticity to non-rhoticity and vice versa. Although most varieties of American English preserved historical rhoticity, non-rhoticity occurs in American English as well (e.g., Labov, 2006). Importantly, non-rhoticity in American English is not an independent innovation, but a consequence of extensive contact with British varieties where rhoticity exhibited a high degree of variability. Subsequently, non-rhoticity spread along the East Coast, as well as some areas in the South of the U.S. until the mid-20th century when rhoticity became the prestige variant. Some of the formerly non-rhotic areas have become fully rhotic since (e.g., most areas in the South), others remained variably rhotic (e.g., Boston, New York City). However, categorically non-rhotic speakers have virtually vanished even in the more robustly non-rhotic areas such as New York City, where rhoticity exhibits gradience along the rhotic–non–rhotic continuum and is subject to considerable variability governed by grammar-internal and -external variables (e.g., Becker, 2014; Nagy & Irwin, 2010; Feagin, 1990, among others).

The historical loss of /r/ in English thus can be understood as an ongoing, cyclic sound change. As will be shown in the next chapter, structural properties observed in historical changes to rhoticity such as restrictions on the context in which /r/ can also be dropped emerge in synchronic varieties. The similarity of the structural variables that drive past change and present variability shows that rhoticity in American English exhibits the same underlying predisposition to change also observed in other varieties of English.

2.3.3 Synchronic variability of English postvocalic /r/

Sociolinguistic research has devoted considerable attention to the social functions of postvocalic /r/ and its variability in the United States. Much of the modern dialectal variation in the presence and absence of postvocalic /r/ is confined to the dialects along the East Coast of the United States, especially the varieties in New England such as New York City and Boston, as well as in some regions in the South (e.g., Becker, 2014; Nagy & Irwin, 2010; Feagin, 1990). As described in the previous section, American English non-rhoticity derives from close ties and regular contact with British speakers, especially those from the southeast of England (e.g., Piercy, 2012). Thus, non-rhoticity was a historical prestige variant for speakers of American English who orientated towards the British norm. The prestige of non-rhoticity speech declined and rhoticity emerged as the American English prestige norm, and within the 20th century, much of the historical non-rhoticity had subsided even in areas where non-rhoticity was considered a robust local variant (e.g., New York City, see Labov, 2006). The slow shift from non-rhotic to rhotic speech resulted in a continuum where speakers are neither categorically non-rhotic nor rhotic; instead, rhoticity is subject to considerable variation governed by social factors. In this way, individual speakers produce intermediate degrees of rhoticity along a gradient continuum. Although categorical non-rhoticity was prevalent in speakers from non-rhotic areas at the beginning of the 20th century, recent studies (e.g., Becker, 2014) show that categorical non-rhoticity has become rare (if found at all) in younger speakers. In contrast, it is common to find categorically rhotic speakers in formerly non-rhotic areas. Becker (2014), for example, did not find categorically non-rhotic speakers in New York City but found that seven of 65 speakers produced rhoticity categorically, and the least rhotic speaker in her sample produced 19% rhoticity. The gradient patterns of rhoticity are subject to variables which affect the rate of rhoticity and modulate the magnitude of change to a structure. Previous research shows on the one hand a robust effect of social variables on the presence of postvocalic /r/, and on the other hand a robust effect of structural characteristics and phonological environment on the likelihood of the presence of a consonantal realization of postvocalic /r/.

Regarding external factors, social class, ethnic identification, stylistic variation such as formality, and speaker age are robust predictors of rhoticity within a speech community and the individual speaker (e.g., Becker, 2014; Nagy & Irwin, 2010; among others). In American English, non-rhoticity is commonly associated with a low socioeconomic status, informal speech styles, and higher speaker age. Ethnic affiliation also plays an independent role as speakers of African American English (henceforth 'AAE') often produce lower degrees of rhoticity as compared to their European American counterparts (e.g., in New York City, see Labov, 2006). This is a pattern caused by non-rhoticity in AAE. While the variables listed so far straightforwardly relate to grammar-external factors, other variables match the internal-external divide less clearly; speech rate, for instance, affects rhoticity across different speech styles (e.g., on the formal-informal-continuum) but is arguably neither an external variable nor an internal one. For instance, a highly formal speech style such as a list-reading style unequivocally triggers high degrees of rhoticity, whereas conversational speech styles lead to increased reductions and frequently to less rhoticity.[12]

Regarding structural properties, previous research shows that several grammar-internal variables can be found to condition the presence and absence of postvocalic /r/ which are listed in (13).

(13) Relevant internal variables for rhoticity in American English.

(13a) Stress, including emphatic stress,
(13b) Quality of the pre-rhotic vowel,
(13c) Morpho-phonological environment,
(13d) Word class (functional or lexical).

The effects of the variables listed in (13) are robust across a multitude of studies, although the strength and direction of the effects seems to vary across studies and some dialects (e.g., Nagy & Irwin, 2010) show sensitivity to additional variables, e.g., the presence of multiple /r/ leading to dissimilation, although such effects seem confined to a small number of regional varieties. Among the robust variables affecting English rhoticity, stress has been shown to have a preserving effect on rhoticity (Feagin, 1990; Becker, 2014; Nagy & Irwin, 2010) as expected through observations of the phonetic properties of stressed syllables such as their higher perceptual salience and the resulting resistance to reduction. In contrast, unstressed syllables disfavor consonantal realizations of /r/, which is further enhanced by the presence of weak rhotic types (e.g., approximants) in a language. Again, this is in line with the phonetic

[12] Note that most often, style is included as a sociolinguistic/external variable.

properties of unstressed syllables, which are less perceptually salient and favor reduction processes (Beckman, 1998).

The quality of the pre-rhotic vowel and the morpho-phonological environment following postvocalic /r/ can be divided into more fine-grained subcategories. A summary of the subcategories of both variables as implemented in various previous studies are provided in Table 2.4 and Table 2.5, and will be discussed in detail in the following two subchapters, Chapter 2.3.3.1 and Chapter 2.3.3.2.

Table 2.4: Types of pre-rhotic vowels frequently used as sublevels for the variable ' pre-rhotic vowel' across various studies.

Vowel	**Representative word**
ɝ	NURSE
ɪ	NEAR
ɛ	SQUARE
ɑ	START
ɔ	NORTH
ə	SCHWA

Table 2.5: Types of morpho-phonological environment frequently used as sublevels of the variable 'morpho-phonological context' across various studies.

Syllable structure	**Description**	**Example**
Vr#V	Word-final, next word starts with V (linking-/r/ context)	*beer in*
Vr##	Word-final, before a pause	*...beer.*
Vr#C	Word-final, next word starts with C	*beer to*
Vr|.C	Morpheme-final, following C in the next syllable	*beerless*
Vr|C.	Morpheme-final, following C in the same syllable	*beers*
VrC.	Morpheme-internal, following C in the same syllable	*fierce*
Vr.C	Morpheme-internal following C in the next syllable	*bearded*

2.3.3.1 Synchronic variation due to vowel context

While the effect of stress is straightforward, the effect of differences in the quality of the pre-rhotic vowel is less clear. The vowel NURSE ([ɝ], also referred to as *stressed SCHWA* or *syllabic* SCHWA), for example, has been argued to have a preserving effect on rhoticity, more so than other vowels, and leads the acquisition of rhoticity in varieties changing from non-rhotic to rhotic (e.g., Feagin, 1990). Indeed, NURSE was excluded from the analyses in several sociolinguistic studies as this context was not expected to change significantly (e.g., Becker, 2014). Such an exclusion seems unjustified as studies that included NURSE have shown it to be variable across some speech communities, albeit here, too, NURSE is usually more resistant to /r/-loss than other stressed vowels (see Nagy & Irwin, 2010 for White and African American speakers in New Hampshire and Boston). In contrast, the frequencies of /r/-dropping following the remaining stressed vowels (START, NEAR, SQUARE, and NORTH in the study presented here, but also elsewhere) rank intermediately on the continuum between the low rate of /r/-dropping in NURSE contexts and high rate of /r/-dropping in SCHWA contexts.[13] The degree of /r/-dropping among the intermediate ranks is less predictable, although it has been argued that the deletion of postvocalic /r/ seems governed by some general phonetic factors. In a study on the re-emergence of postvocalic /r/ in speakers from Alabama, Feagin (1990) argues that back vowels lag behind front vowels in the re-emergence of rhoticity, suggesting that /r/ in front vowel contexts is favored whereas /r/ in back vowel contexts is disfavored. These results stand in opposition with Hall and Hamann's (2010) typological study on [rhotic + front vowel] sequences such as /ri/ and /ir/. Hall and Hamann demonstrate that these sequences are disfavored cross-linguistically, and the rhotic is prone to deletion. Considering these conflicting results, the constraints that regulate the fine-grained distributional differences across the different pre-rhotic vowels remain unclear. However, the hierarchies of [stressed vowel + rhotic] sequences from previous studies support Feagin's claim; NORTH, for instance, seems to disfavor rhoticity across a variety of English dialects while NEAR seems to favor rhoticity. The comparison of the hierarchies observed in a selection of previous studies can be found in Table 2.6.

[13] But cf. Nagy and Irwin (2010) study on rhoticity in New England, who found that NURSE did not exhibit the lowest frequency of /r/-dropping in the white New Hampshire speakers. Here, NURSE ranked third, following NEAR and SQUARE, which had the lowest rate of /r/-dropping.

Table 2.6: Vowel hierarchies for rhoticity across varieties of American English.[14]

Area	Hierarchy of rhoticity by pre-rhotic vowel (from most rhotic to least rhotic)	Direction of change
New York City (Becker, 2014*)	NURSE – NEAR – START – SQUARE – NORTH	Non-rhotic ↓ rhotic
New England (Nagy & Irwin, 2010)	NURSE –START – SQUARE – NEAR – NORTH - SCHWA	
Anniston, AL (Feagin, 1990)	NURSE – NEAR– SQUARE – START – NORTH - SCHWA	
Dorset[15] (Piercy, 2012)	NURSE – NEAR— START – SCHWA – SQUARE - NORTH	Rhotic ↓ non-rhotic

The phonetic and phonological causes of the hierarchical distribution across different vowel contexts and the causes of deviant behaviors in some speech communities are unknown. However, dialect-specific differences regarding the hierarchy of the pre-rhotic vowel may fall out from dialectal differences regarding the exact phonetic realization of pre-rhotic vowels, but also more generally from the interference of social variables and language contact. Nagy and Irwin (2010), for instance, demonstrate that the intrusion of other dialects in a speech community could also alter the social meanings of selected realization variants and lead to unusual patterns in the distribution of postvocalic /r/.

The enormous variability due to different pre-rhotic vowels leads Feagin (1990)[16] to suggest the adaptation of a coarse classification into three categories that are regulated by

[14] Due to differences in coding for the pre-rhotic vowel category, the list shows a selection of studies with comparable coding schemes only. Even some differences are important to keep in mind: Firstly, some of the studies mentioned above do not distinguish SCHWA and NURSE as different types of vowels; in these studies, the NURSE category also contains SCHWA-tokens. If this is the case, using the variable STRESS is used as an additional characteristic to distinguish the two. Studies using this scheme are marked by an asterisk.

[15] Dorset English (listed in Table 2.6 and Table 2.8) is currently *losing* rhoticity whereas the remaining varieties listed are *gaining* rhoticity.

[16] Despite this, Feagin (1990) hypothesized that front vowels lead back vowels in the movement towards full rhoticity. This assumption could not be confirmed, indicating that there is no universally fixed hierarchy between front and back vowel rhoticity. Indeed, this may be a factor leading to greater variation in this group as compared to other groups of vowel constraints. Similar behavior is attested in Coetzee (2008), who found that t/d-deletion is strongly influenced by grammatical factors. However, the ranking of the grammatical constraints regulating deletion may differ across dialects. What stands out here is that Coetzee found two patterns, Pre-C > Pre-Pause > Pre-V and Pre-C > Pre-V > Pre-Pause. He remarks that Pre-C deletion seems to

overarching constraints. This constraint set may include a constraint responsible for the low frequency of /r/-dropping with NURSE, a constraint to regulate /r/-dropping following stressed vowels except for NURSE, and a constraint which requires the high frequency of /r-/deletion with SCHWA. Feagin's classification yields the hierarchy in (14).

(14) Simplified constraint hierarchy of /r/-dropping across pre-rhotic vowels from least (left) to most /r/-dropping (right) (from Feagin, 1990):

NURSE >> [START, SQUARE, NEAR, NORTH] >> SCHWA

2.3.3.2 Synchronic variation due to morpho-phonological context

Across morpho-phonological contexts, too, robust hierarchies emerge in the frequency of /r/-dropping across different contexts. Indeed, Harris (1994) goes as far considering morpho-phonological context a central variable in the categorization of rhotic and non-rhotic varieties. In particular, he illustrates three basic patterns for rhoticity found in English dialects, shown in Table 2.7, where (+) indicates the presence of consonantal /r/.

Table 2.7: Phonological environments for /r/ deletion (from Harris, 1994, p. 359).

	Structure	**Examples**	**R1**	**R2**	**R3**
a)	[rv´	red, rack, rude	+	+	+
(b)	[rv	ravine, revolt, resort	+	+	+
(c)	Cr	tray, agree, petrol	+	+	+
(d)	Vrv´	Corinne, terrain, carouse	+	+	+
(e)	rv	very, parent, sheriff	+	+	-
(f)	r]v	bear a, before a, poor again	+	+	-
(g)	r]v´	bear up, before eight, poor Eva	+	+	-
(h)	rC	board, cart, source	+	-	-
(i)	r]C	bear to, before nine, poor man	+	-	-
(j)	r‖	bear, before, poor	+	-	-

be universally favored whereas Pre-V and Pre-Pause deletion may be sub-regulated by additional influences, such as social factors regulating the weights of these constraints.

Rhotic dialects of American English represent category R1, non-rhotic dialects of American English fall into category R2 in Harris' classification.[17] However, Harris refrains from further subcategorization of particularly context (h), although this is of particular interest for diachronic changes from rhoticity to non-rhoticity and vice versa, as well as synchronic variation found in systems that fall in between R1 and R2.[18] Category (h) in Harris' scale is frequently separated into six subcategories provided in Table 2.8.

Table 2.8: Hierarchies of rhoticity across morpho-phonological contexts in varieties of American English.

Area	**Hierarchy of rhoticity – Syllable context**	**Direction of change**
New York City (Becker, 2014)	Vr#V – Vr## = VrC – Vr|C. – Vr#C – Vr|.C	Non-rhotic ↓ rhotic
Boston (Nagy & Irwin, 2010)	Vr#V – Vr## – VrC – Vr|C – Vr#C – Vr|.C	
New Hampshire (Nagy & Irwin, 2010)	Vr#V – Vr## – VrC – Vr|C – Vr#C – Vr|.C	
Dorset Piercy (2012)	Vr#V – Vr## – Vr|C – VrC – Vr#C – Vr|.C	Rhotic ↓ non-rhotic

The results of the different studies summarized in Table 2.8 show that Harris' categorization in Table 2.7, particularly (h), may be an overly general categorization with respect to the position of the syllable boundary in [rC]-clusters, which seems to be subject to fine-grained sociolinguistic differences. Again, as with vowel contexts, variability in the frequency of /r/-

[17] Category R3 is represented by some dialects of American English and AAE in the South, where /r/ in words such as *very* are also subject to /r/-loss.

[18] Harris (1994) implies a hierarchy for the order of contexts. However, most sociolinguistic studies use a more fine-grained differentiation of morpho-phonological context (as shown in Table 2.8), which renders Harris' categorization unsuitable for the following illustration of sociolinguistic observations of rhoticity. Typically, statistical data of pairwise comparisons for various syllable contexts is not included in the studies reported here. As such, these studies may overemphasize such fine-grained differentiation. Regardless of whether the distinction of subcategories is phonologically meaningful as an independent variable, or merely a result of socially conditioned variation, the adoption of the fine-grained differentiation shown in Table 2.8 provides an important point of comparison of the present study with previous studies, which is why the more fine-grained coding was adopted here.

dropping within and across speech communities differs among the various subtypes of morpho-phonological environments. For example, pauses seem to have a preserving effect on rhoticity (e.g., Becker, 2014, Nagy & Irwin, 2010) and frequently show the lowest rate of /r/-dropping among the morpho-phonological subtypes. The remaining morpho-phonological contexts are more variable, although some generalizations emerge here as well. For instance, morpheme-final /r/ followed by a consonant-initial syllable in the same word (i.e., [Vr|.C‘], e.g., *fearful*) seems to disfavor rhoticity. Likewise, word-final /r/ (if a consonant follows in the next word) seems to favor non-rhoticity. An implicational hierarchy for morpho-phonological contexts like the one for vowels shown earlier in (14) is shown in (15).

(15) Simplified constraint hierarchy for syllable context (based on previous studies):

Vr#V – Vr## – VrC – Vr|C – Vr#C – Vr|.C

As shown so far, the hierarchies across vowels and morpho-phonological contexts are well-attested across varieties of English, although some differences emerge mainly in vowel contexts, where stressed vowels (except NURSE) show stronger internal variation while NURSE and SCHWA are relatively reliable in their status as most and least favorable for /r/. Nevertheless, the general pattern implies that underlying laws are at work, a mostly unexplored assumption. Since sociolinguistic research investigated variable rhoticity in English primarily as an epiphenomenon of social variables and their interaction with structural variables, the role of universal trajectories and internal constraints for changes to English rhoticity remains mostly unexplored. Previous research, e.g., Himmel and Kabak (in preparation) suggests that the patterns of variability illustrated above are symptoms of underlying MARKEDNESS constraints which favor rhoticity in some contexts and disfavor it in others, while the impact of social forces can adjust the weights of these constraints to alter their order temporarily. Whether the hierarchies result from phonetically or phonologically conditioned constraints which are subject to minor adjustments by social variables, or whether the constraint hierarchies are modulated entirely and permanently by social factors to yield grammars which emerge epiphenomenally as markers of social variables needs further work.

2.3.4 Relationships between phonological change and phonetic variation in /r/

While categorical changes to rhoticity are well-attested in English, phonetically gradient changes have been less well-researched. Nevertheless, some studies suggest that /r/ is subject to phonetically gradient changes as well.

In particular, phonetic changes in /r/ can be parasitic on phonological processes of lenition commonly observed in diachronic and synchronic variation. Bermúdez-Otero (2011) argues that /r/ undergoes a cycle of lenition which initially emerges at the phrase level and subsequently progresses to the word level. He furthermore suggests that this cycle can also be observed in articulatory and phonetic changes of /r/ and argues that as compared to word-initial /r/, a lenited variant of word-final prevocalic /r/ displays the features shown in (16).

(16) Phonetic specifications of lenited /r/ (from Bermúdez-Otero, 2011, p. 18).

(16a) shorter duration,
(16b) earlier timing of the tongue-root gesture,
(16c) smaller magnitude of the lip gesture,
(16d) smaller magnitude of the tongue-tip gesture,
(16e) greater magnitude of the tongue-root gesture,
(16f) greater intensity, and
(16g) higher F3.

The points in (16), especially (16g), find support in the study by Hay and Maclagan (2010). Here, Hay and Maclagan show that intrusive /r/ (i.e., the pronunciation of an /r/ where it is not etymologically present as in sequences like *law(r) and order*) in New Zealand English is subject to phonetically gradient variation modulated by the frequency of intrusive /r/ produced by a speaker in addition to a variety of linguistic and external factors. Here, Hay and Maclagan showed that the overall rate at which a speaker used intrusive /r/ was a strong predictor of the height of F3 in the instances of intrusive /r/ a speaker produced: Speakers who inserted intrusive /r/ more frequently produced their intrusive /r/ with a lower minimum F3, i.e., with a stronger degree of constriction, than speakers who used intrusive /r/ less frequently. In other words, speakers who produce intrusive /r/ more frequently produce those /r/ more ‘/r/-like’. As such, their results suggest that the phonological process, i.e., the frequency at which a constraint for insertion of intrusive /r/ applies is closely related to the phonetic properties of /r/ in the context the constraint regulates. Hay and Maclagan provide evidence supporting the view that phonetic and phonological change to postvocalic /r/ are related, interacting processes. More precisely, the impact of general phonological constraints which apply to postvocalic /r/ may extend beyond their regulatory function: They are not only responsible for determining the presence and absence of /r/ in postvocalic position, but also feed categorical information into the phonetic system where it is translated into gradient variability. The phonetic system, on the other hand, may be directly linked to the phonological system in which phonetically gradient change makes adjustments to constraint weights to introduce and enhance phonological variability responsible for the categorical presence and absence of postvocalic /r/: such adjustments may also cause permanent changes to the constraint hierarchy.

To sum up, English rhoticity has been shown time and again to be subject to a variety of structural constraints which emerge in language change, language variation, phonetics, and phonology. Although rhoticity in English is well-researched from a sociolinguistic perspective, our understanding of the trajectories of the changes to postvocalic /r/ in English is limited: Crucially, we lack insights from the behavior of rhoticity in populations beyond monolinguals, a gap that will be addressed from an L1 attrition perspective in the study I present below. In particular, I will pick up on the typological, historical and sociolinguistic observations outlined above and show that these generalizations re-emerge in bilinguals – crucially, the bilinguals in the present study are native speakers of American English and therefore have access to a native grammar which arguably contains the very same underlying constraints but is subject to enhanced patterns of change. Before turning to the implications of the properties observed for rhotics reviewed above for language change across the lifespan and particularly the case of L1 attrition, English laterals are reviewed in the following section.

2.4 Laterals in English

The following section focuses on English laterals and will demonstrate that laterals, although similar to rhotics in their phonetic and phonological properties and behavior, are historically more resistant to change than rhotics. The chapter will briefly address the causes for the resistance to changes observed in laterals and how these are also reflected in their synchronic and sociolinguistic properties before turning to a summarizing discussion of the implications of the phonetic and phonological aspects of liquids for their behavior in bilingual populations.

2.4.1 Phonetics and phonology

2.4.1.1 Categorical and gradient behavior in American English laterals

The English lateral approximant has two allophonic variants, a clear allophone [l] and a dark allophone [ɫ], two common variants from a cross-linguistic perspective as mentioned in Chapter 2.2.2. Acoustically, English laterals show a formant structure characteristic of approximants, and indeed one that is highly similar to that of English /r/ (Espy-Wilson & Boyce, 2001). That means that F1 is typically low and comparable to F1 in high vowels. F1 is furthermore subject to minor phonetic gradience between the two allophones, where it is slightly lower in clear /l/ as compared to dark /l/. Despite this variability, F1 contributes little to acoustic differences between clear and dark /l/. In contrast to F1, F2 is the primary acoustic correlate of the different acoustic quality of laterals as it expresses velarization (Recasens, 2004). This means that higher F2 values correlate with laterals on the clear side of the spectrum, and lower F2 values correlate with laterals on the dark side of the spectrum (Recasens, 2004; Yip, 2011). Finally, F3 characteristically rises at the onset of a lateral and levels out at a comparatively high frequency (e.g., compared to neutral F3 values in vowels) in both lateral allophones.

Thus, the position of a lateral on the clear-dark continuum is determined by its F1-F2 profile. Cross-linguistic evidence furthermore shows that the F1-F2 profile also determines the quality of the vowel allophone in /l/-vocalization: Clear laterals are phonetically closer to high front vowels and are thus vocalized to high front vowels; dark laterals correspond to high back vowels and are vocalized to high back vowels. The vowel-correspondences are reflected cross-linguistically in synchronic and diachronic cases of /l/-vocalization as seen in the examples in (17), which show vocalization of clear laterals to high front vowels in Austro-Bavarian dialects of German and in Italian.

(17) /l/-vocalization to high front vowels in Munich German and in Italian (Howell, 1991, p. 73).

(17a) Munich German: alC > oiC: falsch > foisch, halb > hoib

(17b) Italian: Cl > Ci: plenu > pieno, clave > chiave

The same pattern is observed in many Germanic languages and dialects as the ones in (18): in various German dialects such as Westphalian in (18a) or in Dutch in (18b).

(18) /l/-vocalization to high back vowels in Germanic languages.

(18a) Westphalian: ald > auld: kault ‘kalt’, hauln ‘halten‘ (Howell, 1991, p. 73)

(18b) Dutch: al > ou: ald > oud (Yip, 2011, p. 740)

The correlation between velarization and quality of the vowel allophone also depends on the presence of lateral allophony by way of the acoustical differences among lateral allophones. In English, /l/-vocalization typically results in high back vowels which relates to the historical and synchronic lateral allophony in English, where [l] is restricted to onsets and [ɫ] to codas. The assumption that a binary distinction can sufficiently account for the allophonic behavior of English /l/ has been repeatedly criticized. A wealth of studies found evidence of gradience in laterals not just across many varieties of English but also cross-linguistically (e.g., various Catalan dialects in Recasens and Espinosa 2005; Catalan and German in Recasens, Fontdevila, and Dolors Pallarès 1995; English, Italian and Catalan in Recasens, Farnetani, Fontdevila, and Pallarès 1993; various English dialects in Turton 2017). These studies show that there is no boundary between clear and dark laterals observed cross-linguistically, and neither can such a distinction be found in English laterals. Instead, gradient phonetic properties of laterals emerge cross-linguistically and across dialects of English. It is this type of phonetic gradience that leads to intrinsic allophony as described in Chapter 2.2.2 where the phonetic environment of /l/ partially determines its phonetic realization. More importantly, the phonetically gradient behavior of English laterals also raises questions regarding the differences between intrinsic and extrinsic allophony. In particular, without a clear boundary between clear /l/ and dark /l/, determining the presence of extrinsic allophony is difficult; even more so if, as in English, extrinsic allophony is joined by intrinsic allophony whereby the phonetic environment makes a significant contribution to the acoustic realization of /l/.

Sproat and Fujimura (1993), for example, found in their microbeam study that the phonetic properties of /l/ vary not only due to the position of the lateral but are also partially determined by the morphological structure and the strength of the morphological boundary before or after /l/. Here, they showed fine-grained distinctions between the different environments which coincide with a gradient phonetic spectrum spanning from extreme clarity to extreme darkness in laterals. In this way, Sproat and Fujimura’s results do not provide evidence of a bimodal distribution of English lateral allophones which suggests that the English clear-dark /l/-allophony must be understood as endpoints of a range of realization variants which exist on a non-categorizable, phonetically gradient continuum.

However, strong interpretations of a lateral continuum which suggest that lateral allophony in English cannot be understood as position-dependent categories but as a multitude of individual points along a single acoustic continuum have not been widely accepted. To illustrate one argument against such an acoustical continuum for laterals, Hayes (2000) proposes – *pace* Sproat and Fujimura (1993) – that American English /l/ is represented by "two phonetic categories that are partially obscured by free variation and near-neutralizing lenition" (p. 93). In this view, the extensive phonetic variability of /l/ is a symptom of the cumulative variability introduced by various other assimilatory and coarticulatory processes rather than a genuinely gradient phonetic continuum.

Hayes' (2000) study of gradience in /l/-allophony provides support for the argument above. In his experiment, the two allophonic variants of /l/ which were embedded in different allophonic contexts subcategorized into a variety of fine-grained structural contexts (e.g., different types of morpheme boundaries), each word was produced twice by a trained speaker, once with clear /l/ and once with dark /l/. This procedure resulted in word pairs with one licit and one illicit member such as the pairs *light* - [laɪt] and [ɫaɪt] for onset laterals and *feel* - [fiəɫ] and [fiəl] for coda laterals (Hayes, 2000, pp. 94-95).

In an acceptability judgment task, native speakers of American English were asked to rate the well-formedness of each member from each token pair. The results showed that, as expected, dark /l/ in word-initial position and clear /l/ in word-final position were universally unacceptable to the raters (Hayes, 2000). In the other positional contexts, the ratings showed that the acceptability of the word pair members was gradient, not categorical, in that both word pair members were at least marginally acceptable. Nevertheless, the raters judged one of the word pair members to be more well-formed in most cases across all structural conditions. This result indicates the presence of a categorical preference of one of the two variants across the structural contexts despite their acceptance of some degree of gradience regarding the acceptability of illicit positional allophonic variants. This result raises the question whether the phonetic gradience in laterals also observed by Sproat and Fujimura (1993) may indeed be an artifact of other phonetic processes; for instance, lateral allophones may fall out from the variable assimilation of laterals to surrounding vowels. Hayes (2000) can be interpreted as evidence for the binary allophonic behavior of English /l/ despite considerable phonetic variation.

In her ultrasound study, Turton (2017) investigated the production of /l/-allophony across five positional contexts in five English dialects. In particular, she shows that English dialects[19] differ in their production pattern of /l/-allophony: While some dialects show a clear split of the clear/dark-/l/-continuum into two comparatively categorical variants (i.e., clear and dark), other dialects lack such a split and instead feature a phonetically gradient continuum. The presence of such continua may indicate that at least in these dialects, extrinsic allophony is to some degree parasitic on intrinsic allophony and falls out from a purely phonetic process rather than a phonological one. Finally, some dialects featured a mixed system with a weak categorization of a phonetically gradient continuum. Turton (2017) claims that neither a purely phonetic nor a purely phonological explanation can account for the variability in English /l/-allophony in which phonetic properties and phonological constraints interact. Instead, she argues that English /l/-allophony emerges via phonological change where each stage yields an allophonic system that differs from others in the phonetic and phonological processes that affect /l/ across positional contexts. Turton's successive stages of change based on work by Bermúdez-Otero's (2007) cyclic approach to phonological change are shown in Table 2.9.

Table 2.9: Category distributions of clear /l/ and dark /l/ in selected varieties of English (from Turton, 2017, p. 8).

Variety	***'leap'***	***'helix'***	***'peeling'***	***'heal it'***	***'peel'***	***Source***
RP	[l]	[l]	[l]	[l]	[ɫ]	Cruttenden (2013)
Am. Eng. 1	[l]	[l]	[l]	[ɫ]	[ɫ]	Sproat and Fujimura (1993)
Am. Eng. 2	[l]	[l]	[ɫ]	[ɫ]	[ɫ]	Olive, Greenwood, and Coleman (1993)
Am. Eng. 3	[l]	[ɫ]	[ɫ]	[ɫ]	[ɫ]	Hayes (2000)

As indicated by the separation of American English into three different dialectal patterns visible in Table 2.9, Turton (2017) claims that the variability of American English /l/-

[19] Although Turton uses the term *dialect*, it is worth mentioning that each dialect is represented by a single speaker in her experimental data.

allophony arises from different coexisting phonological grammars rather than from a variability pattern that emerges from the same grammar. Such fine-grained differences are arguably less helpful when dealing with straightforward cases such as word-initial /l/ in simple onsets and word-final coda /l/ in simple codas which mark the extremes of clarity and darkness but are nevertheless subject to phonetic gradience in phonological change.

2.4.1.2 Coarticulatory resistance and weakness in laterals

As briefly addressed in Chapter 2.2.2, Recasens (2004, 2012) showed that cross-linguistically, clear and dark /l/ differ regarding their co-articulatory resistance to adjacent segments. This observation also holds true for English laterals. Bladon and Al-Bamerni (1976), for example, showed that the acoustic properties of British English laterals, mainly F2, are subject to a higher degree of phonetic variability and coarticulatory variation in clear /l/ as compared to dark /l/.

Recasens (2012) likewise shows that clear /l/ in American English is more sensitive to its phonetic environment, particularly to the front-back dimension of adjacent vowels. Dark /l/, on the other hand, is considerably more resistant to such co-articulatory variation induced by surrounding vowels and is therefore also acoustically less variable. Taking Turton’s (2017) argument into consideration, phonetic gradience and variability seem to emerge as precursors of impending phonetic change and potential phonologization. The robust cross-linguistic differences in the degree of phonetic variability of clear /l/ and dark /l/ give rise to the expectation that the two allophonic variants will show differences under language change, including L1 attrition in bilinguals. In particular, the evidence presented here strongly suggests that clear /l/ is more susceptible to change as it has been shown to change earlier and at a higher rate while dark /l/ is expected to be more resistant and if a change occurs, it should also progress more slowly. This can provide important insights into the question whether variability leading to language change will also lead to individual language change under L1 attrition.

2.4.1.3 American English /l/-allophony in phonological grammars

From a phonological perspective, the presence of allophonic variants finally also raises questions regarding the representation of allophones in a speaker’s phonological grammar. For American English laterals, the assumed underlying representation is the clear variant. To introduce allophony, then, clear /l/ must be subject to a set of constraints which require different degrees of /l/-darkening in codas. This view is not universally accepted; Recasens (2012), for example, argues that clear /l/ cannot be the underlying representation of American English /l/ as this would not produce the phonetic pattern he observed. In a cross-linguistic comparison of laterals in 23 languages, he found that American English patterns with languages in which the underlying representation is a dark variant of /l/. Recasens claims "that the dichotomy between a clear initial allophone and a dark final allophone is associated mostly with F2 lowering in final position in Czech, Dutch and Newcastle English (also in British English RP), and with an F2 frequency increase in initial position in American English" (Recasens, 2012, p. 378), and that "extrinsic allophones […] [are a case of] […] initial clearing in American English" (p. 381). Thus, he argues that /l/-allophony in American English results not from darkening in the coda but from clearing in the onset.

In his constraint-based analysis of lateral allophony, Hayes (2000) assumes that "[t]he loss or diminution of alveolar closure in dark [ɫ] seems fairly plainly a case of lenition" (p. 99), justifying his general constraint shown in (19) which regulates the velarization in /l/; thus, for American English, the constraint requiring laterals to be dark takes precedence over other (hypothetical) constraints that require laterals to be light.[20]

(19) /l/ is Dark[21]

To introduce positional variation between clear and dark /l/, Hayes claims that additional constraints are necessary. First, he suggests a constraint which restricts dark /l/ to postvocalic positions using the positional MARKEDNESS constraint shown in (20).

(20) Dark /l/ is Postvocalic

Hayes (2000) furthermore argues that American English /l/-allophony also results from initial clearing of /l/ which he introduces with the constraint shown in (21).

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[20] Although the constraint requiring laterals to be clear is not shown in Hayes (2000), assuming that such a general FAITHFULNESS constraint (e.g., IDENT(I-O)) that occupies a low rank seems reasonable.

[21] Despite Hayes (2000) claiming that he sees dark /l/ as a case of lenition, this constraint suggests that he concurs with Recasens (2012) in that American English /l/ is dark.

(21) Prevocalic /l/ is Light

With these constraints, categorical /l/-allophony can be modeled as shown in Tableau 1 which illustrates the relevant constraints, candidates, and the violations for /l/ in onsets as in *light* and /l/ as in *feel*.

Tableau 1: Clear /l/ - dark /l/-allophony in English (Hayes, 2000, p. 103)

Input		Dark /l/ is Postvocalic	Prevocalic /l/ is Light	/l/ is Dark
light	☞ [laɪt]			*
	[ɫaɪt]	*!	*	
help	[hɛlp]			*!
	☞ [hɛɫp]			

Importantly, changes to the constraint ranking also yield the positional effects observed in Turton (2017). The grammar in Tableau 1, for instance, can be modified to account for phonetic differences regarding /l/ in intervocalic position at a morpheme boundary in words such as *freely*. Here, when PREVOCALIC /l/ IS LIGHT outranks /l/ IS DARK as exempflified in Tableau 2, the grammar selects the candidate with a clear /l/ in *freely* as winning candidate. In comparison, when /l/ IS DARK outranks PREVOCALIC /l/ IS LIGHT, dark /l/ emerges in *freely* as shown in Tableau 3.

Tableau 2: PREVOCALIC /l/ IS LIGHT outranks /l/ IS DARK (from Hayes, 2000, p. 103).

Input		Dark /l/ is Postvocalic	Prevocalic /l/ is Light	/l/ is Dark
freely	☞ [fri:li]			*
	[fri:ɫi]		*!	

Tableau 3: PREVOCALIC /l/ IS LIGHT outranks /l/ IS DARK (from Hayes, 2000, p. 103).

		Dark /l/ is Postvocalic	/l/ is Dark	Prevocalic /l/ is Light
freely	[fri:li]		*!	
	☞ [fri:ɫi]			*

The constraint ranking suggested by Hayes (2000) demonstrates that English /l/-allophony, despite its phonetic variability in complex constructions, can be accounted for using a simple, binary constraint opposition.

2.4.2 Diachronic variability and change of English laterals

The phonetic and phonological characteristics of English laterals are also mirrored in their historical development, and their historical development is also reminiscent of that of rhotics (Minkova, 2014). However, /l/ appears diachronically comparatively more stable and, unlike /r/, has less variable historical roots as compared to rhotics, which partially emerged through rhotacism as mentioned in Chapter 2.3.2 (see also McMahon, 1994). Diachronic changes– particularly vocalization – also arguably affect laterals less severely than they do rhotics, and language change seems to progress more slowly in laterals than it does in rhotics. For instance, Minkova (2014, p. 132) remarks that the "complete pre-consonantal loss of more obstruent-like /l/ is less advanced historically" (p. 132) as compared to rhotics. Despite the quantitative differences of change affecting the two sounds, change and variability in English /l/ has the same quality as changes to rhotics, meaning that they follow similar trajectories under language change.

Diachronically, two related phonetic processes affected English laterals time and again across varieties of English, velarization and vocalization. Phonetically, the two are closely related: Velarization is assumed to be an intermediate stage of a more far-reaching lenition process followed by vocalization and finally complete deletion of /l/ (Hayes, 2000). It is difficult to evaluate the presence, onset, and progression of velarization from a historical perspective due to its gradient nature; cases of /l/-vocalization throughout the history of English provide indirect evidence of the pervasive nature of velarization in English.

Vocalization of /l/ in syllable codas occurred early in the history of English. Sporadic vocalization is attested in Old English, although the extent is unknown; it is possible that vocalization was limited to individual lexical items (Minkova, 2014). Here, Minkova (2014) argues that vocalization in Old English is also indicative of a velarized lateral segment in the phonemic inventory, as the result of /l/-vocalization provides important cues to the phonetic quality of /l/ in Old English. Recall from Chapter 2.4.1 that clear /l/ phonetically resembles high front vowels whereas dark /l/ corresponds to high back vowels. Historical /l/-vocalization in English consistently yielded high back vowels as substitutes, as can be seen in the modal auxiliaries *could*, *would* and *should*, just to name one example (Minkova, 2014, p. 130). The arguments above supply robust evidence that Old English /l/ was indeed velarized, at least in codas.

2.4.3 Synchronic variability in English laterals

Sociolinguistic variation and variability of laterals is much less extensively researched than for /r/, and phonetically gradient characteristics and phonological variability regarding /l/-velarization even less so than /l/-vocalization (Minkova, 2014). Nevertheless, a handful of studies indicate that whenever socially constrained variability of /l/ is observed, the social meanings seem less diverse and salient than those of /r/ and emerge primarily as markers of regional identity. Fine-grained social variability to mark group membership and identity within a speech community is much rarer and seems restricted to exceptional cases of local identity (e.g., as a marker of Irish descent in Newfoundland, see Clarke, 2012 below). Minkova (2014) emphasizes the differences regarding the variability between /r/ and /l/, which show that /l/ “has not become the definitive dialect marker that /r/-loss is considered to be” (p. 132). Regardless of the prevalence of socially significant variability in /l/, such cases can nevertheless provide instructive insights into the patterns of change in /l/ and enrich cross-linguistic observations from a sociolinguistic perspective.

One variety in which /l/ serves as an important social marker is Newfoundland English (henceforth ‘NflE’). In traditional NflE, /l/ is invariantly clear in both onsets and codas but, as Clarke (2012) shows, this has changed recently as younger speakers of NflE have been shown to favor dark /l/ in coda position. The frequency of dark /l/ is subject to social variation within the speech community. For instance, Clarke (2012) found that dark /l/ expresses information about a speaker’s age, socioeconomic background, and gender. She found that especially young speakers, females, and speakers with a high socioeconomic status produced dark /l/ more frequently, upper-class speakers almost categorically so. Nevertheless, Clarke’s results offer a fragmented picture of the status of /l/-allophony in NflE as she did not investigate whether /l/ in onsets was subject to change as well, or if and how darkness in onset and coda laterals interacted in some way. Thus, the effects of grammar-external variables on the allophonic distribution of /l/ rather than its phonetic specifications remain unexplored.

Like Clarke (2012), Mackenzie, de Decker, and Pierson (2015) investigated laterals in NflE. They found that dark /l/ had become the new standard variant in NflE. Unlike Clarke (2012), Mackenzie et al. (2015) also investigated /l/ in onsets and compared them to coda /l/

and found that onset /l/ as well as the allophonic distance between onset and coda /l/ seemed to carry more significant social information than coda /l/ did. In particular, Mackenzie et al. (2015) found that gender affected /l/-darkness asymmetrically across age. Male speakers produced onset and coda laterals with similar degrees of velarization, and young male speakers showed increased darkness in both positions. Female speakers, on the other hand, showed an increase of darkness only for onset laterals while their coda laterals remained mostly unchanged. Mackenzie et al. (2015) take this to indicate that the female speakers are moving towards a male norm in the production of allophonic distance. This result may also be taken to indicate that allophonic distance takes precedence over /l/-darkness in the expression of social meaning.

Sociolinguistic variability of /l/ is also attested in African American English. van Hofwegen (2010), for example, demonstrated that onset /l/ in North Carolina AAE speakers showed considerable darkening across generations and that younger speakers of AAE had shifted towards the local European American norm. Crucially, although social variables influenced changes to /l/, the extent was limited: although the laterals were darker for old male speakers than old female speakers, the gender difference was shown to decrease in younger age groups and had disappeared entirely for the youngest speakers in the sample. While this indicates that /l/ indeed carried relevant social information and was associated with gender, it only did so in interaction with age (van Hofwegen, 2010). Due to the limited effect, it may well be the case that the gender difference was merely a symptom of more general differences regarding gender also observed in other changes in progress.

Similarly, Durian (2008) found differences in the laterals produced by speakers of European American English (henceforth ‘EA’) and speakers of AAE in Columbus (Ohio). In his study, he showed that apart from ethnicity, other social variables (age and gender) did not affect the frequency of /l/-vocalization. Instead, variability was modulated primarily by structural constraints already known to influence /l/-vocalization. However, even this effect emerged mainly in the AAE speakers. Conversely, EA speakers were sensitive only to the height of the preceding vowel whereas other structural constraints did not significantly impact the quality of their laterals. In contrast, AAE speakers were sensitive to the influence of a broader range of structural factors such as the position of the lateral.

Considering that vocalization represents the most advanced stage in the phonological process leading up to the lenition of laterals (see also Selkirk, 1984), the sensitivity of /l/ to structural constraints found in van Hofwegen (2010), but also elsewhere, may also be taken to show that social variability in /l/ (like many other phonological processes) reflects universal patterns also observed in cross-linguistic comparisons. That is to say, clear /l/ is highly vulnerable to change induced by social variables and likely to undergo darkening in all positions. As expected via general observations in phonology, laterals in coda position are more likely to undergo darkening as compared to initial laterals. Furthermore, the study by Mackenzie et al. (2015) highlighted that the acoustic quality of laterals does not reflect the full extent of change and variability in laterals. Instead, taking the relationship of initial and final realization variants of /l/ (operationalized by the F1-F2-distance) into account offers valuable insights into language change and, as I will also show in my study below, offers a fruitful basis for the investigation of changes to laterals in late bilinguals.

2.5 Linking diachronic and synchronic variability to L1 attrition

In the review of the phonetic and phonological characteristics of liquids from typological, diachronic and synchronic perspectives in the chapter above, I highlighted the high frequency of change and the high degree of persistent and recurrent variability liquids are known to display across languages, and which also characterizes their own historical development. Nevertheless, the behavior of /r/ and /l/ in language change is predictable in that it follows similar pathways along a set of structural constraints which yields a fine-grained continuum of structural restrictions that keeps re-emerging across different social groups and speaker populations and across various times.

The variability of liquids offers an instructive case to investigate L1 attrition and can help shed light on universal processes that characterize L1 attrition on the one hand, and sound change more generally on the other. For instance, recall that I presented evidence for a relationship between L1 attrition and language variability and change in Chapter 1, and that I argued that L1 attrition is not merely a negative function of L2 acquisition shaped by L2 interference, an account for which I will also argue in more detail in Chapters 3 and 4. I will provide supporting evidence throughout this dissertation that L1 attrition instead mirrors language change in that the hierarchical order of change in L1 phonological attrition follows similar grammar-internal constraints which are also observed in monolinguals. The structural constraints known to induce gradience in /r/ and /l/ across positional, vocalic and morphophonological contexts will allow us to investigate whether the L2 triggers L1 attrition as well as what the principles that guide the progression of L1 attrition are.

Moreover, I also pointed out that /r/ and /l/ differ in numerous ways: /r/ seems to vary more readily than /l/ does, and also varies more extremely with regard to the magnitude and frequency of variability, but also the speed at which variability emerges. Finally, /r/ varies along an often more fine-grained continuum of structural contexts. As the study below aims to shed light on attrition of /r/ and /l/, these differences may also effect how extensively the L1 changes and how far change progresses; this is especially relevant if, as I argued above, L1 attrition can be likened to sound change and is therefore not expected to introduce new structural patterns but instead enhances variability in those phonological processes which are either already variable in a speaker's L1 or are at least highly likely to do so.

The next chapter will review existing approaches to L1 attrition in more detail and review the variables argued to play a role in L1 attrition.

Chapter 3

Variability in learners: Phonetic and phonological (un-)learning

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3.1 Changing systems in the bilingual mind: The effect of an L2 on the L1

The following chapter introduces L1 phonetic and phonological attrition to provide a theoretical background for the study presented below and discusses previous empirical findings as well as their theoretical implications. I will demonstrate that previous empirical studies provide only limited insights into the process of attrition and previous results cannot always be accounted for by existing theoretical models. In this sense, I argue that very little is known about L1 phonetic attrition in terms of the component or property of an L2 that triggers attrition, how attrition is enhanced or inhibited by various structural properties of a linguistic system and the specific combination of languages, and whether phonetic attrition is subject to structural constraint beyond those introduced by the L2. I argue that the field lacks appropriate theoretical frameworks which can account for the changes observed under L1 attrition in phonetics and phonology.

As L1 phonetic attrition and particularly L1 phonetic attrition in position-specific realization variants such as allophones are poorly understood, the second part of the chapter will address phonetic learning and development from a language acquisition perspective. In this way, I will offer insights into phonetic variability due to distributional variants in the bilingual mind. The chapter provides a brief overview of L2 phonological learning of allophonic variation and shows that the acquisition of distributional variants of corresponding L1-L2 categories is modulated by structural factors which may also play a role for L1 attrition in phonetics and phonology.

3.1.1 Defining 'L1 *attrition'*

The acquisition of L2 phonetics and a phonological system entails that learners establish new phonetic categories that approximate the L2 target as well as the rearrangement of the phonological grammar which is expressed by phonological constraints. At the same time, interference from the L1 on the L2 must be suppressed to attain target-likeness in a second language. This process does not only bear consequences for the L2 (for example increasing L2 proficiency or target-likeness), but also for all other languages embedded in a speaker's linguistic system. When change in the L1 occurs during the acquisition or the extended use of an L2,[22] change that emerges in the L1 is referred to as *L1 attrition*. Schmid (2013, p. 117) broadly defines L1 attrition as "[...] the process of language change experienced among speakers for whom the language under observation had stabilized prior to the onset of attrition effects." It is worth pointing out that Schmid's definition of L1 attrition lacks any reference to L2 acquisition or the causes of L1 attrition, and that the two need not necessarily be identical even if one were to accept an L2 context as the primary site of L1 attrition. This definition contrasts with many previous definitions of L1 attrition. While the term *attrition* was often understood to refer to a loss of linguistic competence, recent developments follow Schmid's (2013) understanding of L1 attrition and have since approached the concept from a more holistic perspective. This shift raises important questions about the nature of L1 attrition which have been the locus of recent debates (Schmid & Köpke, 2018). In their programmatic contribution addressing a multitude of domains in L1 attrition research, Schmid and Köpke (2018) controversially defined the term L1 attrition as

> "[…] any of the phenomena that arise in the native language of a sequential bilingual as the consequence of the co-activation of languages, crosslinguistic transfer or disuse, at any stage of second language (L2) development and use, as language attrition. First language (L1) attrition is therefore considered to be the process by which a) pre-existing linguistic knowledge becomes less accessible or is modified to some extent as a result of the acquisition of a new language, and b) L1 production, processing or

[22] It is worth pointing out that the neutral wording and the lack of a statement which causally links L1 attrition and L2 acquisition was chosen intentionally to acknowledge that the process leading up to L1 attrition may not differ from other processes of change but merely one expression of the same process that also guides other types of language change. The importance of this distinction is especially evident in light of research on lifespan changes in monolinguals I presented in Chapter 1.2 where I demonstrated that an L1 remains adaptive even when no L2 is present, and that the changes in the L1 of monolinguals are similar to those of bilinguals.

> comprehension are affected by the presence of this other language." (Schmid & Köpke, 2018, pp. 637-638)

Crucially, viewing L1 attrition as a linguistic development which leads to a modification rather than a loss implies that L1 attrition does not inherently differ from other developments which shape the languages of bilinguals. Instead, Schmid and Köpke argue that L1 attrition is merely an endpoint on a continuum which also includes other effects of Cross-linguistic Influence (henceforth 'CLI'). Their claims raised some controversy as to what exactly constitutes cases of attrition – here, Schmid and Köpke (2018) argue that L1 attrition is clearly one end of a broader continuum which incorporates all incarnations of CLI-effects. In this view, every bilingual is an 'attriter' regardless of the strength and quality of CLI the bilingual experiences.

Another controversy revolves around the theoretical implications L1 attrition bears for theories of L2 acquisition and bilingualism more generally. Various language-internal and language-external variables modulate L2 acquisition and development. One of the most powerful predictors of future L2 proficiency and attainment is the *Age of Acquisition* (henceforth 'AoA'), i.e., the age at which L2 acquisition starts. In comparison to *late bilinguals,* i.e., learners with an AoA above 12 years of age, *early bilinguals,* learners for whom L2 acquisition started before the end of the *Critical Period* ('CP'), typically argued to end around age 12, have been shown to reach higher proficiency levels (e.g., Birdsong, 1992; Johnson & Newport, 1989) and are less likely to sound foreign-accented in their L2 (e.g., Derwing & Munro, 2013; Flege, Munro, & MacKay, 1995). Moreover, early bilinguals have been shown to attain native-like proficiency in their L2 whereas late bilinguals are believed to remain non-target-like in the production and perception of their L2, although an early AoA does not guarantee nativelikeness. The AoA-induced differences between early and late bilinguals are accounted for by maturational constraints which result from biological age such as brain maturation which is considered the driving force and restricts linguistic development as speaker age increases (e.g., Birdsong, 1992).

Maturational constraints leave little room for L1 attrition: While L1 attrition in early learners does not necessarily interfere with maturational constraints as their grammars are believed to be open to change and restructuring, L1 attrition in the presumably stable and unchangeable grammar of adult speakers is not expected. Recently, several studies provided evidence that mature grammars are not invariant and that L2 acquisition affects the L1 in various ways which may lead to non-convergence with the respective L1 monolingual norm (e.g., Cook, 2003; Grosjean, 1998; Jarvis & Pavlenko, 2008; Pavlenko & Jarvis, 2002; see also Kartushina, Frauenfelder, & Golestani, 2016 for a general overview). Crucially, these results are not exceptional in their relevance to maturational constraints as studies of change across the lifespan of monolingual speakers addressed in Chapter 1 provide additional evidence of the adaptability of an L1.

Nevertheless, maturational constraints expressed in a speaker's age determine the pathway of L1 attrition just like any other language development. Indeed, a speaker's AoA (in the L2) and their *age of decreased contact* (henceforth 'AoDC') has been shown to play a determining role for the emergence of L1 attrition and to which degree a speaker will experience L1 change. Early bilinguals who lost contact with their L1 before puberty have been shown to experience extensive L1 attrition and occasionally complete loss, e.g., by international adoptees (see Pallier et al., 2003; Ventureyra, Pallier, & Yoo, 2004) who experienced the complete loss of their L1 due to an early AoDC. Late bilinguals (whose AoDC occurs in their late teens or adulthood) usually experience only mild signs of L1 attrition, and there are no reports of a complete loss of an L1. Montrul (2008), for example, suggests that even late bilinguals who experience extreme L1 attrition in morphology and syntax are unlikely to produce error rates beyond 5%. Schmid (2013) assumes similar L1 attrition patterns in phonetics and phonology, arguing that "attriters compare favorably to even the most advanced L2 learners" (p. 119) and claims that "it seems extremely unlikely that attrition could ever reach the level of phonological restructuring" (p. 119).

Regardless of the AoA of a second language, the decrease of contact with and use of the L1 is implicitly or explicitly assumed to be a primary trigger of L1 attrition (de Leeuw, Schmid, & Mennen, 2010; Schmid & Dusseldorp, 2010). Here, some terminological clarification is in order. L1 attrition has been interpreted as a type of '*loss'* of L1 *competence* and understood to yield unusual, extraordinary, or unexpected changes to the L1. Furthermore, L1 attrition is often understood to be a permanent structural change affecting an L1 grammar in a way that is distinct from changes considered 'regular' or 'expected' in all bilinguals which arguably stem from performance issues (e.g., resulting from inhibitory control and its limitations) rather than changes to a speaker's L1 competence (e.g., Chang, 2010). Crucially, L1 differences between monolinguals and late bilinguals seem to arise from differences in performance rather than a loss of competence and arise when L1 use decreases due to L2 acquisition. Thus, if L1 attrition is indeed primarily shaped by language use, a reversal to L1 dominance is also expected to reverse the effects of L1 attrition.

The idea of L1 attrition as a permanent loss raises some theoretical and experimental problems. Testing the permanence of change to the grammar of an individual empirically is difficult, if possible at all. If attrition affects competence, the effects of attrition on an individual's speech (i.e., non-convergence with the monolingual norm) should emerge as consistent and persist across contexts known to modulate speech behavior; this requires longitudinal studies tracing the linguistic development of an individual speaker across the lifespan. Also, speakers affected by L1 attrition should not have advantages in (re-)learning their L1 after a structure was lost, which necessitates relearning studies of the 'lost' L1. This requires a level of experimental control (e.g., amount of L1 input throughout the attrition period as well as during the study) that is hardly feasible in practice. While L1 relearning by adult bilingual attriters has not been tested empirically, studies on relearning of a lost L1 by early bilinguals are few and far in between (but see Oh, Au, & Jun, 2010 for an exception). Furthermore, studies investigating language overhearing in childhood, i.e., speakers who overheard a language without acquiring it, can also provide insights into L1 relearning. It should be noted, however, that incomplete acquisition of the L1 by early bilinguals strongly decreases the comparability of the processes driving L1 loss in early bilinguals and L1 loss in late bilinguals. Nevertheless, the loss and reacquisition of an early-lost L1 by early bilinguals later in life still provides valuable insights into whether the complete L1 loss is possible under conditions which favor such loss.

One study that investigated the loss of an L1 due to complete loss of contact with the L1 during early childhood comes from Oh et al. (2010). In particular, Oh et al. investigated whether complete loss had occurred in the L1 of Korean adoptees (most adopted before one year of age) through a relearning paradigm, testing their perception of the Korean three-way plosive distinction (lenis, tense, aspirated) by their adoptee group as compared to first-time American learners of Korean who attended the same Korean class. If the adoptees indeed cpmpletely lost their L1, they should perform on par with monolingual native speakers of English learning Korean for the first time. Oh et al.'s (2010) results reveal that although the adoptees did not have a general advantage over the English learners in the Korean stop contrast perception task, the Korean adoptees outperformed the first-time American learners on lenis and aspirated stop distinctions. Oh et al. take this as evidence of the lasting advantages of early exposure to a language and argue that a forgotten language leaves a lasting trace. However, Oh et al. (2010) did not test the groups' pre-instruction performance, and it is possible that the adoptees retained the ability to discriminate Korean stops; in that case, the result would reveal little, if anything, about L1 attrition.

Au, Oh, Knightly, Jun, and Romo (2008) address a similar question in their study on the effect of exposure to another language during early childhood, albeit focusing on fine-grained differences in early childhood exposure. In their study, Au et al. investigate the production of Spanish phonology using a foreign accent rating, and Spanish morphology using a variety of tasks (e.g., grammaticality judgements, and noun and verb phrase production) by novice L2 learners of Spanish, childhood overhearers, and childhood speakers who spoke Spanish actively until the age of seven. Au et al.'s results showed that in comparison to novice learners, the childhood overhearers were perceived as less foreign accented but did not outperform the novice learners on the morphological tasks. The childhood speakers, on the other hand, were perceived as less foreign accented than novice L2 learners and childhood overhearers and outperformed both groups in the morphological tasks. Au et al. (2008) interpret their results to provide evidence for lasting accessibility of linguistic knowledge acquired in childhood, even if the knowledge was not embedded in a productive linguistic system but one merely initialized by occasional overhearing. They furthermore claim that their study "offers some evidence that childhood language experience can remain accessible after years of disuse" (Au et al., 2008, p. 1009). Evidence from language overhearing in childhood thus suggests that even minimal exposure can have lasting effects on a speaker's linguistic system and increase performance in a language despite a gap of several decades between first exposure and relearning (or re-exposure). Taking this into consideration, a loss of the L1 (or parts of an L1) in adulthood seems unlikely.

Contrasting evidence which supports that L1 attrition in early bilinguals may be permanent and complete comes from two studies on L1 attrition in Korean-French adoptees. Here, the presence of traces of the adoptees' L1 (Korean) was investigated using fMRI imaging (Pallier et al., 2003) and perception experiments of Korean stop contrasts (Ventureyra et al., 2004). In both studies, the adoptees did not differ significantly from the monolingual French controls, neither regarding brain activation patterns upon hearing their L1, Korean (Pallier et al., 2003), nor regarding their performance in perceiving the Korean three-way stop contrast (Ventureyra et al., 2004). The study by Ventureyra et al. (2004) additionally distinguished adoptees with re-exposure to Korean to those without and found that re-exposure did not lead to advantages on the discrimination task. The two studies provide substantial evidence that the adoptees indeed lost their L1 completely.

The studies by Ventureyra et al. (2004) and Pallier et al. (2003) contrast with other studies which investigated L1 attrition from a neurological perspective and found evidence of differences in neural activity between monolinguals and adoptees. Pierce, Klein, Chen, Delcenserie, and Genesee (2014), for example, tested the perception of Chinese tone by Chinese-French adoptees. The adoptees in their fMRI study lost contact with their L1 in early childhood, between six and 25 months of age. Despite the early offset of contact with their L1, the adoptees showed brain activity comparable to that of L2-dominant early Chinese-French bilinguals who did not lose contact with their L1. Moreover, the adoptees and the early bilinguals both differed from the monolingual control group in their performance on the tone perception task, indicating that the adoptees were more similar to the early bilinguals than to the monolingual controls. The results suggest that the L1 of the adoptees was not entirely lost; indeed, the adoptees seemed to match the performance of the experimental group with highly similar language biographies, the early bilinguals. Pierce et al.'s results raise some critical questions regarding previous fMRI studies on L1 attrition as they provide evidence that the loss of contact and long-term disuse does not necessarily induce the complete attrition of an L1 even in very young speakers. Instead, L1 knowledge – although of undetermined quantity and quality – can persist into adulthood and remain accessible to the adoptees, likening their behavior to early bilinguals.

To return to the question of permanence in L1 attrition, the following arguments support the view that L1 attrition does not hinge on an unusual type of loss. Firstly, the studies on L1 loss in early learners summarized so far demonstrate that permanence is not an informative measure to distinguish L1 attrition from other processes of change. Indeed, if only a permanent loss were genuinely indicative of L1 attrition, attrition would not occur at all considering that even the earliest attriters (with the most vulnerable grammars) do not consistently show signs of complete L1 loss. Secondly, an abundant number of cases in which L1 change has been shown to emerge in healthy monolingual speakers throughout their lifespan, as well as bilinguals whose L1 shows signs of L2 influence, would remain unaccounted for, leaving regular cases of L1 change as loose ends in a theory of bilingualism. Recently, various debates have picked up on these issues and, supported by an increase of empirical evidence, led to a shift of the concept understood by the term attrition, away from the notion of 'loss' and towards a regular form of language development included in the kaleidoscope of change that emerges in the languages of adult bilinguals. Along these lines, Schmid and Köpke (2018) argue

> "that to make such a distinction between online/transient and representational/ permanent effects of the L2 on the L1, with only the latter being considered instances of attrition, is both artificial and unhelpful, as they merely represent developmental

> stages on the same continuum. Attrition effects begin as soon as L2 development sets in, in the first instance as online phenomena of co-activation where production or processing is to some extent affected and subserved by both languages […]. They may or may not eventually lead to apparent changes to or restructuring of knowledge, processing or production as a result of long-term crosslinguistic interference.” (p. 641)

However, Schmid and Köpke’s argument in favor of a holistic position in which any change in a bilinguals’ linguistic system is part of a continuum was criticized heavily. Kupisch, Bayram, and Rothman (2018) criticize Schmid and Köpke’s overgeneralization of the term ‘bilingual’ as they fail to address well-known differences of the interactions between the L1 and the L2 across various types of bilinguals. Tsimpli (2018), on the other hand, criticizes the lack of differentiation between different types of CLI and argues that CLI-effects differ in quality and nature, and cannot be unified into a single process that emerges across different linguistic domains and language constellations. It is worth mentioning that many of these arguments rest on thin empirical evidence, and their validity crucially hinges on assumptions which remain to be tested. For instance, the cause of L1 attrition and the structures open to L1 attrition are unknown despite the recent surge of research on L1 change and attrition. In light of these considerations, it seems reasonable to adopt Schmid and Köpke's (2018) broad definition of attrition, even if only for lack of an alternative.

3.1.2 Theoretical approaches to the causes of L1 attrition

A second issue in L1 attrition – even when leaving aside the highly problematic terminological and conceptual issues – is the question of the source of changes to the L1 under attrition. Previous attrition research has made little advances in terms of investigations of how L1 attrition progresses, and why. Firstly, the domains of an L1 which are more likely affected than others remain unclear, although empirical studies (to be reviewed below) strongly suggest that structures differ with regard to their vulnerability. Secondly, the structural source of changes to the L1 are unknown, although direct interference of an L2 as main cause L1 attrition is often implicitly assumed. In this perspective, attrition should closely reflect the properties of the L2. In an L2-based view, attrition is seen as a cognitive process which results from general properties of memory and its limitations which play a role in forgetting. Various hypotheses address this perspective, for example the *Inverse Relation Hypothesis* (Yoshitomi, 1992) which suggests that structures are less likely affected if they were learned ‘best’. Similarly, the more well-known *Regression Hypothesis* (Jakobson, 1941) suggests that L1 attrition progresses in reverse acquisition order. However, neither of the two finds strong empirical support (e.g., Keijzer, 2007).

As mentioned previously, L2 acquisition and the decreased L1 use that follow from it are often suspected to trigger L1 attrition, and the selection of theoretical approaches used to account for the effects of L1 attrition by previous studies reflects this intuition. Herdina and Jessner (2002), for example, who argue that L1 attrition leads to an increase in variability in the L1 of late bilinguals, see decreased L1 use as the primary determinant which governs not only whether L1 attrition will take place, but also which features will be affected. As such, Herdina and Jessner's concept of L1 attrition relies almost exclusively on the influence of external variables among which L1 use is the most important one.

Similarly, the *Activation Threshold Hypothesis* ('ATH'; Paradis, 2004, 2007) has gained considerable popularity as a psycholinguistic framework. Especially research on heritage language speakers but also research on L1 attrition draws heavily from the predictions of the ATH. The ATH predicts that linguistic structures from the L1 and the L2 differ with regard to their *activation threshold* (Paradis, 2004), i.e., the processing effort necessary to activate a linguistic structure. Paradis (2004) describes the activation threshold as follows:

> "[A]n item is activated when a sufficient amount of positive neural impulses have reached its neural substrate. The amount of impulses necessary to activate the item constitutes its activation threshold. Every time an item is activated, its threshold is lowered, and fewer impulses are required to reactivate it. Thus, after each activation, the threshold is lowered – but it gradually rises again. If the item is not stimulated, it becomes more and more difficult to active over time. *Attrition is the result of long-term lack of stimulation*." (p. 28, emphasis added)

According to Paradis (2007), the ATH (just like other frameworks that rely on neural activation as a primary explanatory approach, see Ecke, 2004, for a review) interprets L1 attrition as an expression of increased activation thresholds of L1 structures resulting from diminished L1 use. More precisely, Paradis (2007) argues that with each instance of use, the activation threshold of linguistic structures decreases, which increases recall speed in future instances of use. In contrast, the activation threshold of a structure increases with prolonged disuse, causing the recall process to become slower and more effortful. In this framework, L1 attrition emerges: if the activation threshold reaches (and exceeds) a critical threshold, the likelihood of future retrieval attempts to fail increases, and the structure may be inaccessible

(Paradis, 2007). Importantly, the critical threshold is exceeded when the neural impulses which are required to activate a linguistic structure in recall exceed the neural capacity available to the recall process. In this sense, the ATH is linked to general theories of memory and forgetting and renders linguistic knowledge equivalent to other types of knowledge. Importantly, the ATH does not predict true language loss as such as the mental representation remains an unchanged part of the speaker's linguistic system, the item is merely temporarily inaccessible. Access can be re-established if the activation threshold of the structure drops below the critical threshold again. Activation in the ATH crucially depends on language use, which is a powerful predictor of L1 loss in general and the magnitude at which a speaker will experience loss in particular. This prediction suggests that L1 attrition progresses under L1 disuse and that the magnitude of L1 attrition (for example expressed in the quantity of L1 loss) correlates with the frequency of use. The ATH furthermore entails that an L2 structure competes for activation with its counterpart in the L1 and therefore predicts straightforward L2 interference during L1 use since the accessible L2 structure will replace the inaccessible L1 structure (Paradis, 2007).

The predictions of the ATH, however, are not borne out by empirical research. Although the studies by de Bot, Gommans, and Rossing (1991) and by Köpke (1999) found that low-frequency L1 use correlated with the magnitude of L1 attrition, no such correlation was evident in other studies (see Schmid, 2007, for a summary), and the connection between language use and the degree of L1 attrition a speaker experiences remains unclear. These results also contrast with the assumption that attrition is an exceptional process restricted to infrequent L1 users and leaves room for speculations that the initial trigger of L1 attrition is found elsewhere.

The ATH predicts that L2 structures compete for activation with L1 structures and substitute them once they have become inaccessible, implying that direct L2 transfer from the L2 determines the emerging changes in L1 attrition. This prediction is also not borne out in empirical studies. While previous work showed that some of the changes under L1 attrition could be accounted for by L2 transfer, many cannot. Increasingly, empirical evidence (including the study presented in this dissertation) points to other sources of L1 attrition and suggests that the structural characteristics of the affected features which also shape their behavior in language contact and change play an essential role. To illustrate, some structures seem prone to language change, suggesting that they are equipped with an inherent property that regulates the likelihood and magnitude of variability and change. These properties also seem to be at work cross-linguistically: Hierarchies which are typologically robust in that they have been shown to emerge across a multitude of languages seem to follow constraints similar to those observed in L2 learning and L1 attrition. These notions will be explored in more detail in the next subchapter.

3.1.3 Vulnerable and stable domains in language attrition

As mentioned above, previous studies found that some changes to the L1 of late bilinguals could not be explained by L2 transfer alone. To shed light on this explanatory gap, various hypotheses regarding the domains in which attrition affects the L1 more severely than others have been proposed, mainly addressing the question whether some linguistic features are more vulnerable (or more resistant) to change than others. The Inverse Relation Hypothesis by Yoshitomi (1992), for example, predicts that the *quality* of the mental representation of a linguistic structure determines the stability of the structure under attrition: the structures learned 'best' through constant reinforcement are presumably more resistant to change. In particular, constant reinforcement (e.g., by regular L1 use) of an item's representation is believed to increase the stability of its mental representation, whereas infrequent reinforcement will cause the mental representation to remain in its default, comparatively unstable state, opening the structure to lifespan change. Yoshitomi`s (1992) proposal is closely related to the Regression Hypothesis, which actually can refer to a group of hypotheses which predict structural stability either based on (i) the recency of acquisition or (ii) by the quality of acquisition. The former predicts that representations are more resistant to change the longer a speaker has acquired them ('*first in, last out*'), whereas the latter predicts that the mental representation of a linguistic structure becomes more resistant through reinforcement (Köpke & Schmid, 2004). It is worth mentioning that both interpretations strongly correlate and often predict stability for the same structures, but not universally so. The two interpretations of the Regression Hypothesis suggest that L1 attrition is not sensitive to language-internal structural constraints but to external and individual variables: The stability of a structure is determined by frequency or recency of use respectively, and a lack of use induces change.

Like the approaches before, the Regression Hypothesis again relies on language use as the primary trigger of L1 attrition which brings up the same theoretical challenges as before, namely the lack of evidence for the effect of language use in a vast majority of empirical studies. The frequency of reinforcement for individual items is arguably subject to considerable inter-personal variation. Köpke and Schmid (2004) claim that the progression of

L1 attrition can only be reflected accurately by analyses which focus on individual differences. Such an approach neglects the fact that similar and frequently used structures have been shown to change under L1 attrition; for example, L1 speakers of pro-drop languages have been shown to differ from monolinguals in the production and perception of overt and null pronouns (e.g., Tsimpli, Sorace, Heycock, & Filiaci, 2016).

More recently, Sorace's *Interface Hypothesis* (henceforth 'IH') aimed to account for acquisition and attrition of syntactical structures and the emergence of differences between monolinguals and bilinguals received an increase of interest as it "account[s] for patterns of non-convergence and residual optionality found at very advanced stages of adult second (L2) acquisition" (Sorace, 2011, p. 1). Especially for L1 attrition, the IH offers an analytical approach which differs from other approaches to L1 attrition as it does not rely on the L2 as the primary structural source in L1 change. Instead, it suggests that the association of the structure itself to one or more than one linguistic domain determines its resistance to change.

In the IH, persistent non-nativelikeness in the L2 of learners and non-convergence with monolinguals in bilinguals experiencing L1 attrition can be explained by the association of the structures to either *internal* or *external* interfaces. In particular, Sorace (2011) claims that the IH

> "[…] predicts that structures involving an interface between syntax and other cognitive domains present residual optionality (in L2 acquisition), emerging optionality (in L1 attrition), and protracted indeterminacy (in bilingual L1 acquisition), but structures that require only syntactic computations are completely acquired in L2, remain stable in L1, and are acquired early in bilingual L1 acquisition" (p. 5).

It is worth mentioning that Sorace (2006) also establishes connections between optionality and diachronic language change, as she argues that "variability at interfaces may be regarded as the motor of diachronic change, because it is at that level that 'imperfect acquisition' from one generation to the next is likely to begin" (p. 122).

Some have taken issue with the assumptions and predictions of the IH, for example, its lack of clear explanation why interface structures favor change, and whether interface structures behave similarly within and across languages (Rothman, 2009). Furthermore, the IH neglects quality of input despite the wealth of studies that show a robust effect of input on persistent non-nativelikeness in many types of bilingualism (Rothman, 2009). Nevertheless, the IH has become a central tool in research on language attrition in syntax and its neighboring domains. In this way, the IH attempts to offer a holistic framework which unifies various strands of research on bilingualism and accounts for the phenomena by taking language-internal properties into account.

A closer look at L1 attrition in phonetics and phonology reveals that in comparison to other linguistic domains, phonetic and phonological L1 attrition made few advances regarding the development of new theoretical developments or the extension of existing theoretical frameworks. In phonetics – and arguably also in phonology – memory-based approaches such as the ones described above are rarely (if ever) used to account for L1 attrition. These studies instead rely on approaches centered around the contribution of the L2 and typically adapt well-established L2 learning models such as Flege's (2007) *Speech Learning Model* (henceforth ‘SLM’) which predicts changes to L1 sounds under L2 influence. While the L2 indeed seems to interfere with the L1 on various structural levels, and the phonetic system is known to show signs of bidirectional influence, the changes observed in previous studies cannot be accounted for by L2 influence alone. In particular, some studies found that phonetic categories in the L1 were subject to change although they lacked an acoustically similar L2 sound; in contrast, some L1 sounds seem robust to change, even in the presence of an L2 sound predicted to trigger a shift. Such asymmetries raise questions whether the L2 is solely responsible for L1 attrition in phonetics and which properties of an L1 structure play a role in determining whether it will be affected by L1 attrition and to which extent.

Indeed, current frameworks like the ones outlined above which account for general L1 attrition do not straightforwardly account for phonetic and phonological L1 attrition or easily translate into meaningful predictions. Research in phonetic L1 attrition mainly draws from existing L2 acquisition research, primarily from the SLM as it offers several advantages over other models in attrition and acquisition research. For instance, Flege (2007) assumes that AoA does not directly limit the acquisition of L2 phonetics but that the mechanisms that drive phonetic L1 acquisition remain available to learners throughout the lifespan and also guide L2 phonetic acquisition. This assumption does not imply that late L2 phonetic acquisition is unconstrained by AoA as the SLM also predicts bidirectional influence between the L1 and the L2 in mature phonological systems. In particular, late learners are expected to exhibit persistent non-target-like phonetic realizations in their L2 as a result of the integration of the L1 and the L2 into the same phonological space (Flege, 2007). Age modulates the degree of L1 influence on the L2 as continuous L1 input throughout the lifespan arguably increases the category strength (i.e., the category’s stability and force in attracting L2 sounds) of a speaker’s L1 phonetic categories (Flege, 2007). Here, category strength refers to the strength of the mental representation of a sound category regarding its phonetic and phonological characteristics, expressed for example by the category's acoustic center as well as its acoustic dispersion in the phonological space of the speaker which are shaped and strengthened by evidence in the L1 input (Flege, 2007). Increased category strength also increases the resistance of a sound category to L2 input and influence if the L2 input conflicts with L1 category information.

The existing L1 sound categories are known to interfere with category formation of the incoming L2 sounds in various ways. A learner is expected to establish a new phonetic category for the L2 sound only if the L2 sound is perceived as sufficiently *different* from existing L1 sound categories. In contrast, a new L2 sound is expected to be mapped onto the existing L1 sound category in the presence of a *similar* sound, resulting in *equivalence classification* of L2 sounds and L1 sounds. Crucially, equivalence classification inhibits the formation of a new category for the affected L2 sound which will instead be mapped onto an existing L1 category, a process referred to as *phonetic category assimilation* (Flege, 2007). This process results in a single merged phonetic category unifying both the L1 and the L2 sound. The high degree of phonetic similarity to the original L1 category often results in strong L1 influence on the learner's L2 pronunciation especially in the initial stages of L2 acquisition (Flege, 2007). However, the phonetic information the L2 continuously contributes to the merged L1-L2 sound category is expected to induce a phonetic shift towards the L2 sound. This process leads to a more target-like pronunciation in the L2. Crucially, the shift affects the realization of the sound in the L1 by way of their shared category membership which leads to an L2-like quality in the L1.

The L1 may also be subject to L2 influence if L2 sound category formation succeeds. Here, *phonetic category dissimilation* is observed when, as Flege (2007) argues, the "phonetic space becomes more crowded" (p. 370), causing "L1 and L2 phonetic categories of a bilingual [to] disperse to maintain phonetic contrast" (p. 370). In other words, category dissimilation leads to an asymmetric distribution of the sound categories in the phonological space and results in a decreased distance between the two neighboring sound categories, leading both sound categories to shift in opposite directions to increase distance. Both the L1 and the L2 sounds are expected to show signs of deflection, i.e., both categories will exhibit non-convergence with the monolingual norm in each of the languages. In this way, Flege (1995) claims that "[p]honetic categories established in childhood for L1 sounds evolve over the lifespan to reflect the properties of all L1 or L2 phones identified as a realization of each category" (Flege 1995, p. 239).

Importantly, research in L1 attrition benefits from the extensive empirical support from L2 acquisition research the SLM received in the past as it supplies a model in which L1 attrition is one of the central and expected outcomes in L2 acquisition. However, as will be shown below, empirical work on phonetic attrition reveals some inconsistencies in relation to the predictions of the SLM. In particular, changes to L1 phonetics in bilinguals do not seem to affect their L1 sound categories in a homogenous way. That is to say, while L1 sounds the SLM predicts to change due to influence from by a similar L2 sound seem resistant to change other L1 sounds not predicted to change have been shown to change despite the lack of an L2 equivalent. These inconsistencies raise questions as to why some L1 categories shift more readily and seem more than others upon phonetic L2 acquisition under L1 attrition while the presence of L2 equivalents seems to play a subordinate role.

Furthermore, while the SLM supplies the dominating theoretical approach to research on phonetic changes in an L1, there is virtually no previous research addressing potential changes to L1 phonology (but see de Leeuw, Tusha, & Schmid, 2018, for an exception to this with their recent study on L1 attrition of phonology). In the realm of phonetics and phonology, the L2 is not only assumed to induce attrition but also to be the source of structural transfer. Neither of the assumptions finds strong support in previous research: While the L2 could be shown to play a crucial role in L1 attrition, the assumption that it does indeed supply the structures incorporated into the L1 is far from robust. Furthermore, L1 attrition in late bilinguals is characterized by high inter-speaker variability: speakers experience variable degrees of attrition, ranging from relatively extensive (e.g., foreign accent) to subtle changes, and some speakers seem entirely unaffected (e.g., Schmid, 2011).

3.2 L1 phonetic drift, change, and attrition in bilinguals

Attrition of L1 phonetics entails both the development of a perceivable foreign accent in an L1 as well as changes to the phonetic properties of a bilinguals' L1. The former will be addressed in the following subsection, and the latter will be addressed in the remainder of this chapter.

As discussed earlier in this chapter, L1 attrition arguably results from L2 influence on the L1 and leads to a loss of L1 structures. Phonetic change in the L1 is not universally considered L1 attrition proper: Via the SLM, L1 phonetic change under the influence of an L2 is neither expected to result in the loss of L1 competence nor that the change leads to a permanent or irreversible restructuring; both characteristics are often considered indicative of attrition. This leads to the emergence of the term *phonetic drift* (Chang, 2010) to refer to L1 phonetic change caused by category 'drift', i.e., sounds drift away from their original location in a bilingual's phonological space, leading to non-convergence with the monolingual norm. As such, L1 phonetic attrition in bilinguals may be closely related to general patterns observed in sound change.

3.2.1 Perceivable changes to the L1: Foreign-accentedness in the L1

Foreign accent ratings, i.e., the subjective rating of speech samples by native speakers, are frequently used in linguistic research to determine a learner's attainment in their L2 (see Jesney, 2004 for an overview). In L1 attrition, foreign accent ratings are used to address the question whether long-term L2 exposure leads to native speakers perceiving bilinguals as foreign-accented in their L1. Here, some studies show that some late bilinguals seem to develop a perceivable foreign accent in their L1 (e.g., Bergmann, Nota, Sprenger, & Schmid, 2016; de Leeuw, 2008; de Leeuw et al., 2010; Hopp & Schmid, 2013).

Bergmann et al.'s (2016) approach differs from previous rating studies in that they also directly investigate a correlation between perceived accentedness and fine acoustic detail using spontaneous speech data collected from German-American English late bilinguals and various pre-existing data as a monolingual comparison.[23] In their judgment experiment, the late bilinguals scored lower in a nativelikeness rating than the monolingual control group: On a 6-point scale, the German monolingual control group received an average rating of 5.05, whereas the bilinguals received a mean rating of 4.05. Furthermore, 39.4% of the bilinguals received a rating below that of the lowest monolingual score (lowest monolingual score = 3.7), demonstrating that long-term L2 exposure can lead to a significant decrease in perceived nativelikeness and affects a significant number of subjects. Bergmann et al. furthermore found that perceived non-nativelikeness was related to two external variables: Firstly, that higher L1 use scores predicted higher scores on the 6-point accentedness scale, and secondly, that a lower accentedness score was associated with a higher *Length of Residence* (henceforth 'LoR').

[23] Bergmann et al. (2016) use data collected at different time periods and within different projects. The monolingual data come from the Michigan area (48 subjects), Texas and neighboring states (10 subjects), and the Toronto/New York area (5 subjects).

The correlation between foreign-accentedness and phonetic change is not straightforward. Bergmann et al. (2016), for example, predicted that a lower score for perceived nativelikeness correlates with more severe changes to formant frequencies (see Chapter 3.2.2 for a review of the acoustic analyses in Bergmann et al., 2016). The late bilinguals were separated into two groups based on their accentedness score, the *nativelike attriters*, i.e., those who scored within the native monolingual accentedness range of 3.7-6 points, and the *non-nativelike attriters*, i.e., those who received an accentedness score below 3.7, a score which corresponds to the lowest rating given to one of the native monolingual speakers. Bergman et al.'s analyses showed that phonetic changes did not correlate with the speaker's perceived foreign accent, and they found no correlation between perceived foreign accent and detectable acoustical change. However, they focused on a small set of segmental changes, and it is unknown whether the change was significant enough to be perceivable by the native judges in the foreign accent judgment. Furthermore, the rater's judgments could be influenced by other segmental or suprasegmental changes in the speech samples which were not analyzed in Bergman et al.'s study. The lack of a reliable connection between perceived nativelikeness and acoustic nativelikeness could, for example, result from a multitude of changes and various interactions among different changes, and therefore go undetected in Bergman's et al.'s experimental design.[24]

3.2.2 Phonetic change in bilinguals

Despite a growing number of studies, very little is known about L1 phonetic change, mainly due to limited theoretical frameworks and the small set of phonetic properties investigated so far, mainly focusing on Voice Onset Time (henceforth '*VOT'*; see studies by Becker, 2014; Cedergren & Sankoff, 1974; Chang, 2012; 2013; Flege, 1987; Flege & Eefting, 1987; Major, 1992; Sancier & Fowler, 1997; among others) and, less frequently, vowel quality (e.g., Bergmann et al., 2016; Chang, 2012; Kartushina et al., 2016). Other segmental and suprasegmental features, in comparison, have received very little attention, if any (but for

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[24] While it is difficult to speculate what these interactions could look like, it could be imagined that changes do not occur across the board within a single segment, and instead influence phonetic properties of other segments in their vicinity, or that the overall segmental change is modulated by an uncontrolled structural variable such as prosodic structure and/or position. Such an interaction could also progress along trajectories and life cycles of sound change. Bermúdez-Otero (2007), for example, states that "the ascent of phonological rules [progresses] from the phrase level through the word level into the stem level" (p. 504).

exceptions see de Leeuw, Mennen, & Scobbie, 2012 for laterals and suprasegmentals; Ulbrich & Ordin, 2014 for rhotics).

In his study on L1-L2-bidirectional influence, Flege (1987) investigated the production of English and French VOT and /u/ by three groups of American English-French bilinguals, one group of French-American English bilinguals and monolingual controls for both languages. In particular, his bilinguals, American students of French, American professors of French, Americans living in Paris, and French speakers in Chicago differed with regard to their L2 proficiency. Flege's results showed that the high proficiency speakers (Americans in Paris and French women in Chicago) differed from the monolinguals both in English and French in their VOT: Americans living in Paris produced English stop with a significantly shorter (i.e., more French-like) VOT than the monolingual English controls. Likewise, French women in Chicago produced significantly longer (i.e., more English-like) VOT in their French than the monolingual French controls. In contrast, Flege's less experienced learners did not differ from their respective monolingual norm in their L1, a result Flege interprets as evidence for the predictive power of L2 experience and immersion for L1 change. Importantly, the bilingual speakers used distinct VOT for English and French, suggesting that the observed L1 change does not fall out from using a merged L1-L2 category but was instead a genuine case of L1 phonetic change.

Major (1992) similarly investigated the production of VOT by late English-Brazilian Portuguese bilinguals, focusing on the effect of external variables such as L2 proficiency and the level of formality on the phonetic change in the L1.[25] Major's results mirror those observed by Flege (1987): The bilinguals differed from the monolingual controls in both languages, confirming the presence of bidirectional influence in the bilingual group. Also, Major (1992) showed that severity of L1 change was subject to intrapersonal variability across formality conditions. The difference between monolinguals and bilinguals was smaller in the formal tasks and more substantial in the casual tasks. Crucially, Major (1992) also found that variability due to formality seemed to proceed hierarchically. In particular, all speakers who differed from the L1 English monolingual controls in the formal speech condition also differed from the L1 monolingual norm in the spontaneous speech condition. The reverse pattern, i.e., differences in formal speech but not in spontaneous speech, was not

[25] Major (1992) did not collect data across different formality levels in the bilingual's L2 (Brazilian Portuguese); the VOTs he reported for bilingual Brazilian Portuguese come from a reading task.

observed. The precedence of change in the spontaneous speech condition can be taken to show that phonetic change emerges in spontaneous speech first and subsequently progresses to formal speech. Moreover, the difference between the bilinguals' L1 VOTs and the monolingual's VOT was larger in the spontaneous speech condition. Major's (1992) study thus provides evidence that the degree of L1 attrition in phonetics decreases when bilinguals can carefully monitor their speech as is the case in formal tasks. Finally, Major found an interaction between L2 proficiency and formality, suggesting that L2 proficiency is a relevant predictor of L1 change in spontaneous speech but not in formal speech.

While the studies above focused on long-term bilinguals, phonetic change has also been observed in bilinguals with little or no L2 exposure. Chang (2012), for example, showed that changes do not only seem to emerge after a significant amount of time or at high L2 proficiency levels, but already begin to take hold in the initial stages of L2 acquisition. In his study, he repeatedly tested 19 native speakers of English across six weeks during a beginner's Korean class. His results showed that Korean affected the learner's L1 English within a few weeks after the onset of L2 acquisition. In particular, Chang showed that the VOT of aspirated plosives in the learner's L1 shifted towards the Korean target. He explains this as novelty effect in the initial stage of acquisition and argues that the novelty of the incoming L2 phonetic system leads to rapid changes in the L1.

Chang's (2012) results resonate with Schmid (2011), who argues that L1 attrition mainly takes place in the first decade of decreased contact with the L1 and acquisition of the L2 and presumably levels out afterward. The claim that the critical phase for L1 attrition takes place much earlier than previously hypothesized also finds indirect support in previous studies in that, as Schmid (2011) claims, even significantly different lengths of residence do not significantly predict the degree of attrition across bilingual populations with a LoR above ten years. Schmid (2011) sees the cause of such early change in the relationship between the L1 and the developing L2 as the effort of acquiring and integrating the L2 seems to impact L1 structures and to increase interference between the two languages.

Importantly, the view that L2 acquisition has a particularly powerful effect on the L1 during the early rather than late stages of L2 acquisition can be taken to imply that the L2 is the determinative force also from a structural perspective. In other words, if the influx of an L2 induces a change in the L1, it seems plausible to assume that the L2 is also the source of structural change. Indeed, while the VOT studies reviewed above imply a strong influence of

L2 phonetic category formation on existing L1 phonetic categories, other studies which deal with segments other than stops raise questions about the contribution of the L2 to L1 attrition.

Bergmann et al. (2016) investigated acoustic changes in late bilinguals (L1 German/L2 English) by testing L1 category assimilation of in German vowels, /a:/, /ɛ/, /ɔ/, and the German lateral /l/, which they argued could be matched to L2 equivalents and induce L1 attrition as the SLM predicts. Furthermore, Bergmann et al. tested whether the degree of perceived foreign accentedness in the L1 of a bilingual correlated with the degree of L1 acoustic change to investigate whether the changes observed within a bilingual's speech were perceivable to native speakers. Bergmann et al. (2016) findings showed that the late bilinguals shifted their L1 categories /l/ and /a:/ towards their L2 English as predicted by the SLM. In contrast, neither /ɛ/ nor /ɔ/ showed evidence of a shift towards a possible L2 equivalent. To account for their results, Bergmann et al., who considered English /ɔ:/ and /ɑ/ possible equivalents with /ɑ/ as the closest English equivalent to German /ɔ/, claim that the late bilinguals did not map any English sound to their mental representation of German /ɔ/. The presence of two potential equivalents arguably led to differential equivalence classification between individuals within the bilingual group leading to a high degree of inter-speaker variability, although this was not explicitly tested. Bergmann et al. moreover argue that the two potential equivalents might not have been sufficiently similar to induce category equivalence classification, but do not provide phonetic or psycholinguistic evidence for their second assumption. Finally, Bergmann et al. mention regional variability to account for the stability of /ɛ/ and argue that bilinguals may not have received consistent L2 input for their /ɛ/-category, which they claim shows substantial variability in their monolingual data. This explanation lacks sufficient backup as well: A closer inspection of the datasets in Bergmann et al. revealed that the English control data which was adopted from three different corpora and included speakers from California, Texas, and New York and Canada, whereas the German-English bilingual group included speakers from New York City and Toronto only. Furthermore, one monolingual dataset did not contain data for /a/. Crucially, this does not only decrease the amount of control data, but the dataset also lacks information on /a/ was the same dataset to provide the opposing acoustic values for /ɛ/. Likewise, Bergmann et al.'s second explanation for the lack of change to /ɛ/ takes the considerable variability into account. More specifically, they argue that variability in monolinguals provides the learners with conflicting acoustical input in their target variety, which remains unconfirmed. These issues leave room for speculations on the actual source of differential effects in their L1 phonetic data, necessitating an expansion of L1 attrition research to include variables beyond L1-L2 similarity.

Indeed, various studies suggest that phonetic similarity between an L1 and an L2 sound (or the lack thereof) alone is insufficient in accounting for the variety of patterns of L1 phonetic attrition. Some studies, for example, show that a clear L2 equivalent is not necessary for L1 phonetic attrition to occur. In his study on L1 phonetic change in American learners of Korean, Chang (2010) traced the phonetic development of the beginning learners' L1 and L2 over the course of a 12-week Korean class. He found that the predictions of the SLM are not borne out on the segmental level. His analysis of 11 American English vowels (/i, ɪ, e, ɛ, æ, ɑ, u, ʊ, o, ɔ, ʌ/) in the learners' vowel systems showed that equivalence classification could not exclusively explain changes in L1 production. Chang found that only two L1 vowels exhibited significant change, a decrease in F1 of /ʌ/ in female speakers, and an increase in F2 of /ʊ/ in male speakers; while the remaining vowels showed changes in F1 and F2, none reached significance. The result for /ʌ/ is particularly interesting as it raises questions regarding the explanatory power of the application of category equivalence classification on the level of individual segments: In his estimation of phonetic equivalence between English and Korean vowels, Chang shows that "English /ʌ/ lies relatively far from Korean /ʌ/ and is instead closer to Korean /a/" (p. 129). Importantly, average formant frequencies of F1 in Korean /a/ are higher as compared to average F1 in English /ʌ/, predicting that drift should affect /ʌ/ by an increase in F1. As mentioned above, Chang's results showed that female speaker's F1 decreased rather than increased, suggesting that the learners shifted away from the L2 equivalent rather than towards it. Chang also found that the learners entire vowel space showed lowered F1 values which corresponds to a phonological raising of the entire vowel system.[26] Chang (2010) interprets the raised vowel space to provide evidence that the whole L1 vowel space of the American learners shifted upwards to approximate the higher vowel space of their L2.[27] He furthermore argues that these results indicate a global phonetic link between L1 and L2 and notes that "the cross-language linkage underlying this drift cannot be

[26] F1 mirrors vowel height; note that a high F1 corresponds to low vowels and a low F1 corresponds to high vowels respectively.

[27] The raising of the entire vowel space leads to a more target-like production of Korean vowels for female native speakers of American English. Male speakers in Chang's (2010) sample also raised their vowel space, which does not lead to an increase in target-likeness. Chang argues that this is an effect of instruction environment: All Korean language instructors were female which led the male speakers to approximate the instructors' norm.

based on a segmental unit of analysis; instead, it is probably established over the entire vowel system" (p. 170). Importantly, Chang's findings provide support for the argument that L2 interference is not the sole determinant of L1 attrition, but, like Chang, 2010 concludes, "a cross-language phonetic phenomenon that is much more multifaceted than the segmental interference constituting the focus of current L2 speech models" (p. 170).

Mayr, Price, and Mennen (2012) studied L1 phonetic attrition in a pair of Dutch monozygotic twin sisters, 'MZ' and 'TZ': The bilingual sister, MZ, who moved to England at age 32 (LoR = 30 years) and subsequently became L2 (English) dominant, and the monolingual sister, TZ, who had never moved away from the Netherlands. Mayr et al. (2012) analyzed VOT and the vowel system in both sisters' L1 (Dutch) to investigate whether MZ's extended use of English affected her L1. The results showed that the Dutch of MZ had undergone phonetic change in various domains. Two patterns emerge in the results that are worth considering in more detail.

Firstly, as predicted by the SLM, MZ showed non-convergence with her twin sister in the VOT of voiceless plosives in her L1, Dutch, which she produced with longer, i.e., English-like VOT. In contrast, her VOT in voiced plosives did not show influence from English as her production of VOT here did not differ from her monolingual sister's VOT. The comparison of MZ's VOT in plosives in her L1, Dutch, and her L2, English, showed that she produced voiced plosives in English with shorter VOT than she did in Dutch, rendering her L2 voiced plosives non-targetlike.

Secondly, MZ's vowel system had shifted in the first formant (F1) which led to increased openness of her entire vowel system, yielding a vowel system unlike her L1 norm and closer to her L2 target-norm. Such a shift in F1 was predicted for the L1 vowels with a clear L2 phonetic equivalent, but not for others. However, some sounds of Dutch which lack an English equivalent – for example, the monophthongs /y/ and /ø/, and the diphthongs /ɛɪ/, /ɔu/ and /œy/ –also showed a shift in F1. Likewise, L1-L2 vowel pairs which Mayr et al. considered too different were shown to participate in the acoustic change towards English.

Taken together, previous results strongly suggest that L1 attrition in phonetics cannot be fully accounted for by purely L2-based frameworks such as the SLM's L1-L2 equivalence classification and, as Mayr et al. (2012) observe, that "a token-by-token explanation cannot fully account for the observed patterns" (p. 696). Consequently, previous results also indicate that L1 attrition in phonetics does not emerge as L2-induced CLI-effect but operates within and across various phonetic domains, following constraints beyond those introduced by the

L2. Indeed, Flege (2007) addressed the limitations of a binary categorization in his SLM, arguing that an overly simplistic application of category equivalence cannot account for the variation observed in linguistic development. In particular, he argued that categorization by perceived similarity, i.e., one based purely on (perceived) acoustic similarity and expressed in opposites such as ‘perceived as similar’ and ‘perceived as different,’ cannot accurately reflect phonetic gradience in cross-language variation and variability. Here, Flege (2007) highlights cases of differential substitution where learners from different L1 backgrounds have been shown to substitute a new L2 sound using *different* L1 segments despite the availability of both substitutes in both L1. To illustrate, although both German and Russian have /s/ and /t/, German L2 learners of English have been shown to substitute /s/ in place of English interdental fricatives. In contrast, Russian learners have been shown to substitute for /t/ instead. In Lombardi's (2003) account based on *Optimality Theory* (henceforth ‘OT’), differential substitution is argued to emerge due to different constraint rankings of the two languages such that “[θ] → [s] only happens in languages where there is explicit L1 evidence for a language-specific ranking of the constraints on Manner” (p. 227), a case referred to as “transfer case” (p. 227). In contrast, Lombardi claims that “[θ] → [t] happens in languages where there is no such evidence, and results from aspects of the grammar that have been retained from the initial UG (Universal Grammar) state” (p. 227), the “universals case” (p. 227). These differences highlight that analyses based on similarities between L1-L2 segment pairs must also be extended to include general laws observed elsewhere. This suggestion is by no means a new one and has been previously stressed by Flege (2007), who argued that “[c]ertain features may enjoy an advantage over others because of the nature of their acoustic (or gestural) specification, or their reliability of occurrence” (p. 268). Notably, Flege (2007) stressed the importance of taking phonetic and phonological characteristics such as perceptual and articulatory mechanisms, distributional restrictions as well as universal laws of sound change into account. Indeed, these may provide instructive insights to the question why some segments seem more susceptible to L1 change whereas others seem more resistant. To test for such dependencies and hierarchies in L1 phonetic attrition, an expansion of L1 phonetic attrition research to investigate phonetic properties other than VOT is necessary. Here, liquids provide an instructive case as they differ not only in their phonetic realization variants across languages but also in the way phonetic variants are distributed across positional contexts. As already mentioned above, most studies investigated L1 phonetic attrition of VOT and the vowel system. Other segmental properties received very little attention in comparison, and changes to liquids under L1 attrition are mostly uninvestigated. The following subchapter will review the small number of previous studies of liquids in L1 attrition and show that liquids offer a unique perspective on the developmental trajectories in L1 attrition.

By zooming in on L1 attrition and L2 acquisition of allophonic patterns, Chapter 4 will review previous studies and discuss their implications, namely that the acquisition and attrition of allophones indeed seems to be subject to general phonetic and phonological laws.

Chapter 4

(Un-)learning liquids and liquid allophony: Phonetic and phonological aspects

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4.1 L1 attrition of liquids: Phonetic and phonological restructuring in bilinguals

The section below will extend the previous section on L1 attrition in phonetics by focusing on previous research on L1 phonetic attrition of liquids. In particular, the section is intended to synthesize previous studies on liquids in L1 attrition and to demonstrate that previous results suggest that L1 attrition in phonetics and phonology does not merely emerge from bidirectional (or L2) transfer and instead seems to follow more general principles also observed elsewhere. In contrast to phonetics, structural changes to L1 phonological grammars, e.g., changes to allophonic distributions or the suspension of segmental contrasts, received little attention and are not predicted or readily accounted for by existing approaches. Although largely unexplored, it has been argued by Schmid (2013) that “it seems extremely unlikely that attrition could ever reach the level of phonological restructuring” (p. 119). This assumption has been contested by recent (albeit sparse) empirical evidence which – as will be reviewed in more detail in the section below – shows that L1 attrition seems to affect phonological constraints that regulate positional distributions of segmental realization variants (i.e., allophones) in the L1, and that attrition can affect phonological contrasts as well. Here, allophones offer a particularly compelling case as they are located at the intersection between phonological constraints that govern positional restrictions on the one hand, and phonetic gradience, variability, and variation on the other. They offer a unique perspective to explore if and how phonetic sound change and phonological restructuring (observed in changes to positional restrictions) are connected to L1 change and attrition. Here, I will draw from language acquisition research to provide additional insights into allophonic variability in the phonetic and phonological grammars of bilinguals to inform and support the account of L2 influence on the L1 which will be developed in Chapter 8 of this dissertation.

While only three studies – de Leeuw (2008), de Leeuw, Opitz and Lubińska (2018) and Bergmann et al. (2016) – directly aimed to investigate L1 attrition in laterals, L1 change to laterals has also been observed in a handfull of studies on L2 acquisition (e.g., Solon, 2017).

de Leeuw (2008) explored phonetic changes to word-final laterals in the read speech of German-Canadian English late bilinguals and asked whether the bilinguals' clear laterals in word-final position in their L1 (German) were affected by the dark word-final laterals of their L2 (English), i.e., whether their laterals were subject to L1 phonetic attrition. In her acoustic analysis of word-final laterals, de Leeuw measured the frequencies of F1 and F2 at 30ms before the offset of the lateral. Her results showed that late bilinguals' German laterals differed from those produced by the monolingual German controls as bilinguals produced word-final laterals with higher F1 frequencies across the board, and the male speakers[28] produced laterals with lower F2 frequencies, both of which correspond to more English-like laterals; that is to say, the German laterals produced by the bilinguals had become darker. de Leeuw also analyzed English laterals and showed that bilinguals in English also differed from the monolingual English controls in that the bilinguals produced clearer laterals than the monolingual native speakers of English. The results indicate that the late bilinguals were subject to L1 phonetic attrition of laterals but crucially did not unify the L1 and the L2 sound into a single merged category, providing evidence that L1 attrition and change do not require an L2 equivalent to replace a phonetic structure in the L1. Instead, attrition seems to emerge even when late bilinguals maintain a relatively clear separation between the L1 and the L2.

Bergmann et al. (2016) investigated word-initial laterals in their group of German-American bilinguals. Using spontaneous speech data for the late bilingual group and various pre-existing datasets for a monolingual comparison,[29] Bergmann et al. measured F1 and F2 frequencies in word-initial laterals in both languages. Their results show that the late

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[28] Note that in de Leeuw's (2008) sample, only three speakers were male whereas seven were female.

[29] Bergmann et al. (2016) compiled data from various sources for their study; thus, the datasets differed with respect to the time of collection and the purpose for which the data was collected. The monolingual dataset contained 48 speakers from Michigan, 10 speakers from Texas and neighboring states, and five speakers from the areas around Toronto and New York. These inconsistencies, especially with regard to the bilingual population, may also account for some explanatory issues.

bilinguals produced German laterals with a higher F1 as compared to the German monolingual data, whereas their F2 remained unchanged.

Bergmann et al.'s results reflect de Leeuw (2008) observations for coda laterals in showing that laterals are subject to change when located in word-final position, and that a change to laterals can occur in onset and coda position. However, the comparability of the results is strongly limited as the studies differ regarding how laterals were measured (30ms before the lateral offset in de Leeuw (2008), at the intensity dip in Bergmann et al. (2016)), and questions pertaining to the phonological dimension of English laterals, for example, whether L1 phonetic attrition affects laterals differently in onsets as compared to codas, remain unaddressed. Recall from Chapter 2 that laterals do not change uniformly across positional contexts in diachronic language change and seem to be subject to similar constraints that give rise to phonetic differences regarding positional distribution and phonetic properties across languages: These insights offer interesting perspectives to explore L1 attrition in more depth.

In this way, an L1 attrition perspective is not only a promising contribution but helps understand the behavior of laterals. That is to say, laterals offer a unique test case to explore the forces that shape L1 attrition and can help tease apart the contribution of an L2 as well as universal laws of phonetics to L1 attrition. Crucially, de Leeuw et al.'s (2018) study on L1 attrition of laterals provides tentative evidence that general laws may take precedence over constraints in an L2. In contrast to L1 attrition of allophonic realizations of liquids summarized above, de Leeuw et al. (2018) focused on L1 attrition of liquids in Albanian, a language which uses velarized /l/ and non-velarized /l/ contrastively. de Leeuw et al. explored whether the contrastive function of laterals in the L1 (Albanian) of Albanian-English late bilinguals was affected by the influence of their L2, English. More precisely, they investigated whether the Albanian-English bilinguals adopted the positional restrictions on the phonetic realization of laterals from their L2, English, and would produce the Albanian velarized lateral with a lower degree of velarization in onsets, and the non-velarized lateral unchanged (or more strongly velarized) in codas, i.e., whether they reduced the contrast between their L1 laterals. In their study, native monolingual Albanian speakers rated the nativelikeness of the bilinguals' laterals in onset and coda positions. The judgments revealed that some speakers were perceived to sound non-nativelike, albeit to a limited extent: Only two speakers were perceived to sound non-nativelike in some tokens with velarized /l/ in onsets (75% and 17% of the tokens respectively). In contrast, six speakers were perceived to sound non-nativelike in some tokens with non-velarized /l/ in the coda (between 17% and 100% of the tokens per speaker).

Interestingly, the distribution of non-nativelike tokens indicated the presence of an onset-coda asymmetry in magnitude of L1 attrition: The likelihood of non-velarized coda laterals to become more velarized (i.e., final light /l/ becoming darker) was higher than the likelihood of initial velarized laterals becoming less velarized (i.e., initial dark /l/ becoming lighter). Yet, de Leeuw et al.'s (2018) acoustic analyses showed that most bilinguals produced /l/ with formant values that did not differ from the monolingual controls' range. The results provide only weak evidence that general phonetic laws and phonological restrictions on positional variation and variability are active in L1 attrition.

In the case of rhotics, research on L1 attrition of phonetics is equally sparse. Again, two studies previously aimed to shed light on L1 phonetic attrition in rhotics, and – as also for L1 attrition in laterals above – both dealt with German-English late bilinguals and differed regarding the position of the rhotic under investigation: de Leeuw et al. (2018) investigated word-initial rhotics while Ulbrich and Ordin (2014) investigated changes to postvocalic /r/. In their case study on L1 attrition of German word-initial rhotics, de Leeuw et al. (2018) observed that late German-Canadian English bilinguals showed signs of influence from the L2. In an impressionistic auditory judgment, change to word-initial rhotics was particularly visible in one of de Leeuw et al.'s subjects who produced 43% of his German rhotics in word-initial position as an English approximant rhotic. The authors further submitted the non-German-like approximants to an acoustic analysis and compared them to the speaker's English rhotic productions. The results showed that the speaker produced approximant /r/ in German with F2 and F3 frequencies within the monolingual English range, indicating that he aligned with the English target in both languages. However, the F2 and F3 frequencies in his German rhotics were significantly higher than F2 and F3 in his English productions of /r/, indicating that the speaker distinguished his two languages acoustically despite using a segment from his L2 not present in his L1. de Leeuw et al. (2018) therefore show that attrition can affect highly salient L1 segments such as rhotics and can do so extensively in affecting almost half of the speaker's word-initial rhotics. Furthermore, the results indicate that a separation between L1 and L2 are maintained even in advanced cases, where an L2 segment has replaced a phonetically dissimilar L1 segment.[30]

Ulbrich and Ordin's (2014) study on the production of German and English postvocalic /r/ by German-English late bilinguals supplies further evidence that /r/ is affected by the L1 change in late bilinguals. In their experiments, Ulbrich and Ordin (2014) compared the production of English postvocalic /r/ across various structural contexts by two groups of late bilingual native speakers of a fully non-rhotic or /r/-vocalizing German dialect. Ulbrich and Ordin's results showed that the two bilingual groups differed in their production of English rhoticity. The Oxford bilinguals acquired a non-rhotic English variety (British English) which was expected to leave their L1 non-rhoticity intact, whereas the Belfast bilinguals acquired a rhotic variety (Irish English) which was expected to affect their L1 non-rhoticity.

The results showed that L1 non-rhoticity in the Belfast bilinguals who were exposed to rhotic English exhibited significant changes in their L1. Here, the Belfast bilinguals shifted from their L1 pattern of /r/-vocalization in German codas towards using a more non-vocalized realization of /r/. In contrast, the Oxford group showed only minor changes in the formant frequencies of /r/, suggesting that their L1 non-rhoticity was not only preserved by the lack of rhoticity in the L2 but also remained unaffected by other phonetic changes.

Ulbrich and Ordin's (2014) acoustic analyses revealed that the bilinguals in the Belfast group had adopted a steep drop of F3 towards the end of the pre-rhotic vowel – an essential characteristic of English rhoticity – in their L1, and this F3-drop emerged consistently across the different pre-rhotic vowel contexts. The change Ulbrich and Ordin observed suggests L2 influence on L1 non-rhoticity only if the START vowel precedes /r/. Also, the results did not follow a clear pattern in the remaining vowels: For instance, Ulbrich and Ordin argue that the results for SQUARE could not be interpreted due to the Oxford bilinguals' production of rhotic correlates in SQUARE in their L2, English. This result was unexpected as the bilinguals did not align with the phonetic non-rhoticity in the Oxford English monolingual controls.

Particularly compelling is the case of SCHWA, for which Ulbrich and Ordin included tokens featuring 'suffix -er' in their data. Here, the bilinguals produced German 'suffix-er' within the same F2 and F3 frequency ranges as the German monolingual controls. There is

[30] The reader is referred to the extensive discussion of phonetic heterogeneity among rhotics in Chapter 2.

thus no evidence for L1 phonetic attrition in the SCHWA of bilingual 'suffix-er.' In their L2 (English), the bilinguals produced 'suffix-er' on par with the English monolinguals, indicating a clear separation between both languages. Ulbrich and Ordin (2014) suggest that the lack of L1 change is related to the high frequency of 'suffix-er' in German. They interpret their results to support usage-based theories and argue that L2 exemplars reshape the psychoacoustic space previously occupied exclusively by the L1. However, they do not address whether other variables may also contribute to the differences of L1 change in /r/ across contexts. Crucially, the results seem to suggest that the influence of rhoticity in an L2 on L1 non-rhoticity is constrained by variables other than the frequency of a context. In light of the diachronic and synchronic variability of postvocalic /r/, Ulbrich and Ordin's (2014) results can be taken to imply that phonetic specifications of neighboring sounds such as the quality of the pre-rhotic vowel do not only shape variability and change to rhoticity across time but also predict the pathway of L1 phonetic attrition.

Anecdotal evidence for a clear case of L1 phonological attrition in rhotics comes from a case reported by Schmid (2011), who observed that a German-American late bilingual speaker in her sample[31] exhibited an exceptional degree of non-convergence with the German monolingual controls. In particular, the speaker exhibited a consonantal realization of postvocalic /r/. Also, her consonantal realizations of postvocalic /r/ were non-monolingual-like with regard to the German norm not only in that she used a consonantal variant but also in that her use of an English-like alveolar approximant in postvocalic position. Importantly, the speaker's productions of German /r/ in onset positions remained unchanged, i.e., were still convergent with the monolingual norm. While Schmid reported this as potential (albeit anecdotal) evidence for phonological change, it is in line with phonetic studies showing that /r/ is subject to lifespan change and suggests that allophones may display differential behavior under L1 attrition.

The studies reviewed above suggest that just like laterals, rhotics are susceptible to change under L1 attrition. Unlike laterals, rhotics lack the fine-grained onset-coda asymmetry found in laterals. In that sense, rhotic sounds offer less favorable grounds for investigations on

[31] The speaker was part of a larger sample in Schmid's 2000 dissertation which largely focused on morphological, syntactical, and lexical aspects of attrition and therefore does not provide in-depth analyses on phonological L1 attrition. The review above draws from Schmid's (2011) textbook '*Language Attrition'*, a research manual rather than an empirical contribution. At the time of writing this dissertation, I am not aware of a publication investigating the speaker more closely.

such asymmetries; The locus of variability in rhotics is found in the postvocalic position instead which is known to display phonetic gradience as well as categorical phonological change. Rhotics furthermore offer a vast spectrum of interactions with adjacent segments, allowing for gradience and hierarchical progression of change in L1 attrition to be explored.

4.2 Allophonic and phonetic acquisition of liquids in bilinguals

Due to the limited scope of previous research on L1 attrition of liquids and particularly L1 attrition of liquid allophony discussed in the previous subchapters, this chapter will briefly highlight insights into the acquisition of positional restrictions. To that end, the following subchapter provides further support of the link between L1 attrition as sound change across an individual's lifespan. In lieu of systematic studies of the L2 acquisition of rhoticity across various structural contexts, the section will present studies exploring laterals only.

Barlow, Branson, and Nip (2013) explored the acquisition of /l/-allophony by Spanish-English bilingual children (mean age = 4;7) in their two languages. In the bilinguals' native Spanish variety, /l/-allophony is absent, and clear /l/ is used invariably across all positional contexts, while their L2, English, features clear /l/ in the onset and dark /l/ the coda (discussed extensively in Chapter 2 of this dissertation). In their acoustical analyses, Barlow et al. (2013) measured both F2 and the F1-F2 distance, where higher F2 as well as more substantial F1-F2 differences are indicative of clear variants of /l/. Their results revealed that in English, the bilingual children had acquired targetlike positional allophones, as their onset laterals were clearer than their coda laterals. In Spanish, the bilingual children were also targetlike in that they did not produce positional differences and used clear laterals across the board.

While the bilinguals produced targetlike phonological distributions in each language, the phonetic realizations were non-targetlike. In comparison to the monolingual controls in each language, the bilingual children produced pre- and postvocalic /l/ in English with more substantial F2-F1 differences (more L1-like) and with a smaller F1-F2 difference in Spanish (more L2-like), which suggest that the bilinguals maintained distinct realizations for their two languages, albeit different from monolinguals in both languages. Furthermore, the comparison of the bilinguals' English and Spanish productions showed that the F1-F2 distance was lower in their English than in their Spanish. Finally, the bilinguals' postvocalic laterals differed across both languages whereas their prevocalic laterals did not: Their English postvocalic /l/ was darker than their Spanish postvocalic /l/ whereas their prevocalic /l/ in Spanish and English did not differ/. Barlow et al. (2013) take their results to show the bilingual children had merged their onset laterals into a single phonetic category but kept the categories separate for laterals in coda position. Barlow et al. (2013) argue that the partial phonetic separation of the languages and the targetlike production of the allophonic patterns in both Spanish and English provides evidence that the bilingual children had established separate phonological grammars for each language but operated in a merged phonetic system for both of their languages as implied by their merged category in prevocalic position.

In a similar study, Barlow (2014) investigated the production of laterals in Spanish and English by late bilinguals (mean AoA = 8.3 years), focusing on the acquisition of an allophonic pattern due to L2 influence. She shows that late Spanish-English bilinguals not only acquired the allophonic pattern of their L2, English, as evident in their darker laterals in codas as opposed to onsets, they also transferred the allophonic pattern variation from their L2 to their L1 (Spanish). In particular, Barlow's results reveal that the late bilinguals produced Spanish laterals in codas with a significantly lower F2-F1 distance than in onsets. This change in their F2-F1 difference seems to approximate a more English-like norm, indicating that the L1 of the late bilinguals is subject to phonetic and phonological L2 influence on the L1 in that the L2 impacts the phonetic shape of L1 sounds and can also introduce new allophonic patterns into the L1 (Barlow, 2014).

Finally, Solon (2017) studied the production of Spanish laterals and the suppression of lateral allophony, which is present in the L1 (American English) but absent from the L2 (Spanish), by instructed English learners of Spanish across various proficiency groups (first year, second year, third year, fourth year, and graduate). Her results showed that regardless of L2 proficiency level, learners produced Spanish laterals with lower F2 frequencies (i.e., darker in quality) than the monolingual control group, indicating that even advanced learners exhibit consistent phonetic non-nativelikeness. Solon's comparison of the acoustic difference between Spanish onset and coda laterals across groups revealed that less proficient learners produced darker laterals in codas than they did in onsets, but fourth year and graduate learners did not produce distinct positional allophones. The results showed that advanced learners were targetlike in that they successfully suppressed positional lateral allophones in their Spanish. Finally, Solon found that the interaction of task and proficiency level as well as the interaction of task and vowel quality modulated the degree of velarization in the lateral. Less proficient learners used darker laterals in the formal speech tasks, contrasting with advanced learners who did not produce task-based differences. Regarding vowel quality, the presence of back vowels correlated with the darkness of the laterals in some learner groups. In that sense, Solon's (2017) study demonstrates that non-allophony in the L2 requiring learners to suppress an L1 allophonic pattern can be acquired, but the successful suppression of L1 allophony seems confined to highly proficient L2 learners.

Finally, the asymmetry in the acquisition of lateral allophony which emerges in comparing the studies by Barlow (2014) and Solon (2017) implies that the direction of allophonic acquisition, from allophonic to non-allophonic like in Solon (2017), or from non-allophonic to allophonic like in Barlow (2014), plays a vital role for the progress of acquisition and can also be expected to affect L1 attrition. The comparatively late success in suppressing L1 allophony observed in Solon (2017) contrasts with the successful acquisition of an allophonic rule observed in Barlow (2014). This suggestion is merely a tentative one as neither the types of bilinguals nor the proficiency measures are comparable: In particular, Barlow's (2014) late bilinguals had a mean AoA of 8.3 years and proficiency was estimated using a self-assessment. Solon (2017), in contrast, tested instructed learners, using the length of formal instruction to reflect AoA, and proficiency using a grammatical proficiency score. Nevertheless, these implications validate future investigations into the acquisition of an L2, but also the loss of allophonic distributions in an L1, a question I will address in the study presented below.

4.3 Gradience and categoricalness in L1 attrition of phonetics and phonology

The studies on L1 attrition in the domain of phonetics and phonology, and especially the studies on L1 attrition of liquids and their allophonic and phonological characteristics that I reviewed above left several questions unaddressed which point towards unexplored domains which offer instructive insights into the process of L1 attrition. In particular, I pointed out that despite the lack of empirical support, previous work often implicitly assumed that the frequency of L1 use (together with other, albeit marginal external variables) induces L1 attrition and also modulates its progression throughout an individual’s linguistic development. This assumption contrasts with research on language development in other linguistic subfields (such as the studies outlined above) which has shown time and again that language use cannot exclusively explain the full spectrum of the effects of bilingualism on an individual’s linguistic system.[32] Somewhat oddly, these robust empirical findings have not been a prominent part of the research landscape of L1 attrition.

Moreover, much research focused on detecting transfer of linguistic features from the L2 to the L1 but neglected the research on changes which cannot come from the L2 to investigate whether attrition is (also) an expression of processes guided by universal laws which are also present in other areas of phonetics and phonology. The review on L1 attrition also demonstrated that typological, synchronic and diachronic variability and change to liquids is not limited to these domains, but also emerges in bilinguals across the lifespan as shown in some studies. Although these studies provided evidence that liquids are subject to constraints beyond those in the L2 and yield a hierarchical order of contextual variants in L1 attrition, this has yet to be tested empirically. The study presented in this dissertation aims to address some of these questions by shedding light on the origin of L1 attrition in an individual, offering a unified perspective on phonetic and phonological models of sound change as well as variability in L1 attrition to develop a fuller picture of an L1 in the bilingual mind.

So far, I covered two strands of research, the phonetics and phonology of liquids, focusing on their variability and behavior under sound change on the one hand, and L1 attrition as sound change in an individual and the link between L1 attrition and L2 acquisition on the other hand.

First, I highlighted that cross-linguistic, phonetic, and phonological evidence from diachronic and synchronic perspectives point towards the variability of liquids. In particular, we saw that they are involved in a range of phonetic and phonological processes which weaken or strengthen them, and regularly alternate with segments of the same type or segments closely related on phonetic and articulatory grounds. Variability and change in liquids does not only highlight the similarities between the two types of liquids, rhotics and laterals, but also points to shared developmental patterns (e.g., vocalization) that emerge and re-emerge within and across languages time and again as they also did throughout the historical development of English. Importantly, the previous chapters also demonstrated that

[32] Although a vast body of research addresses the problems in limiting research on bilingualism to L1-L2 interaction alone, the reader is referred to Grosjean (1989), whose programmatic essay provides a critical discussion of some inherent differences between monolinguals and bilinguals, and the dangers of comparisons using monolinguals as the yardstick for bilinguals' patterns in language use.

both the likelihood and the magnitude of emerging variability and change in liquids are shaped by (sometimes hidden) structural constraints and their interaction which arise from the phonetic specification of and the phonological restrictions on the liquid in question. In this sense, liquids offer a unique test case as they leave open various outcomes for language attrition which can shed light on the underlying processes that drive such developmental change.

Secondly, I reviewed previous research on L1 attrition to highlight that although L2 acquisition plays a vital role in L1 attrition, evidence for direct L2 influence by way of transfer from the L2 to the L1 is inconclusive. Similarly, external factors have received a great deal of attention, but have not been shown to predict the domains and the L1 structures attrition is more likely to affect, how severely the L1 will change, or in which ways L1 attrition progresses throughout variable contextual environments of a single structure. Especially L1 attrition in phonetics primarily investigated changes to the L1 from an L2 perspective; that is, most research has been conducted to investigate whether the predictions of the SLM hold for L1 attrition. Perspectives like these are often based on the (implicit) assumption that the L2 plays a vital role in L1 attrition, although the mechanism remains unclear. While intuitively appealing, the actual source of L1 attrition and the patterns that emerge under attrition are unknown as previous studies cannot fully account for L1 attrition based on the L2 alone. This gap may also be taken as to indicate that an L2 influence-based perspective on L1 attrition fails to capture the mechanisms in L1 attrition fully.

Chapter 5

Present study: Competing phonetic and phonological systems

5.1 Research objectives and research questions

The present study aims to address previous gaps by exploring the behavior of liquids, a class of sounds unified by the high degree of variability patterning along the same universal constraints within each member of the class, along a fine-grained structural continuum to shed light on the driving forces that determine the emergence and the course of L1 attrition. To that end, I will address these questions using bilinguals whose L1, English, and L2, German, contrast with each other on a whole number of phonetic and distributional specifications. This diversity offers a wide variety of contextual variants which may be differentially affected by L1 attrition; it is precisely these fine-grained differences which include both acoustic properties of /r/ and /l/ across various structural contexts and extend to their positional distributions that bear the potential to reveal which contexts can be affected and whether changes across these contexts can fall out from L2 influence alone. Moreover, in contrast to phonetic attrition, phonological attrition remains largely unexplored.

The present study investigates L1 attrition of liquids by exploring the relationship between L2 acquisition and changes to rhoticity and lateral allophony in the L1 of late bilinguals. More precisely, I ask which phonetic and phonological characteristics determine the emergence of L1 attrition and the structural properties of L1 attrition in progress of English liquids in the grammars of late bilinguals. As far as rhoticity is concerned, the research questions are as follows:

RQ (1): Research questions on L1 attrition of rhoticity

RQ (1a): To what extent does non-rhoticity in an L2 affect the allophonic distribution and the phonetic realization of L1 rhoticity?

RQ (1b): Which structural variables previously attested to affect rhoticity in language change and variability guide the progression of L1 attrition of rhoticity?

RQ (1c): Which language external variables guide the progression of L1 attrition of rhoticity?

Concerning laterals, the research questions are as follows:

RQ (2): Research questions on L1 attrition of laterals

RQ (2a): How does the absence of /l/-allophony in an L2 influence the phonetic realization of /l/-allophony in the L1?

RQ (2b): How do the acoustic properties of clear /l/ in the L2 influence the clear and dark /l/-allophones in the L1?

RQ (2c): Which language external variables guide the progression of L1 attrition of laterals and /l/-allophony?

Before turning to the description of the design features of the study below, I will briefly highlight the most important characteristics of liquids in the L2 of the late bilinguals in this study, German. More precisely, I will point out that German /r/ and /l/ behave similarly under language change and are comparable in terms of the patterns of variability from a phonetic and phonological perspective within the language. As far as their allophonic distribution and phonetic specifications are concerned, many varieties of German differ from English in a number of important ways. These differences can help shed light on L1 attrition in the late bilinguals' languages, which will be discussed later in this dissertation.

5.2 Comparing English and German

To uncover the allophonic domains in which English-German late bilinguals potentially deviate from the English monolingual norm due to the influence of an L2, the following sections are intended to briefly summarize relevant phonetic, phonological, diachronic, and synchronic characteristics of German liquids.

German rhotics are subject to considerable regional, social, and individual variation, although regional variation often takes precedence of the other two sources of variation (Wiese, 2000). Yet, research on German liquids and on /r/ in particular is sparse especially in terms of recent empirical investigations which are limited to a handful of regional dialects; in contrast, older material is often limited to prescriptive or impressionistic rather than data-based accounts.

Generally, the phonetic variants of rhotics in the dialects of German are said to fall into one of two primary or ‘conservative’ categories, apical trills and uvular trills, both of which are articulatory complex and highly marked sounds.[33] It is important to note however that the two conservative realization variants are rarely used by speakers of contemporary German, who tend to substitute them with fricatives or closely related sounds such as vowels (Schiller, 1999). Wiese (2003) sees this extensive synchronic variation as an extension of diachronic change and that recent changes in German /r/ are part of a continuum which was also active diachronically. In that sense, Wiese’s (2003) argument can be interpreted to suggest that the synchronic variants of German /r/ are incarnations of diachronic language change which emerge in a cyclic fashion and alternate with other members of the continuum in short intervals. Reductive processes which affect /r/ are believed to be subject to structural constraints which – in some dialects obligatorily, in others optionally – block vocalization and deletion (Wiese, 2011).[34]

[33] Little is known about the origin of uvular /r/ in German. One widespread hypothesis on the origins of uvular /r/ is contact with French which may have led to its introduction to German (Schiller, 1999). Conversely, Schiller (1999) argues that uvular /r/ may have been present in German before the first contacts with French. For a detailed discussion of the historical origins of German uvular /r/, see Schiller (1999).

[34] It is worth mentioning here that apart from vocalization and deletion, other processes also result in an avoidance of /r/ in postvocalic /r/ in German. In some East Franconian dialect regions (most prominently around Nuremberg), for instance, postvocalic /r/ followed by a labial or velar consonant in complex codas is avoided by insertion of epenthetic vowels, leading to a resyllabification of the previously postvocalic /r/ into the syllable onset of the new syllable. In these dialects, the word *Berg* surfaces as [ʻbɛrɪj] (see Rowley 2013).

Thus, modern Standard German is often classified as variably rhotic, for example by Müller (2012) who suggests that German r-vocalization is moderated by clear-cut rules. In line with prescriptive norms for German pronunciation, he argues that vocalization is sensitive to the length of the preceding vowel, where /r/-vocalization is obligatory when postvocalic /r/ follows a long vowel and blocked if /r/ follows a short vowel. Müller illustrates this with the *Restricted R-Vocalization* rule shown in (22).

(22) Restricted /r/-vocalization (from Müller, 2012, p. 95).

Coda

ʁ → ɐ̯ / V: ⊥

There are, however, some exceptional patterns in which /r/-vocalization is obligatory after a short vowel, as shown in the vocalization rule in (23).

(23) Realization of /əʁ/ (from Müller, 2012, p. 94).

Rhyme (w)

əʁ → [ɐ̯] / ⊥ (CC)

Additionally, morphological information exceptionally triggers obligatory vocalization in prefixes with /ɛ/, which Müller (2012) illustrates in the rule shown in (24).

(24) /r/-vocalization in German prefixes (from Müller, 2012, p. 96).

/ɛʁ-, fɛʁ-, tsɛʁ-, hɛʁ-/ → /ɛɐ̯-, fɛɐ̯-, tsɛɐ̯-, hɛɐ̯-/

Condition: σ_w

The rules illustrated in (22), (23) and (24), however, are not representative of rhoticity in contemporary Standard German, or indeed many other German dialects. Some (e.g., Wiese, 2000; Hall, 1993; Krech, Stock, Hirschfeld, & Anders, 2009) claim that norms that prescribe consonantal variants of /r/ are largely enforced by pronunciation dictionaries rather than a reflection of native speaker norms. Müller (2012) considers variable rhoticity, i.e., occasional consonantal realizations of postvocalic /r/, a feature of the *conservative* accent which has been replaced by a *progressive* accent where /r/-vocalization has been generalized to short vowel contexts. The generalized rule, shown in (25), also finds empirical support (e.g., studies by Graf & Meißner, 1996; Ulbrich & Ordin, 2014)[35] and reflects modern German rhoticity both in Standard German and in many German dialects more accurately as compared to more conservative accounts.

(25) Generalized R-vocalization (from Müller, 2012, p. 108).

Coda

ʁ → ɐ̯ / ⊥

Conditions:

i. No application to ambisyllabic /r/

ii. Optional after checked vowels

In contrast to English, the German allophone of postvocalic /r/ is [ɐ] – often referred to as *dark* S*CHWA* or *a-*S*CHWA*, which leads to diphthongization of the vowels that precede the /r/ with the exception of [a] and [ə]. When [a] precedes a postvocalic /r/, [a] is lengthened rather than diphthongized, a result of the high acoustical similarity between [a] and [ɐ]. The sequence [ər], on the other hand, is not diphthongized but fully substituted by [ɐ]. This substitution results in minimal pairs for words ending in [ər] and those ending in [ə], such as *bitte* [bɪtə] and *bitter* [bɪtɐ].

The relationship between the phonetic quality of /r/ and the likelihood of vocalization in German is unknown, although anecdotal observations[36] suggest that phonetic quality of /r/ may influence the frequency of vocalization. Hall (2003), for example, argues that apical trills are more resistant to vocalization than uvular /r/ which are found in most dialects of modern German. Wiese (2003), however, observes that a change in phonetic quality is possible regardless of the direction, thus observing no blocking tendencies of phonetic qualities of /r/.

[35] The author of this dissertation, a native speaker of East Franconian which is also the target variety of the late bilinguals and the native dialect of the German monolingual controls in this study agrees with the results of these studies in that East Franconian and most German dialects are fully non-rhotic. Intuitively, even minor degrees of residual rhoticity in German trigger an association with an exceptionally high speaker age.

[36] I refer to these as anecdotal observations as they are based on re-interpretations of comparatively old dataset rather than recent experimental data.

Schiller (1999) remarks that the type of coda can also influence the likelihood of /r/-vocalization and that /r/ is more likely to be vocalized in simplex codas. However, Schiller does not provide empirical data to back up his claim.

In contrast to English, German postvocalic /r/ arguably carries a lower sociolinguistic load. For example, modern German rarely makes use of the rhotic/non-rhotic dichotomy to express social and individual speaker characteristics within a speech community. Conversely, the phonetic quality of /r/ may indeed convey social and individual information on the speaker such that some regional variants of German /r/ fulfill a social function as markers of regional identity. One such example is of relevance due to the regional affiliation of the speakers in the study presented below: In particular, the conservative East Franconian[37] variant of /r/ functions as a highly salient marker of regional identity despite its severe stigmatization outside of East Franconia.

Although a wide range of other processes involving postvocalic /r/ is attested across regional varieties of modern German, much of the remaining is confined to /r/-sandhi, albeit to a lesser degree. In several Bavarian dialects, for instance, linking /r/ is attested, a feature absent in most dialects of German.[38] However, many of these observations are based on comparatively old datasets (e.g., Ulbrich, 1972). Apart from a general change in phonetic quality, changes in the positional distribution of German /r/ can be observed diachronically. Like the development observed in English, German developed complete non-rhoticity only recently.[39]

While little research has been dedicated to modern German rhotics, even less is known about the status of laterals in the mainstream varieties of German. This lack of interest most likely falls out from the arguably regular and symmetric behavior of laterals in German, which generally does not feature context-sensitive /l/-allophony in most varieties. The lack of

[37] East Franconian is a subgroup of the Franconian dialects, but typically referred to simply as Franconian (or, in German, Fränkisch). It is spoken in Northern Bavaria, but also in Northeastern Baden-Württemberg, and some areas of Southern Hesse and Thuringia.

[38] The absence of linking /r/ in most varieties of German is argued to be a consequence of the lack of vowel-initial words in these dialects. It has been argued that words which seem to be vowel-initial in fact have a glottal stop in the onset. This property prevents a preceding coda /r/ to be resyllabified into the following onset.

[39] As much of the literature on German /r/ is based on older datasets, it is difficult to estimate when this process happened. Typically, data indicates that speakers born in the second half of the 20th century show a strong decline of rhoticity. Note that in the data I present below, which was collected from 2014-2016, even older speakers (50 years and above) show complete non-rhoticity, which indicates that these speakers either participated in the change across their life span, or that the loss of rhoticity occurred earlier than typically estimated.

distributional variability seems to link to a lack of phonetic research as German laterals are considered invariant across positional contexts, although they can be expected to be strongly affected by the surrounding sounds.

These assumptions are largely confirmed by a cross-language comparison of velarization in laterals by Recasens (2012), who demonstrates that German laterals are of the very clear lateral type as compared to other languages in his sample. Like English laterals, German laterals too are subject to regional and sociolinguistic constraints, albeit socially conditioned variability is much more limited in German laterals. Nevertheless, some regional varieties show clear-dark-allophony of /l/ (e.g., Viennese German, see Moosmüller, Schmid, & Kasess, 2016) and /l/-vocalization (e.g., some Bavarian dialects, see Howell, 1991); however, if /l/-allophony emerges in German, it seems to follow universal trajectories also observed crosslinguistically, e.g., also in English.

5.3 Experimental design

The following paragraphs contain descriptions of the experimental tasks which were used to elicit acoustic data for the auditory and acoustic analyses of rhotics and laterals in Chapter 6 and Chapter 7 respectively, as well as the tasks used to estimate the late bilinguals' proficiency in each language. In addition, various sociolinguistic characteristics were elicited in the sessions to investigate the effects of external variables on the bilinguals' languages; these will be described in Chapter 5.4 below. The full set of test materials can be found in Appendix A.

5.3.1 Materials and procedure

The speakers performed three production tasks in their L1 (English), a text reading task, a map task and a conversation task, which were designed to investigate L1 attrition in the phonetic and distributional characteristics of English liquids. The three English tasks were designed to differ with regard to formality level with the text reading task as most formal condition, the map task as semi-formal condition, and the conversation task as the most informal condition. The formality condition was included to reflect the hierarchical emergence of L1 attrition across different levels of formality in previous research. In particular, informal speech was shown to be highly sensitive to attrition effects and to exhibit changes earlier than more controlled tasks (e.g., Major, 1992; see also Chapter 3 of this dissertation). Thus, the English speakers – the late bilinguals in their L1 and the monolingual American controls – performed a text reading task, a grocery map task, and a free conversation task (in that order). The German speakers – that is, the late bilinguals in their L2 and the German monolingual controls performed a text reading task as well as a conversation task in German. For the bilingual group, the German tasks were conducted after all English tasks had been concluded. Two of these tasks, the text reading task and the conversation task, were also used to elicit data in the bilinguals' L2 (German). The German data was collected to countercheck the patterns emerging in liquids in the bilinguals' L2 to determine whether L1 changes were directly related to their L2. The following paragraphs provide detailed descriptions of the individual tasks.

5.3.2 Text reading task

As already mentioned, formal speech data was elicited using a text reading task in English and German. Previous studies on L1 phonetic and phonological attrition often resorted to word lists or sentence lists (e.g., de Leeuw, Mennen & Scobbie, 2012) which are likely to elicit a highly formal speech style. As already mentioned before, a formal speech style is known to be affected late in the attrition process (Major, 1992), and may draw the speaker's attention to pronunciation, skewing their pronunciation patterns. To avoid a list reading style, speakers were asked to read a text which was presented as a single coherent and culturally neutral semantic unit in both languages.[40]

The test items for English postvocalic /r/ were evenly distributed across six pre-rhotic vowel categories, NURSE (/ɝ/), NEAR (/ɪə/), START (/ɑː/), SQUARE (/ɛə/), NORTH (/ɔː/), and SCHWA (/ɚ/). The various pre-rhotic vowels were embedded in three different morpho-phonological contexts (WORD-FINAL (followed by a word beginning with a consonant), MORPHEME-INTERNAL, and MORPHEME-FINAL/WORD-INTERNAL) which have previously been shown to influence the presence and absence of postvocalic /r/ (see also Chapter 2.3.3).

The test items for German postvocalic /r/ were chosen to match the English items as closely as possible. Unlike the English set, however, the German set of pre-rhotic vowels was reduced to five, represented by NEAR, START, SQUARE, NORTH, and SCHWA, again with five

[40] The texts in the English and in the German version are included in Appendix A1 and A2 respectively.

tokens per category. NURSE was not included due to the lack of a close equivalent in German. The German pre-rhotic vowels followed by coda /r/ were embedded in the same three morpho-phonological contexts as the English items, although here, too, the distribution of items across morpho-phonological contexts was not controlled for.

Regarding laterals, the set of 18 English lateral tokens were comprised of six tokens for onset laterals, three followed by a back vowel and three by a front vowel, six tokens for coda laterals preceded by a front vowel and six coda laterals preceded by a back vowel. The 18 German lateral tokens were equivalent to the English lateral tokens in that they consisted of six tokens for each of the three contextual categories (6 x onset laterals, divided into front vowel and back vowel following the lateral, 6 tokens for coda laterals preceded by back vowels and 6 tokens for coda laterals preceded by front vowels).

5.3.3 Map task

In addition to the reading and conversation tasks which were also conducted in German, the English-language section of the experiment also included a map task intended to elicit L1 data in a semi-formal speech style as speech style is known to affect the surface severity of L1 change in late bilinguals (Major, 1992) and also affects the production of rhoticity by English monolinguals (Labov, 2006). The map task was thus intended to provide insights into L1 attrition, but also into the sound change affecting rhoticity. For the map task, speakers were seated on a desk with the materials - the map and the grocery list - in front of them. They were instructed to navigate through a grocery store, shown on the map pictured in Figure 5.1, to buy items for four different people on the grocery list. Pre-tests of the task showed that it was exceptionally difficult and time-consuming. Especially navigation on the map and locating the goals on the map posed serious issues for the participants in the pre-test. Thus, to reduce frustration levels and potential fatigue, the list was color-coded to match the aisle color on the store map to enhance orientation and prevent frustration. The speakers were made aware of the color coding in advance and were instructed to try and find the shortest way through the store while packing the items on the list into the shopping bag, each of which was labeled to match a name from the list. They were asked to verbally describe their way through the grocery store as well as the actions they performed in each aisle, e.g., picking up items. This elicitation method was intended to help elicit the test tokens embedded in full sentences rather than individual words as in a reading list. The tokens were embedded in the map of the grocery store as well as in the shopping lists; the tokens located directly on the map were chosen to ensure that the speakers could not avoid them.

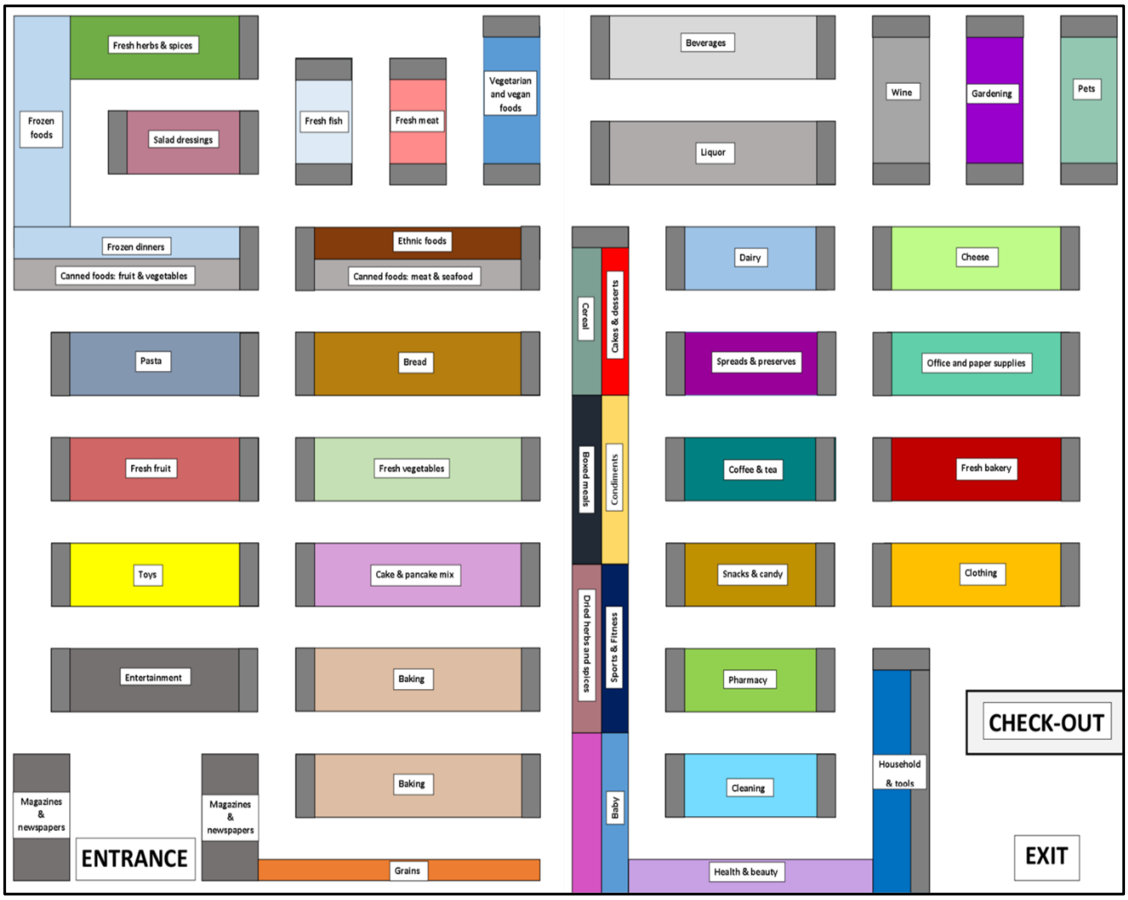

Figure 5.1: Grocery store navigation map from the map task.

The grocery map task contained a total of 24 test items for English postvocalic /r/ and 16 test items for English laterals. The test items for postvocalic /r/ were controlled for the same six vowels (NURSE, NEAR, SQUARE, NORTH, START, SCHWA) as used in the text reading task. For each vowel, two tokens were included which were uttered twice, amounting to 24 (2 tokens x 2 repetitions x 6 vowels) tokens for postvocalic /r/ in total. Again, as in the text reading task, morpho-phonological position varied across items. The test items for laterals consisted of four test items for onset laterals and four test items for coda laterals, each of which contained two items with a back vowel in the syllable nucleus, and two with a front vowel. Like the test items for rhotics, each word was repeated twice, resulting in a total of 16 test items for laterals (4 items x 2 repetitions x 2 positions).

5.3.4 Conversational speech task

Finally, the sociolinguistic interview was designed to elicit spontaneous and informal speech as the third production task in the English dataset, and as the second task in the German dataset. The interviews were semi-structured to maintain consistency of the conversation topics and were based on the sociolinguistic questionnaire.[41] The interviews lasted between 18 minutes and 146 minutes, depending on the speaker's level of comfort and willingness to provide personal information. Throughout the sample, but in some cases, questions were added spontaneously. This was necessary with a hand full of speakers who seemed particularly willing to continue the conversation. With some speakers, the additional questions were a vital part of the data collected, especially for those speakers who were very reserved and avoided talking entirely during some questions or provided only brief answers.

While the late bilinguals and the German monolingual controls were willing to answer the full set of questions on the questionnaire and provided long answers which elicited long sequences of continuous free speech, most American monolingual controls were hesitant to share personal information due to their professional circumstances. In particular, they felt visibly uncomfortable with some questions and often refused to provide answers to questions on their personal life including knowledge of foreign languages and exposure to foreign languages (e.g., stays abroad).

To avoid bringing the speakers into situations which they might perceive as uncomfortable, they were told that they might provide a partial answer or refuse to answer entirely; if the speaker chose to refuse, the questions were omitted. In most cases, the additional questions pertained to recent travel experiences around Europe and local customs and food were accepted, which the monolingual English controls were largely willing to provide detailled descriptions of.

In total, the aim was to collect the same number and structural distribution of tokens, i.e., 30 test items for postvocalic /r/ and 18 test items for laterals in English, and 25 test items for postvocalic /r/ and 18 test items for lateral allophones in German. However, the number of rhotics and laterals in the Conversation task could not be controlled.

[41] See Appendix A3.

The interviews were transcribed starting from the first question of the sociolinguistic questionnaire, and words that contained laterals and rhotics matching one of the conditions were extracted from the audio for analysis. Initial laterals and rhotics which were preceded by another liquid in the previous word, and coda laterals and rhotics followed by another liquid in the following word (e.g., *water leaked*, *fear red*, *feel low*, or *feel really bad*) were excluded from analysis as liquids exert strong co-articulatory forces on surrounding segments (Tunley, 1999). Some speakers produced fewer than the desired number of target items per condition, this affected mostly onset laterals followed by back vowels. In this condition, one speaker produced only two suitable items while the remaining speakers produced between three and six items. Naturally, this leads to unbalanced datasets for the conversation task for both rhotics and laterals; the statistical analyses were chosen accordingly.

5.3.5 Language proficiency tasks

5.3.5.1 C-Test

C-tests were included in the experiment to estimate the overall proficiency level of the late bilinguals in both of their languages. C-tests have been shown to provide reliable estimations of general language proficiency and are also frequently employed in placement tests (see also Klein-Braley, 2016 for an overall evaluation of the efficiency of C-tests). A C-test task consists of five short, coherent, and meaningful texts. In the classical paradigm, the first sentence is left intact, and starting from the second sentence, half of the word is removed from every other word. Each text is chosen in length to match the removal of half of the letters in 20 words in total, which resulted in 20 gaps per text.

The English C-test used in the present study was adopted from Keijzer (2007), and the German C-test was adopted from Schmid and Dusseldorp (2010). Both the German and the English C-test contained five texts in total with 20 gaps each, resulting in 100 gaps per language. The C-tests was timed in both languages with a time limit of five minutes per text. Thus, the C-test lasted a maximum of 25 minutes per language.

It is worth noting here that the written modality of the C-test also causes some serious issues which may affect individual outcomes independently of a speakers' proficiency level. Via the standard protocol, the first sentence of each text is intact. From the second sentence onwards, about half of the letters of every other word are deleted, and a gap line indicates the missing halves on the test sheet. The length of the gap lines is kept equal throughout the test sheets to avoid the speakers using the length of the line as an indication of the correct solution. In some cases, this leads to disproportionally large gaps, for example in cases where only one letter is missing (e.g., if the damaged word is '*in*'). Although the speakers were informed that the lines were all the same length, and that the length of a gap line did not reveal the amount of missing information, some speakers mentioned that they felt that the solution was too short. In some cases, the speakers added another word to fill the gap visually. If one of the two solutions was correct, the solution would have been considered acceptable and not counted as an error. This rule was not applied as speakers rarely provided more than one word to fill the gap, and whenever more than one word was used, none of the two was among the acceptable solutions.

The scoring of the C-tests was based on the solutions from the monolingual controls for each language who were also tested. If the solution provided by a native speaker in the control group deviated from the original text material but was both grammatically appropriate and semantically meaningful, the solution was added to the list of acceptable solutions. In this way, alternative solutions by the bilinguals were treated as correct if a monolingual speaker provided the same solution, and the solution was in principle correct. As the bilinguals did not go through formal instruction in their L2 and all speakers reported strong discomfort with German spelling, orthography was not included in the scoring.[42] The speakers were informed that orthography would not affect the scoring and instructed to guess a spelling if they were uncertain to avoid empty gaps due to spelling uncertainty.

5.3.5.2 Verbal fluency

A letter fluency test, the *Controlled Oral Word Association Test* (henceforth '*COWAT';* see Strauss, Sherman, & Spreen, 2006) was used to estimate the late bilinguals' verbal fluency in both languages. This task was included in addition to the C-tests, which primarily test for semantical and morphosyntactical knowledge, to estimate proficiency using a paradigm more closely associated with phonetic and phonological knowledge. Moreover, as a verbal task, the COWAT does not suffer from the same limitations as the C-test, which contained visual devices that may influence the speakers' answer.

[42] Although orthographical correctness was not included in the present analyses, the scoring methods offer such an option.

In a COWAT, fluency is operationalized as the total number of unique words that begin with the same sound a speaker can recall within a limited time span, usually within 60 seconds. Although most previous work in L1 attrition uses semantic fluency tasks in which speakers are asked to name words from the same semantic field (e.g., types of fruit), verbal fluency was selected for two reasons. Firstly, the relationship between semantic knowledge (and by extension, attrition in semantic properties in the lexicon) and phonetic and phonological knowledge is not straightforward. In contrast, letter fluency tasks tap knowledge at the intersection of the lexicon and phonetic knowledge and can be assumed to provide a more relevant (albeit still not a straightforward) proficiency measure for L1 attrition in phonetics and phonology.

Secondly, the variable interview locations provided some speakers with category members visible (e.g., a kitchen), thereby adding a confound.[43] Both measures have been shown to tap into lexical access, executive control, and inhibitory skills (Luoa, Lukb & Bialystok, 2010).

5.4 Participant characteristics

5.4.1 Bilingual participants[44]

5.4.1.1 Participants

The bilingual participants (n = 12) were recruited in the Lower Franconian dialect area via various social media outlets. The bilingual participants can be considered typical candidates for L1 attrition. All bilinguals were monolingual L1 American English speakers from different regions in the US. Care was taken to exclude candidates who spent a significant amount of time in traditionally non-rhotic areas of the US such as New York City, Boston, and the general Eastern New England area, as well as some areas in the South known to preserve non-rhoticity. Most speakers identified as speakers of General American English, although some (TGEL1-3, TGEL1-4, TGEL1-6, and TGEL1-7) identified as speakers of Southern US varieties. All bilinguals grew up in exclusively monolingual homes and

[43] Various circumstances prevented testing the speakers in the same location: Some were not willing to travel at all, and some were unable to do so due to physical constraints which made traveling difficult and potentially painful.

[44] A full list of bilingual participant characteristics, including the scores for the social variables and the proficiency measures can be found in Appendix A6.

confirmed to being monolingual at least until age 18. None of the bilinguals were proficient in languages other than English and German, although most had received formal instruction in another foreign language during High School, two reported that they had never received formal instruction in a foreign language.[45] Of the ten bilinguals who received formal instruction in a third language, eight reported one year of formal instruction either in Spanish or French; the remaining two received four years of French (TGEL1-12) and three years of German (TGEL1-3).

The late bilinguals were at least 18 years old upon their arrival in Germany and had lived in Germany consecutively for at least ten years; also, all speakers confirmed that they were integrated into German society in their daily life.[46] All bilinguals were employed in a German-dominant workplace and had a native German long-term partner, which lead to more frequent maintenance of family relationships with the German side of the family. All speakers except TGEL1-3 had no previous knowledge of German before coming to Germany, and all of the bilinguals acquired German mainly in a naturalistic setting, although some went through minor formal instruction throughout the years.

In a pre-test conversation, the bilinguals reported that they could entertain longer conversations in German about complex issues of daily life and had at least essential reading and writing skills in German. Finally, all of them were residents of East Franconian dialect areas and reported familiarity with the local German dialect. Table 5.1 provides an overview of the speaker characteristics of the late bilinguals.

[45] Of the two speakers who did not receive foreign language instruction, one mentioned staff shortage at his local high school (TGEL1-8), the other speaker (TGEL1-4) reported that foreign language instruction was not compulsory at his local school.

[46] Note that for a number of Americans living in Germany, daily life remains centered around American society. For example, some American nationals hold civilian employment with the American military, or work for American employers who do not require an integration into the surrounding society. In contrast, all late bilinguals tested for this study held jobs with German employers or, if they were retired at the time of testing, confirmed that their last employment was in a mainly German-speaking environment.

Table 5.1: Individual characteristics of the late bilingual speakers.

Speaker	**Sex**	**Area of origin**[47]	**AoA (years)**	**LoR (years)**
TGEL-1	Male	Illinois	19	33
TGEL-2	Male	Illinois	23	15
TGEL-3	Male	Texas	19	30
TGEL-4	Male	Alabama	26	32
TGEL-5	Male	Maryland	20	30
TGEL-6	Male	Georgia	24	26
TGEL-7	Female	Texas	26	24
TGEL-8	Male	New York State[48]	20	31
TGEL-9	Male	California	22	22
TGEL-10	Male	New York State	23	30
TGEL-11	Male	Missouri	19	38
TGEL-12	Male	Arizona	30	15

5.4.1.2 L1 and L2 affiliation and language use

Language use and cultural affiliation were assessed using the sociolinguistic questionnaire adopted from Keijzer (2007) and modified to suit the population in the study presented here.

Concerning their language habits, language use was estimated in self-assessments. The speakers were asked to estimate their language use on a five-point Likert-scale across various domains, e.g., as the languages used at work and with colleagues, at home with family members and friends, and in various domains of public life (e.g., in church or museums). The bilinguals were asked to provide the answers verbally during the sociolinguistic interview and were made aware of the five possible answers.

Attitude and cultural affiliation were elicited in the same way during the same sociolinguistic interview. Here, the set of questions regarding attitude and the perceived importance of the L1 and the L2 respectively were used for an assessment. The full questionnaire is provided in Appendix A.

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[47] In some cases, place of birth differed from place of socialization as some participants were born into active military families. In these cases, place of socialization (estimated by the number of years spent in an area below the age of 12) was used as area of origin.

[48] The New York State participants were carefully checked to avoid non-rhotic New York City speech affecting the results. Both New York State participants come from military families. None of them have spent any time in New York City except occasional visits, and none of them had family originating from or residing in New York City. Both participants originate from the Northwestern area of New York State and were born only a few miles apart.

The answers were scored in a stepwise fashion on a scale between 0 and 1 to reflect the five-point scale (0, 0.25, 0.5, 0.75 and 1 respectively). The bilinguals' scores for each question of language use were averaged which yielded a compound score; here, a score close to 0 indicated high L2 use, and a score close to 100 indicated high L1 use. Each speaker's average score was normalized via z-transformation to yield the variable 'LANGUAGEUSE.' The same procedure was used to calculate the compound variable AFFILIATION which reflects each speaker's normalized mean cultural affiliation score. The individual values for both variables can be found in the table in Appendix A6.

As expected, most speakers' LANGUAGEUSE score indicated that German is their primary language. This is not surprising considering that most participants held a job with a German employer at the time of testing and most bilinguals had L1 German partners, although the primary language of communication with immediate family varied. For example, some participants reported that they never use English due to the lack of English proficiency of their partner, others reported mixed use.[49] Although one participant reported never using English with his children, most speakers reported a mixed language mode with their children. As mentioned before, none of the participants regularly engaged in cultural activities leading up to an increase of L1 use; instead, German was the primary language for leisure activities and interactions with the extended social network. Also, the comparatively rural areas with close-knit local communities in which all participants lived at the time of testing contributed to a strong preference of German as the language of daily life.

5.4.2 Monolingual controls

5.4.2.1 American English monolinguals

The English monolingual group (n = 12) was recruited in Ansbach (CGEL1-1 to CGEL1-6), all of whom were attendees of a social event, a local American-German friendship group,[50]

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[49] In some cases, I was also able to briefly observe interactions with the partner before or after the testing. Only one participant used English with their partner during these observations, whereas two participants actively began translating for their partner when I used English. A third participant asked me to use English and pointed out their partner's lack of English proficiency. Low proficiency of the partners may be a direct result of the relatively high age of the partners, and thus relatively little formal instruction in English, as well as the educational background of the partners.

[50] Conversation with the participants revealed that this group has very few American members. Additionally, my own observations suggest that the attendees did not constitute a unified group: A small number of Americans socialized mostly with the German attendees, while most American attendees socialized very little with either

and in Ramstein (CGEL1-7 to CGEL1-12), all of whom were members of the same social network. Due to restrictions imposed by the occupation and living conditions of the monolingual participants, as well as the nature of recruitment, all Ansbach participants knew each other and shared a social network, as was the case for all Ramstein participants.

The monolingual participants came from various locations in the US, and regional background was matched to reflect the backgrounds of the bilinguals: The monolinguals came from Texas, Nevada, California, New York State, Georgia, Illinois, Michigan, and Vermont.

All participants had spent time in Germany for at least one year at the time of testing,[51] but, due to their military background and on-base living, reported little contact with their German environment. However, as military bases employ a number of local L1 German speakers of English in civilian jobs, daily contact to German-accented English is highly likely. Previous experience with German-accented English was considered desirable as familiarity with non-targetlike rhoticity produced by native speakers of German suggests that changes in pronunciation due to sociolinguistic accommodation effects can be excluded. Thus, due to extensive exposure and knowledge of phonetic and phonological characteristics of German-accented English, monolinguals were expected to show the same behaviors as bilinguals if the effect was based on speech accommodation only.

Some participants reported basic knowledge of German through formal language instruction: Participant CGEL1-3 reported one year of instruction in High School, and five participants (CGEL1-1, CGEL1-6, CGEL1-7, CGEL1-8, and CGEL1-12) reported a two-week instruction course upon their first stay in Germany, where instruction was limited to counting basic numbers and a set of simple sentences (e.g., ordering drinks). Apart from participant CGEL1-3 who took German for one year in High School, none of the speakers reported instruction in German pronunciation or grammar.

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of the latter groups. This may be caused by the age gap between on the one hand the mostly retired German members and a handful of older American members, and on the other hand the younger American group. Informal conversation with the younger American attendees revealed that most of them were first-time-attendees and were not part of the group. Coincidentally, all six Ansbach participants were members of the younger group.

[51] One participant (CGEL1-12) had come to Germany for a short-term visit and had been in the country for two months at the time of testing but reported multiple extended work-related stays in Germany in the past.

5.4.2.2 German monolinguals

In total, twelve monolingual speakers of German were recruited as a control group to establish a baseline for the bilinguals' L2 data. All German monolinguals were recruited in the East Franconian dialect area. They reported being speakers of either the local dialect or Standard German. Observations largely confirmed these self-assessments, although the speech of most exhibited regional characteristics in pronunciation as well as lexis. The German monolinguals were matched as closely as possible to the bilingual group regarding educational background, gender, and age, although the same close match as was the case with the American English control group could not be achieved.

5.5 Recordings

The bilingual group was recruited in the Würzburg area. At request, the bilingual speakers were offered to be interviewed at their home which nine of the twelve speakers opted for due to difficulties traveling. The remaining three speakers were recorded at the University of Würzburg. The bilingual sessions took approximately two hours for each language with at least one break in between, amounting to approximately four hours total per speaker.

As for the American English control group, the six Ansbach speakers were interviewed in a quiet room at the local public library in Ansbach, and the six Ramstein speakers were recorded in various quiet locations in Ramstein. Each session took approximately 1.5 hours to finish. The German control group was recruited in Würzburg and the surrounding area, and the interviews took place at the speaker's home except for one speaker who was interviewed in a quiet room at the University of Würzburg. As for the American controls, the German control interviews lasted around 1.5 hours per speaker.

Before the session, the speakers were provided with a rough description of the tasks verbally and in written form, after which a form of informed consent was provided and signed. The microphone remained running throughout the session, and speakers were made aware of this. Due to the potentially sensitive nature of the background questionnaire interview, which took place at the very end of the session, speakers were made aware that the microphone was still running, and informed that they might request deletion of personal information which they did not want to be recorded. However, none of the speakers requested any deletions. For both the German and American English monolingual group, sessions took approximately 1.5 hours as the monolinguals performed only half of the tasks and were not required to answer extensive sociolinguistic questionnaires.

The speakers were recorded in Audacity (Audacity Team, 2018) using a Samson G-Track condenser microphone connected to a laptop. The recordings were made at a sampling rate of 44.1 kHz at a resolution of 32 bit. The microphone was stationary and positioned on a table approximately 20 centimeters away from the speakers' mouths. Speakers were asked to avoid extensive body movement and repositioning in order to prevent disruption of the microphone.

As rhotics and laterals were operationalized differently and an analyzed separately, data treatment and analyses procedures will be described in the individual results chapters.

Chapter 6

Analyses and results: Rhotics

6.1 Phonological and phonetic analysis

6.1.1 Data selection and extraction

The dataset for /r/ was assessed auditorily with regard to the presence or absence of perceivable rhoticity and categorized into rhotic and non-rhotic (i.e., a vocalic variant or complete deletion) by the author of this dissertation. A random selection of 100 target items was furthermore rated by a second trained listener[52], which yielded an agreement rate of 94%.[53] Both raters re-evaluated the remaining 6% (n=6) of the items in the subset, and if the disagreement could not be resolved, the item was excluded from analysis. Even so, the reliability of auditory analyses has been questioned due to several problems associated with subjective judgment paradigms (Hall-Lew & Fix, 2012). In particular, individual differences between raters like the native language of the rater, the perceptibility of the sound across

[52] Both the author of this dissertation and the second trained listener are native speakers of German, and both are fluent speakers of English.

[53] The two raters disagreed on six tokens of which three were rated *rhotic* by the first rater and *non-rhotic* by the second, and three were rated *non-rhotic* by the first rater and *rhotic* by the second. This discrepancy can be accounted for by the perceptual characteristics of rhoticity by which it notoriously evades categorical (in this case binary) classification, even in rating experiments with native speakers. For instance, Heselwood and Plug (2011) demonstrated that rhotic quality is not perceived in binary categories but gradient: in their rating experiment, native speakers of American English heard two items which were sampled from a set of synthesized test items and varied with regard to the F3 value across the sound sequence. Heselwood & Plug's raters were asked to evaluate whether the second test item sounded *more rhotic*, *less rhotic*, or *equally as rhotic* as compared to the first test item they heard. Heselwood and Plug (2011) results revealed that although most native judges agreed in their judgement, some item pairs exhibited significant discrepancies. For example, in one pair they observed that 15% of the raters found the second item to sound 'less rhotic' than the first, 40% rated the item 'equally as rhotic', and 45% rated the second token as 'more rhotic'. Upon inspection of F3 in this particular pair, Heselwood & Plug found that F3 was close to 2000 Hertz, a frequency range in which perceivable rhoticity is believed to emerge. Thus, their study indicates that perceivable rhoticity is not determined by a threshold (as suggested by Hagiwara, 1995) and is instead gradient and subject to individual variation.

different phonological environments, and external variables such as a sociolinguistic rater bias leading up to incorrect perceptual coding based on (perceived) sociolinguistic characteristics of the speaker (e.g., Dalcher, Knight, & Jones, 2008) may act as confounds and skew the results. To check for such biases and to cross-verify the reliability of the auditory judgment presented below, an acoustical analysis was carried out, which will be presented further below in Chapter 6.5.4.

6.1.2 Formant analyses in postvocalic /r/

To investigate whether L1 change in the late bilinguals affected not only the distributional properties of postvocalic /r/ but also its phonetic characteristics in their L1 and whether phonetic and phonological acquisition in an L2 directly modulate L1 attrition in phonetics and phonology. Thus, the target items which were classified as 'rhotic' in the auditory analysis above were subjected to acoustic analysis using Praat (Boersma & Weenink, 2018).

As mentioned previously in this dissertation, the frequency of F3 as well as changes to the frequency of F3 arguably gives rise to audible rhoticity.[54] In particular, English /r/ is characterized by an exceptionally low F3 frequency, often 1000 Hz or more below a speaker's neutral F3.[55] The vast distance between the frequency of F3 in vowels and the frequency of F3 in /r/ induces anticipatory F3-lowering in English pre-rhotic vowels, yielding audible rhoticization, commonly referred to as '/r/-coloring' of the vowel.

Audible rhoticity has also been argued to result from the interplay of F2 and F3 in /r/ (e.g., Heselwood, 2009; Heselwood & Plug, 2011). More precisely, the frequency of F3 drops from its default (or 'neutral') frequency range of approximately 2500 Hz to approximate F2,

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[54] The term *audible rhoticity* rather than simply *rhoticity* is used to acknowledge the difference between *acoustic* and *articulatory* correlates of rhoticity. *Articulatory* correlates do not necessarily imply the presence of *acoustic* correlates of rhoticity; for instance, in some progressive varieties of Scottish English which are becoming non-rhotic and thus lack *acoustic* correlates of rhoticity, speakers have been shown to maintain *articulatory* correlates of rhoticity. For a more extensive discussion, the reader is referred to Lawson, Scobbie, and Stuart-Smith (2015).

[55] The word 'neutral' does not imply that F3 usually remains level across various phonological environments but refers to the average F3 observed in a non-rhoticized (or 'neutral') vowel. A vowel's neutral F3 – or, as Hagiwara (1995) shows, the pooled average of F3 across all neutral vowels – can thus be taken as a reference point for F3 in /r/. Crucially, neutral F3 does not drop below the threshold believed to induce audible rhoticity (usually taken to be ~2000 Hz). Hagiwara (1995, p. 52), for example, reports default F3 ranges of 2399 Hz to 2920 Hz across different vowels in male speakers, and 2743 Hz to 3495 Hz across vowels in female speakers, all well above expected F3 frequencies in /r/ itself, 1768 Hz and 2181 Hz in males and females, respectively.

surpassing the 2000 Hz-threshold which has been previously argued to trigger audible rhoticity. It is therefore necessary to take F2 of the pre-rhotic vowel into account as the quality of the pre-rhotic vowel imposes restrictions on F3-lowering. F2 expresses the back-front-dimension of vowels; Front vowels are characterized by high F2 frequencies whereas back vowels naturally have low F2. Arguably, the high F2 in front vowels imposes restrictions on F3-lowering as it blocks F3 from dropping below the value of F2; back vowels are not expected to impose such restrictions as their low F2 allows extensive F3-lowering.

The variable nature of the acoustic correlates of rhoticity (i.e., the height of F3 and F2-F3 distance) as well as the interactions between them indicate that rhoticity cannot be easily assessed without considering surrounding segments. Especially the pre-rhotic vowel can provide instructive insights into changes to rhoticity as they serve as a reference value to estimate the degree of F3-lowering in /r/ itself (e.g., Hagiwara, 1995). Also, the pre-rhotic vowel can also provide information on changes to anticipatory F3-lowering, which may offer insights into L1 attrition of phonetic structures larger than a single segment.

These objectives also have consequences for the type of formant measurement used in the present analyses. For example, measurements taken at fixed times or time intervals are not always suitable for segments (or sequences of segments) that are characterized by transitional phases between a vowel and /r/ as the length and location of the transitional phase differ across structural contexts, speakers, and situational variables. Such measurements do not necessarily yield consistent and comparable measurements which are independent of such confounding variables. Hay and Maclagan (2010) argue that F3 minima are indicative of the strongest degree of rhoticity of /r/. Similarly, maxima of F3 in the pre-rhotic vowel can be interpreted as the maximally neutral F3 which allows for an objective evaluation of the F3 slope in the [Vr]-sequence. Extending on Drager and Hay's (2012) and Hay and Maclagan's (2010) suggestions, the analyses below are based on F3 measurements taken at extreme poles of the F3 contour, the F3 maximum of the pre-rhotic vowel, which reveals the minimal degree of anticipatory /r/-coloring of the pre-rhotic vowel, and the F3 minimum of /r/ in the [Vr]-sequence, which provides insights into changes to the acoustic quality of postvocalic /r/ itself. Taking these considerations into account, F3 values were taken as follows: The target items were visually inspected to identify the [Vr]-sequence, which is taken to extend from the onset of the vowel to the offset of /r/, in the spectrogram. The onset of the vowel was identified using the onset of visible F1 and F2 contours in the spectrogram and labeled in a Praat Textgrid file; similarly, the offset of the [Vr]-sequence was identified using a visible decrease of formant intensity in F1, F2 and F3 when the word ended with the /r/, or the onset of the following consonant if /r/ was part of a consonant cluster and labelled as offset in the same Praat Textgrid file. The isolated [Vr]-sequence was then inspected visually, and markers were inserted at the highest F3 value in the pre-rhotic vowel and at the lowest F3 in the /r/ section. The markers were then checked auditorily to ensure that both markers were indeed located within the sequence and that no disturbing noise was present on the sound file. If the placement was confirmed, F1, F2, and F3 were measured at each marker, and the values were noted in an Excel sheet.

6.1.2.1 Normalization of the formant data

The formant data was normalized using the Bark difference metric (Traunmüller, 1997). Although the Bark transformation originally measures a psychoacoustic dimension, it has been shown to be effective in removing physiological differences between individual speakers from the formant data while retaining a large amount of variability caused by non-physiological differences, i.e., differences due to grammar-internal and grammar-external variables.

For the Bark difference metric, raw formant values in Hz are first transformed onto the Bark scale using the formula by Traunmüller (1997) shown in (26).

(26) $$\mathbf{Z_i = 26.81/(1 + 1960/F_i) - 0.53}$$

Bark-transformed values are indicated by the letter Z followed by the respective formant number; thus, Bark-transformed F1 is referred to as Z1, F2 as Z2, and F3 as Z3. To normalize the formants relevant to rhoticity, Z2 is subtracted from Z3, yielding the normalized value Z3-Z2 which expresses the distance between Bark-transformed F2 and Bark-transformed F3, i.e., the primary acoustic characteristic of rhoticity. Z3-Z2 will be used as dependent variable in the analyses below.

6.2 Statistical analyses

Statistical analyses were conducted in the statistical software R (R Core Team, 2017). Linear mixed-effects models (LMM) for continuous dependent variables (e.g., formant measurements), and Generalized linear mixed-effects models (GLMM) for categorical dependent variables (e.g., absence/presence of /r/) were used for the phonetic and phonological analyses respectively. All mixed-effects models and model comparisons were run using the lme4 package (Bates, Mächler, Bolker, & Walker, 2015). Pairwise comparisons using the Bonferroni-correction method to adjust p-values for multiple comparisons were conducted in the lsmeans package (Lenth, 2016) and its successor, the emmeans package (Lenth, 2018).[56]

Following standard practice, the model that provided the best fit to the observed data (henceforth ‘optimal model’) was selected using the following procedure: First, a full model, i.e., a model including all predictor variables as fixed effects were implemented, and in all analyses, WORD and SPEAKER were added as random effects.[57] Model reduction was conducted by building the maximal model and proceeding to reduce the model in a stepping-down fashion, i.e., removing one variable at a time, to improve model fit. Variables were removed from the model if they did not significantly improve model fit to the data, indicated by $p > 0.05$ for the variable in model comparisons. However, model comparisons of models with many variables often yield multiple variables with $p > 0.05$ in the same comparison step; this was also the case for most model comparisons reported here. When multiple variables had a $p > 0.05$, Akaike’s information criterion (AIC) was used to select a single variable for removal in the reduction step. AIC is frequently used in model comparison as it evaluates the quality of a model by weighting the trade-off between model simplicity and model faithfulness to the data (Burnham & Anderson, 2016). That means the AIC rewards model simplicity (i.e., the removal of variables from the model) and punishes loss of information (i.e., exclusion of variables which account for patterns in the data). The AIC therefore gives a relative estimation of a model’s goodness-of-fit relative to other (simpler or more complex) models by indicating whether removing a variable from the model is beneficial (i.e., if the

[56] *Functions used in lme4*: Generalized linear mixed-effects models and Linear mixed-effects models via the *glmer()* and *lmer()* commands respectively; model comparison and reduction via the *drop1()* command. Model reduction was conducted by building the maximal model and subsequently stepping down, i.e., removing one variable at a time. Variables were removed if they did not significantly improve the fit of the model to the dataset, indicated by $p > 0.05$ for the variable in model comparisons. If multiple variables had a $p > 0.05$, AIC was used to select variables individually. Functions used in lsmeans and emmeans: Pairwise comparisons via *lsmeans(model_name,[…], adjust =”Bonferroni”)*

[57] Exceptions to this are the analyses of the effect of external, i.e., social and individual variables in Chapters 6.3.1.6 and 6.3.2.4. The statistical analyses required averages to be used which means that *Word* could not be included as a random effect. Thus, in these analyses, *Speaker* was the only random effect.

model becomes simpler without losing a significant amount of information) or detrimental (if simplification results in a significant loss of information, see Burnham & Anderson, 2016).

6.3 Results: Presence and absence of /r/

The following subchapter is divided into two sections, the categorical data, and the results from the acoustical data.

6.3.1 Categorical analysis of the presence and absence of English /r/

6.3.1.1 Targetlike quality of /r/ in bilingual English

The auditory analysis of syllable-initial /r/ showed that the bilingual speakers consistently used an approximant variant of /r/ in English. The dataset contained a total of three instances of a non-L1-like variant of /r/; in all three cases, an L2-like equivalent was used. Two of the non-L1-like /r/ in English was produced by TGEL1-10 (bilingual subject 10), and one by TGEL1-6 (bilingual subject 6).

The auditory analysis of syllable-final /r/ showed that in post-vocalic position, all /r/ which were present (i.e., realized as consonants) were L1-like approximants.

6.3.1.2 Group comparison for the presence and absence of English rhoticity

Figure 6.1 shows the overall frequency of rhoticity produced by the late bilinguals and the monolingual English controls. Overall, monolinguals were nearly categorically rhotic (96.58%) while bilinguals showed reduced rhoticity (84.69%).

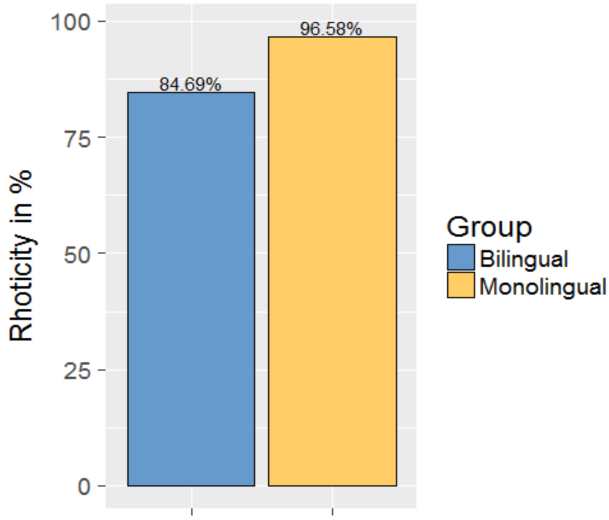

Figure 6.1: [%]-rhoticity degree of English rhoticity (in percent) by group, averaged across tasks and structural contexts.

To investigate group differences in the auditory data, a GLMM with SYLLABLE (four levels: word-final; pause; morpheme-internal; morpheme-final, word-internal), VOWEL (six levels: NURSE, NEAR, NORTH, SQUARE, START, SCHWA), GROUP (bilingual vs. monolingual) and TASK (three levels: grocery map, text, conversation) as fixed effects, and WORD and SPEAKER as random effects, as well as interactions of GROUP with the three structural variables was fit, followed by model comparisons to derive the final, reduced model.[58] The results reveal that none of the interactions of GROUP with one of the structural factors significantly improved the model, indicating that a model limited to variables as main effects provided best fit to the data. All structural variables were shown to be significant as main effects. The final model for the categorical data is given in Table 6.1.

[58] Throughout this dissertation, interactions between GROUP and other independent variables are considered relevant.

Table 6.1: Generalized linear mixed-effects model for the frequency of English rhoticity in late bilinguals in English and English monolingual controls.

<table>
<tr><td colspan="5">Random effects:</td></tr>
<tr><td>Groups</td><td>Name</td><td>Variance</td><td colspan="2">Std. Dev.</td></tr>
<tr><td>Word</td><td>(Intercept)</td><td>0.5742</td><td colspan="2">0.7577</td></tr>
<tr><td>Speaker</td><td>(Intercept)</td><td>0.7997</td><td colspan="2">0.8942</td></tr>
<tr><td colspan="5">Number of obs: 1966, groups: Word, 232; Speaker, 24</td></tr>
<tr><td colspan="5">Fixed effects:</td></tr>
<tr><td></td><td>Estimate</td><td>Std. Error</td><td>z value</td><td>Pr(>|z|)</td></tr>
<tr><td>(Intercept)</td><td>8.7556</td><td>1.1406</td><td>7.676</td><td>1.64e-14***</td></tr>
<tr><td>Vowel (START)</td><td>-1.8898</td><td>0.8755</td><td>-2.159</td><td>0.030877*</td></tr>
<tr><td>Vowel (NEAR)</td><td>-2.7051</td><td>0.9418</td><td>-2.872</td><td>0.004077**</td></tr>
<tr><td>Vowel (SQUARE)</td><td>-3.0957</td><td>0.9013</td><td>-3.435</td><td>0.000593***</td></tr>
<tr><td>Vowel (NORTH)</td><td>-3.1940</td><td>0.8365</td><td>-3.818</td><td>0.000134***</td></tr>
<tr><td>Vowel (SCHWA)</td><td>-5.2015</td><td>0.8460</td><td>-6.148</td><td>7.84e-10***</td></tr>
<tr><td>Task (Text)</td><td>-4.1165</td><td>0.7585</td><td>-5.427</td><td>5.74e-08***</td></tr>
<tr><td>Task (Conversation)</td><td>-4.4225</td><td>0.7534</td><td>-5.870</td><td>4.37e-09***</td></tr>
<tr><td>Syllable (Morph-Int.)</td><td>0.3948</td><td>0.3682</td><td>1.072</td><td>0.283701</td></tr>
<tr><td>Syllable (Pause)</td><td>1.0414</td><td>0.6046</td><td>1.722</td><td>0.084992.</td></tr>
<tr><td>Syllable (Morpheme-Final, Word-Internal)</td><td>1.5020</td><td>0.4575</td><td>3.283</td><td>0.001027**</td></tr>
<tr><td>Group (Monolingual)</td><td>2.3563</td><td>0.4556</td><td>5.172</td><td>2.32e-07***</td></tr>
</table>

The results demonstrate that the structural variables VOWEL, SYLLABLE, and TASK significantly modulate the presence of postvocalic /r/ across both groups. Furthermore, the significant GROUP effect with an estimated increase from the reference level ‘bilingual’ to ‘monolingual’ indicates that the monolinguals produced a higher rate of rhoticity than the bilinguals, which therefore show a significant overall decrease of rhoticity.

To investigate the impact of the individual structural contexts in the language-internal variables, pairwise comparisons were used to explore these differences further; these will be presented in the following sub-sections.

6.3.1.3 English rhoticity by vowel

Let us first explore the significant effect of differences in pre-rhotic vowel quality which was expressed by the variable VOWEL. Figure 6.2 shows the degree of rhoticity produced by the bilinguals in English and monolingual English controls across the different pre-rhotic vowels.

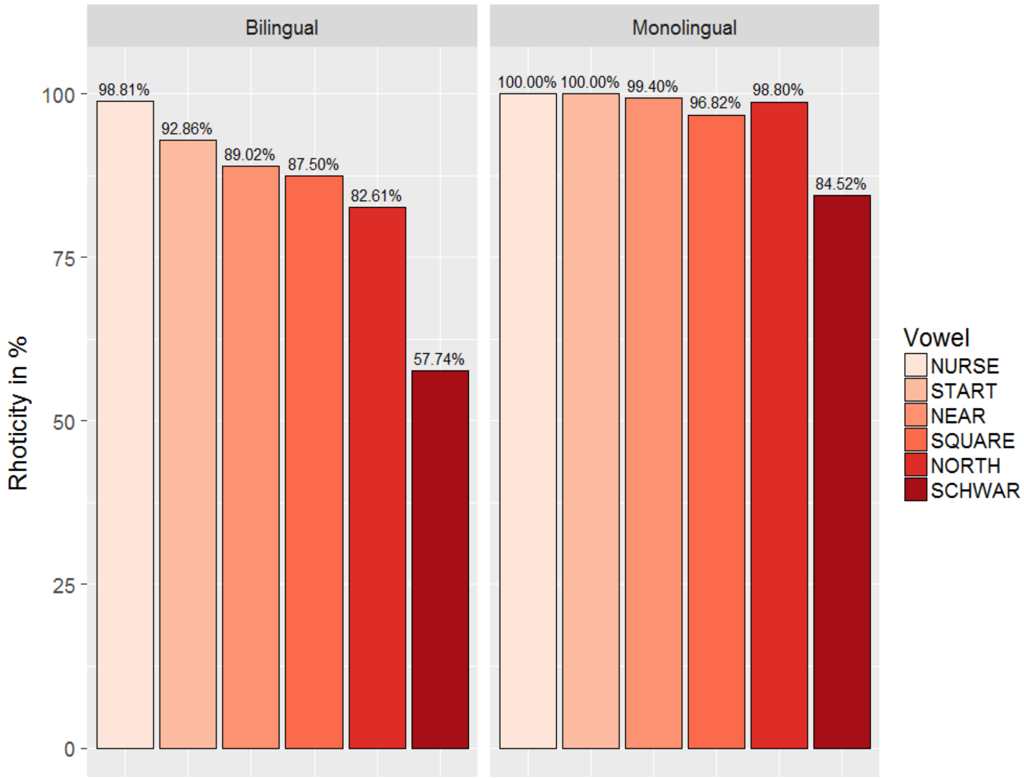

Figure 6.2: [%]-rhoticity produced by bilinguals in English and the English monolinguals, separated by pre-rhotic vowel.

Visual inspection of the distributional pattern in the bar chart in Figure 6.2 reveals that the pre-rhotic vowel quality modulates the degree of rhoticity in both groups but does so more severely for rhoticity in the bilingual group's English. That is to say, the results reveal an asymmetry between bilinguals and monolinguals, and some vowels enhance the effect more than others: After NURSE, both groups produced almost categorical rhoticity, but after SCHWA, where the highest rates of /r/-dropping were observed in both groups, the effect seems enhanced for the bilinguals. It is worth mentioning that this asymmetry suggests the presence of an interaction for GROUP*VOWEL, which however did not reach significance in the model shown in Table 6.1 above. The lack of statistical significance may result from the quasi-categorical nature of the monolingual data with rhoticity above 95% in most structural contexts. Naturally, a lack of variability in the data makes an evaluation of the sources of variability difficult. Due to the insufficiently robust GROUP*VOWEL interaction, an exploration of the potential interaction via pairwise comparison was excluded. Thus, differences between the individual qualities of the pre-rhotic vowel were explored in Vowel as a main effect using pairwise comparisons with Bonferroni-correction.[59] These results revealed that the vowel categories NURSE and START did not differ significantly from each other; however, significant differences in the frequency of /r/-dropping emerged in the following pairs: NURSE and NEAR ($p < 0.05$), NURSE and SQUARE ($p < 0.01$), and NURSE and NORTH ($p < 0.01$). Finally, SCHWA differed from all other vowel contexts (all ps < 0.001). It stands to argue, however, that the categorical nature of the monolingual data is unlikely to contribute significant information to these differences and that the effect is instead likely to be driven mainly by the bilinguals.

6.3.1.4 Rhoticity by morpho-phonological context

Figure 6.3 shows the frequency of rhoticity across morpho-phonological contexts (i.e., SYLLABLE) separated by GROUP.

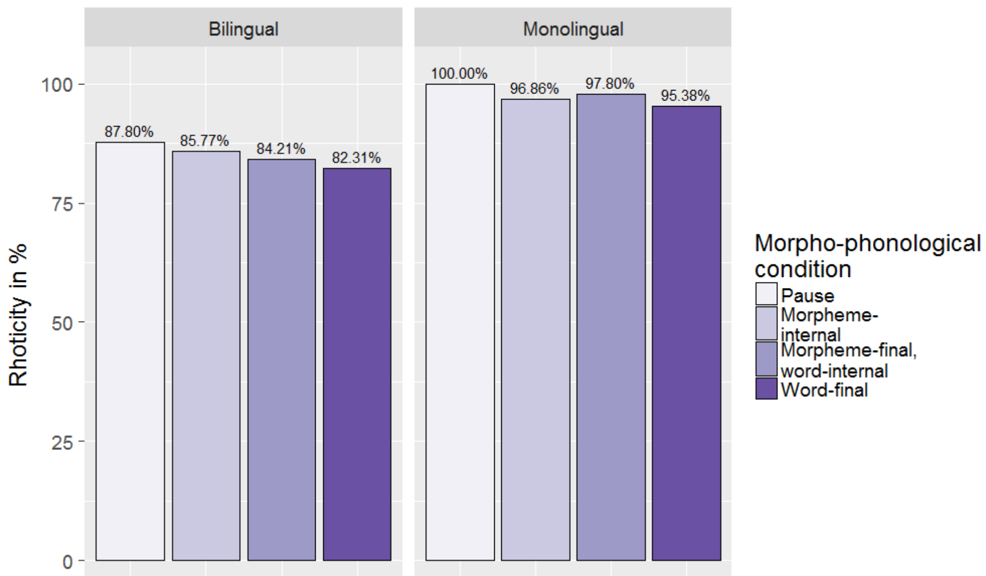

Figure 6.3: [%]-rhoticity produced by English monolinguals and bilinguals in English, separated by morpho-phonological context.

[59] Note that the pairwise comparisons were averaged across the variable GROUP to respect the lack of interaction between GROUP and VOWEL. While Figure 6.2 indicates a possible interaction between the two, the statistical analysis did not justify pairwise comparisons for the potential interaction GROUP*VOWEL.

As mentioned before, the GROUP*SYLLABLE interaction was not significant (p = 0.33), although both GROUP and SYLLABLE were significant main effects. Thus, monolinguals and bilinguals differ in the rate of /r/-dropping across morpho-phonological contexts, but do not differ with respect to the magnitude of the impact of the different types of morpho-phonological context. Subsequent pairwise comparisons of the main effect SYLLABLE revealed a significant difference only for the context-pair word-final position and word-internal, morpheme-final (p < 0.01), whereas all other pairs did not differ from each other.

6.3.1.5 English rhoticity by task

Figure 6.4 shows the frequency of rhoticity across TASKS separated by GROUP. Although the interaction GROUP*TASK was not shown to be significant in the GLMM, visual inspection of the graph across groups suggests that – as was the case for the variable VOWEL discussed above – the small number of non-rhotic tokens produced by the monolingual English controls does not provide sufficient evidence to reliably estimate an interaction.

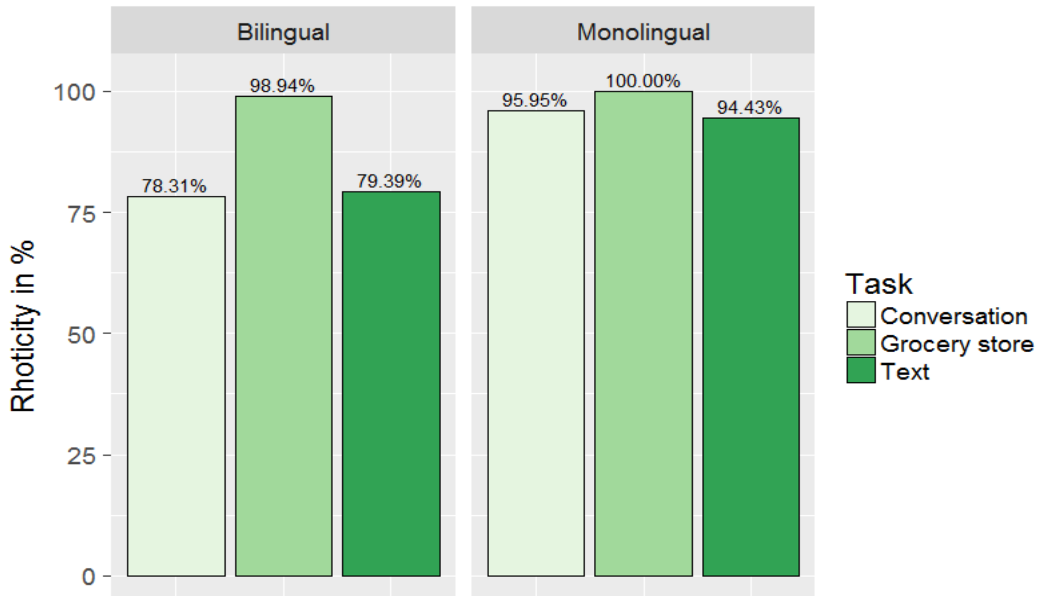

Figure 6.4: [%]-rhoticity produced by bilinguals in English and English monolinguals, separated by task.

Again, due to the lack of a significant interaction in the model, TASK was explored as main effect only using pairwise comparisons with Bonferroni-correction. The comparisons revealed that the grocery map task differs significantly from both text and conversation (both $p < 0.001$), whereas text and conversation do not differ from each other ($p > 0.05$). Again, it stands to argue that these effects are likely to be caused by the bilingual group.

To sum up the results for structural variables in the auditory analyses, the results demonstrated that the full array of structural variables which have been shown to influence English rhoticity in previous studies also significantly impacts the likelihood of /r/-dropping in the English of the speakers, and as indicated by the potential interactions with the GROUP variable, impacts the bilingual group more strongly. The following sections will investigate the effect of external variables which have also been shown to influence rhoticity in synchronic variation and also influence the extent of L1 attrition on changes to rhoticity produced by the bilingual group.

6.3.1.6 Inter-personal variability and the effect of external variables on rhoticity in bilingual English

Figure 6.5 shows the individual rates of English rhoticity by the bilingual group. The overall rate of rhoticity varies across speakers with maximally 95.06% rhoticity (TGEL1-12) and minimally 70.89% rhoticity (TGEL1-9).

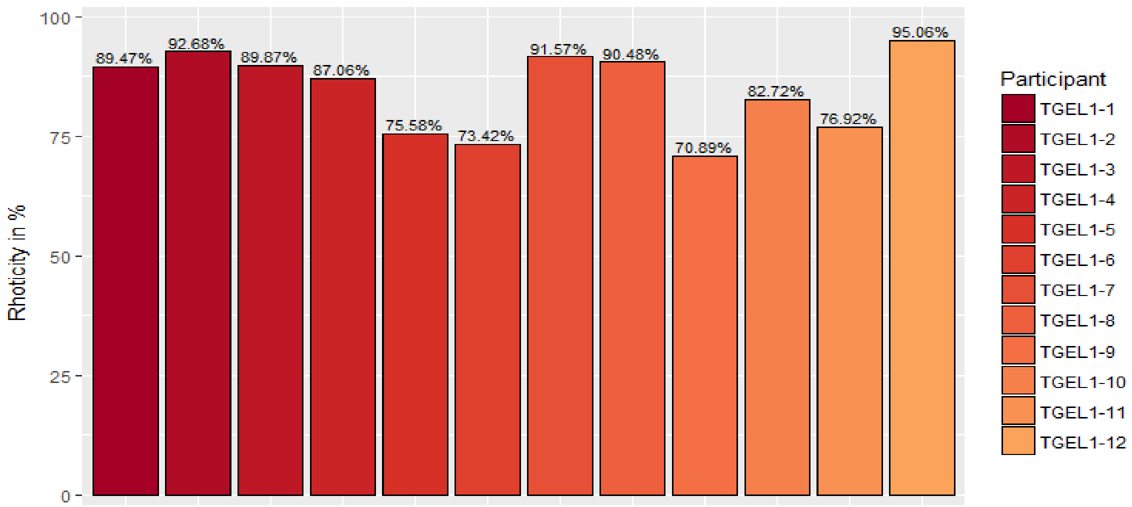

Figure 6.5: [%]-rhoticity rates of individual bilingual speakers in English across tasks.

As described in Chapter 3, a range of grammar-external variables believed to drive L1 attrition in bilinguals were included in the model to investigate the source of interpersonal variation. The GLMM included the external variables L1C-TEST, L2C-TEST, L1 FLUENCY, L2 FLUENCY, L1 USE DAILY LIFE, L1 USE PARTNER, and AFFILIATION,[60] additionally the significant structural variables already shown to impact rhoticity in Chapter 6.3.2.1.[61]

Table 6.2: Generalized linear mixed-effects model for the effect of structural and individual variables on the frequency of rhoticity.

Random effects:				
Groups	Name	Variance	Std. Dev.	
Word	(Intercept)	0.3555	0.5962	
Speaker	(Intercept)	0.2923	0.5406	
Number of obs: 973, groups: Word, 141; Speaker, 12				
Fixed effects:				
	Estimate	Std. Error	Z value	Pr(>|z|)
(Intercept)	2.9134	0.5866	4.966	6.82e-07***
Vowel (NORTH)	-0.6439	0.5506	-1.169	0.24222
Vowel (NURSE)	2.4679	0.9137	2.701	0.00692**
Vowel (SCHWA)	-2.3843	0.5010	-4.759	1.95e-06***
Vowel (SQUARE)	-0.2693	0.5211	-0.517	0.60530
Vowel (START)	0.5803	0.6123	0.948	0.34332
Task (Grocery)	4.3065	0.7299	5.900	3.64e-09***
Task (Text)	0.3088	0.2844	1.086	0.27757
Syllable (Morpheme-internal)	-0.9652	0.5073	-1.903	0.05707.
Syllable (Pause)	-0.7569	0.6749	-1.121	0.26208
Syllable (Word-final)	-1.4953	0.4977	-3.005	0.00266**
L1 C-test	0.3505	0.4632	0.757	0.44926

[60] See Chapter 5 for a detailed description of the characteristics expressed by each of the external variables.

[61] At this point it is important to refer the reader back to the model building process described in Chapter 6.2: Each statistical analysis started from the full model which included the full set of external and internal variables; the full model was subsequently reduced and compared to the previous model for best fit to determine the 'best', i.e., the final model. Note that the analyses in Chapter 6.3.1 are based on the same model, shown in its final version in Chapter 6.3.1.2, which also contains accurate p-values, and here (in Chapter 6.3.1.6) in its full version which does not reflect accurate p-values. The full model is provided here for the sake of demonstrating the lack of significant effects across the external variables.

L2 C-test	-0.1593	0.2753	-0.579	0.56288
L1 Fluency	0.5328	0.3201	1.664	0.09606
L2 Fluency	-0.5511	0.4366	-1.262	0.20691
L1 use (daily)	0.2426	0.3072	0.790	0.42976
L1 use (partner)	0.3824	0.4623	0.827	0.40815
Affiliation	-0.1617	0.3128	-0.517	0.60528

The model is shown in Table 6.2. Model comparisons revealed that none of the external variables yielded a significant improvement over a model without external variables. External variables could thus not be shown to affect language attrition in the categorical presence and absence of English coda /r/.

6.3.2 Categorical analysis of absence and presence of German /r/

6.3.2.1 Auditory analysis of quality of German postvocalic /r/ produced by bilinguals

The auditory analysis of the type of rhotic produced by the bilinguals in their L2 German showed that in those cases where the bilinguals were rhotic in their L2, i.e., when they produced a non-target-like consonantal /r/, their /r/ was an approximant. An exception is provided by three tokens, which were produced with either a uvular trill /r/ or fricative /r/: TGEL1-8 and TGEL1-10 produced one such token in the text task each, the third one was produced by TGEL1-12 in the conversation task.

6.3.2.2 Analysis of the effect of structural variables on rhoticity in German

The analysis of the German monolingual control group revealed that monolinguals were consistently non-rhotic with /ɐ/ or /∅/ as substitutes as expected based on previous assumptions of modern German rhoticity.[62] Due to categorical non-rhoticity in the German monolingual data, no subsequent analysis of the effects of structural variables was possible.[63]

Turning to the German data collected from the bilingual group, the analysis revealed that the bilinguals were not completely non-rhotic German; instead, postvocalic /r/ surfaced in 27.36% of the test tokens. The overall rates of rhoticity produced by the bilingual group in both of their languages, English and German respectively, are shown in Figure 6.6.[64]

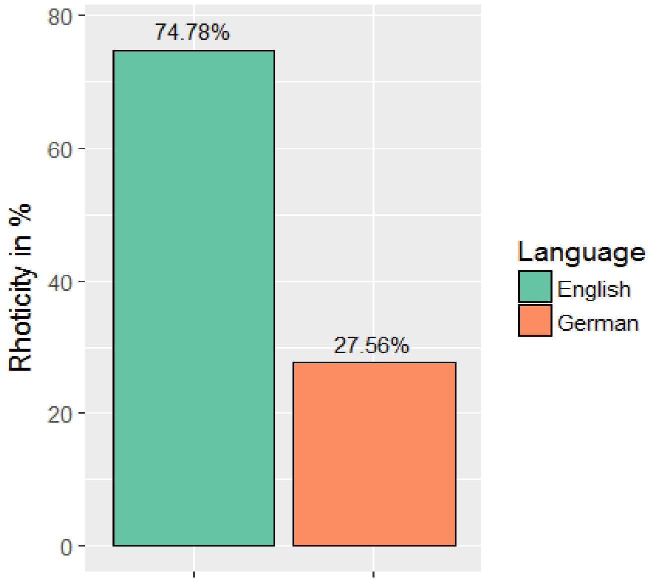

Figure 6.6: [%]-rhoticity in the bilingual group across both languages.

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[62] Exceptions are found in tokens with emphatic stress, all of which were produced with a consonantal /r/ by the monolinguals and bilinguals alike. Due to low frequency, test tokens produced with emphatic stress were excluded from all analyses.

[63] This is not to say that there are no structural variables which regulate German rhoticity: It is conceivable, for example, that structural constraints which do not surface, but may resurface given the right circumstances, such as situational changes, language contact and language change, are underlyingly present.

[64] Although one generally aims to avoid repetition, the instructive value of a direct visual comparison of the bilingual data in both of their languages is considered to outweigh the repetitive nature of the English data here. Furthermore, including the monolingual English and German data, both of which were (nearly) categorically rhotic or non-rhotic does not add instructive value.

As can be seen in Figure 6.6, bilinguals exhibit a large difference in the degree of rhoticity between both of their languages. Furthermore, although bilinguals are significantly less rhotic in German as compared to English, they produce residual rhoticity in German which was not observed in the German monolinguals, rendering them non-targetlike.

Due to the invariant nature of the data, fitting a GLMM to the German data resulted in convergence failures, which suggested that no reliable full model (i.e., a model with all structural variables included) could not be estimated by the algorithm. This error seems to be rooted in the overall structure of the data: All observations in the monolingual data are non-rhotic within the RHOTICITY variable. Thus, when trying to estimate the effect of structural variables on rhoticity, the algorithm fails due to a lack of rhotic observations. Simpler models were possible, but cannot be considered reliable either.[65] Therefore, statistical analyses of the full dataset may not provide reliable p-values. Tentative model comparison, however, revealed that a model including GROUP, VOWEL, and TASK provided best fit to the data in comparison to models in which either GROUP, VOWEL, or TASK were removed as fixed effects. This indicates the significance of all three variables, most importantly a significant difference between the bilinguals and the German control group. As the aim of this analysis was to determine the effect of structural predictors of rhoticity in bilinguals, and primarily whether potential structural influences are derived directly from the L1 or somewhere else, the monolingual control group was excluded from further statistical analyses. This also follows Guy (1997) in his recommendations for handling invariant responses, where he recommends using a subset of the available data in cases of separation.

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[65] A full model including all structural variables (SYLLABLE, VOWEL, TASK and GROUP as fixed effects, and SPEAKER and WORD as random effects) consistently returned convergence errors, while models in which either the variable SYLLABLE or VOWEL were dropped did converge. Convergence errors in GLMM may arise due to several reasons, e.g., the overdispersion of random effects or multicollinearity of variables. In the present study, the most probable cause of convergence errors was that the German monolingual data did not include variance within the factor RHOTICITY, which contained no observations of the [+rhotic] type. This lack of variance causes a convergence failure in the estimate the parameters (i.e., structural variables) influencing the degree of rhoticity. Nevertheless, to exclude a more fundamental flaw in the data or in the model specification which may have caused the convergence error, additional models were built and inspected. Here, two models with reduced random effects (one without SPEAKER and one without WORD) were built. Model comparison revealed that both random effects increased model fit, indicating that convergence was not due to a misspecification of random effects. To check for multicollinearity, the correlation matrix of the full model was inspected. None of the correlations indicated abnormal behavior or relationships among the variables (as indicated by extremely high or perfect correlations), suggesting that this was not the source of the error.

6.3.2.3 Influence of structural variables on rhoticity in German in bilinguals in comparison to their English productions

The results of the perceptual analysis of German rhotics in the bilingual group are presented in Figure 6.7, **Fehler! Verweisquelle konnte nicht gefunden werden.** and Figure 6.9, which provide a visual comparison of the bilinguals' frequency of rhoticity in English with the

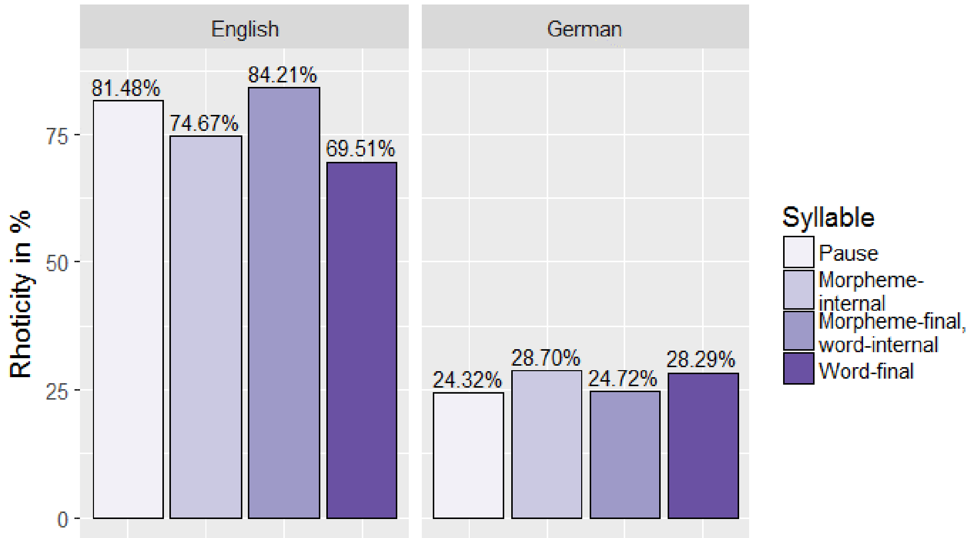

Figure 6.7: [%]-rhoticity comparison of English and German rhoticity across morpho-phonological contexts in the bilingual group.

bilinguals' frequency of rhoticity in German.

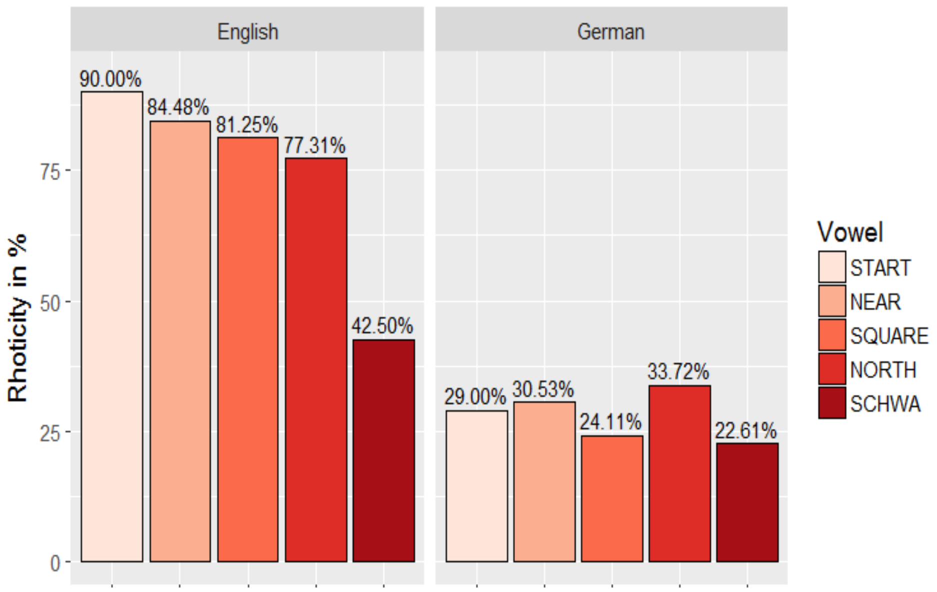

Figure 6.8: [%]-rhoticity comparison of English and German rhoticity across vowel contexts in the bilingual group.

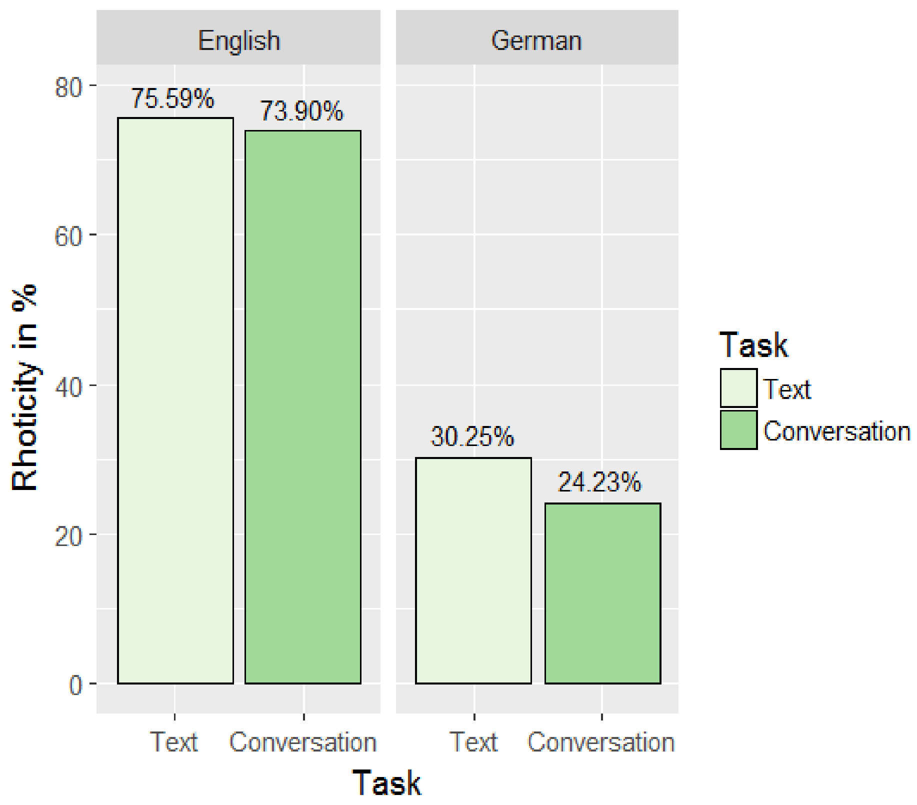

Figure 6.9: [%]-rhoticity comparison of English and German rhoticity across tasks in the bilingual group.

To investigate the effect of structural variables on the realization of postvocalic /r/ by bilinguals in German, a GLMM was built including the same structural variables which have been shown to influence rhoticity in the bilinguals' English to test whether bilinguals transferred phonological constraints of the L1 into the L2. Thus, VOWEL, TASK, and SYLLABLE were used as fixed effects, and SPEAKER and WORD were used as random effects. Model comparison of the full model including all variables revealed that SYLLABLE, VOWEL, and TASK did not significantly improve the model (p = 0.97, p = 0.43, and p = 0.16 respectively), suggesting that none of the structural variables known to influence rhoticity in English influenced the degree of rhoticity in the German of the bilingual group. The results of the full model (i.e., including all variables regardless of significance in model comparison) are shown in Table 6.3.

Table 6.3: Generalized linear mixed-effects model for the frequency of rhoticity in the late bilingual group in German.

Random effects:				
Groups	Name	Variance	Std. Dev.	
Context	(Intercept)	0.227	0.4764	
Speaker	(Intercept)	2.236	1.4954	
Number of obs: 508, groups: Context, 143; Speaker, 12				
Fixed effects:				
	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-1.80930	0.60734	-2.979	0.00289**
Vowel (NEAR)	0.26403	0.43367	0.609	0.54264
Vowel (SQUARE)	0.09655	0.43559	0.222	0.82458
Vowel (NORTH)	0.74703	0.52360	1.427	0.15366
Vowel (START)	0.54240	0.45944	1.181	0.23778
Syllable (Morpheme-Internal)	-0.09581	0.49275	-0.194	0.84583
Syllable (Pause)	-0.11277	0.61299	-0.184	0.85404

Syllable (Word-Final)	-0.02590	0.42196	-0.061	0.95106
Task (Text)	0.31357	0.27399	1.145	0.25242

6.3.2.4 Analysis of the effect of external variables on German rhoticity

As the previous analysis revealed that structural variables did not impact the bilinguals' production of coda-/r/ in German, external and individual characteristics of the bilinguals were analyzed to explore their effect on the late bilinguals' L2. Although not directly related to the question of L1 attrition of phonetic and phonological patterns, this analysis nevertheless reveals important insights into the relationship between L1 attrition and L2 acquisition. To investigate the effects of external variables on the acquisition of L2 rhotics, a GLMM featuring the structural variables (VOWEL, SYLLABLE, and TASK as fixed effects; WORD and SPEAKER as random effects) as well as the full set of external variables (L1C-TEST, L2C-TEST, L1FLUENCY, L2FLUENCY, LANGUAGEUSE, and AFFILIATION) was used. As none of the structural variables was significant, they were excluded from the final model. Model reduction and subsequent model comparisons revealed a significant effect of the two external variables L1C-TEST and L2C-TEST which were left in the model. These results indicate that both the L1 and L2 proficiency C-Test scores were significant predictors of the overall degree of rhoticity. The final model for the effect of external variables on the bilinguals' L2 German is shown in Table 6.4.

Table 6.4: Generalized linear mixed-effects model for the effect of external variables on rhoticity in bilingual German.

Random effects:			
Groups	Name	Variance	Std. Dev.
Context	(Intercept)	0.2514	0.5014
Speaker	(Intercept)	1.2132	1.1014
Number of obs: 508, groups: Context, 143; Speaker, 12			

Fixed effects:				
	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-1.5877	0.3797	-4.182	2.89e-05***
L1 C-test	1.3872	0.6931	2.001	0.0454*

L2 C-test	-0.8494	0.3816	-2.226	0.0260*

The relationship between L1 proficiency and rhoticity in German is shown in the scatterplot in Figure 6.10. In particular, speakers with a high L1 proficiency score produced a higher rate of rhoticity in their German as indicated by the positive estimate in the model. That is, speakers that maintained high proficiency in their L1 were less L2-targetlike in the production of German post-vocalic /r/.

The relationship between rhoticity and proficiency in the L2 showed the opposite effect: As expected, higher C-Test scores in the bilinguals' L2 (German), indicating a higher L2 proficiency, were associated with lower, i.e., more L2-like, rates of rhoticity produced in German. This relationship is presented in Figure 6.11.

Thus, the relationship of L1 and L2 proficiency indicate that a decrease of L1 proficiency and an increase of L2 proficiency both significantly predict the degree of attainment in an L2.

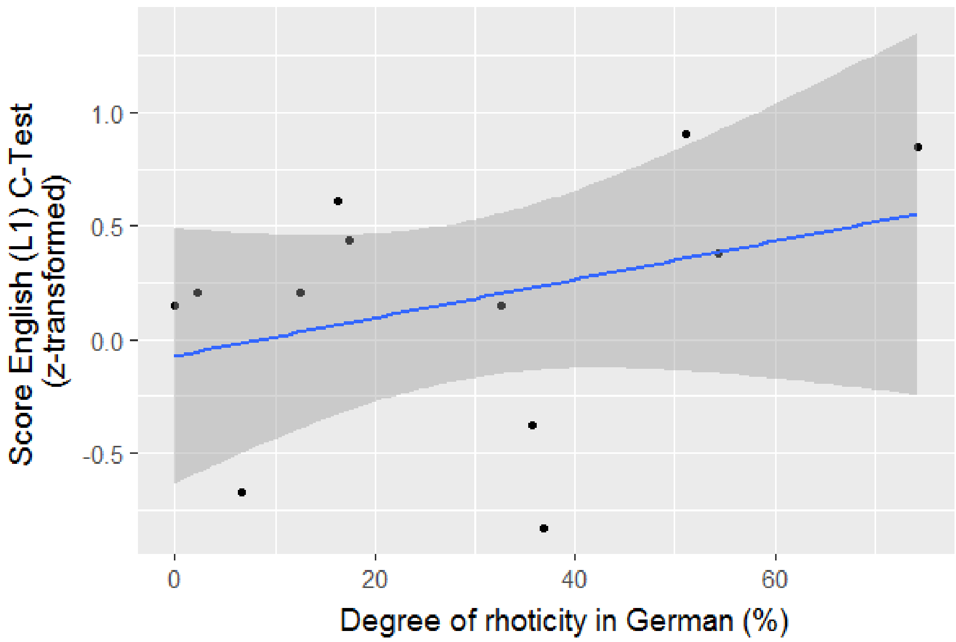

Figure 6.10: Relationship of C-Test scores z-transformed in the L1 (English) and degree of rhoticity in the German of the bilingual group. Scatterplot with added regression line; shaded areas indicate a 95% confidence interval.

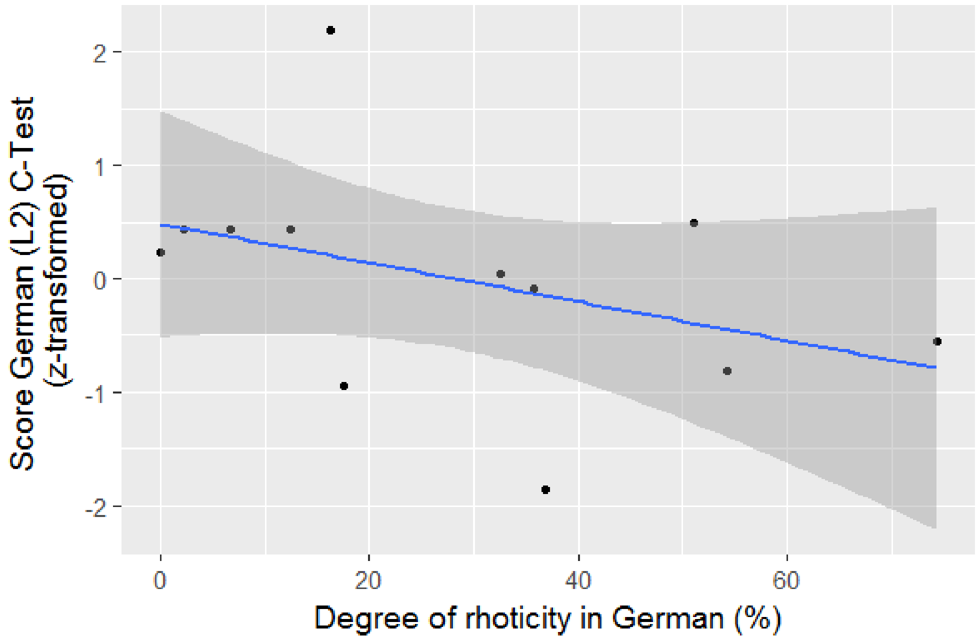

Figure 6.11: Relationship of C-Test scores z-transformed in the L2 (German) and degree of rhoticity in the German of the bilingual group.

6.4 Summary: Categorical data

The analysis of the presence and absence of postvocalic /r/ in both the L1, English, and the L2, German, of the bilinguals and monolingual controls presented so far provided several insights into L1 attrition, which will be summarized and unpacked in this section.

Firstly, the results demonstrate that non-rhoticity in the L2 induces a change to L1 rhoticity; however, such change is not subject to constraints which stem directly or indirectly from the L2. Instead, changes to L1 rhoticity seem restricted by constraints which also seem to give rise to the hierarchical pattern of (albeit marginal) non-rhoticity observed in the monolingual controls. Thus, the L1 grammar regulates the structural pattern of attrition of L1 rhoticity. Furthermore, the constraints carry a disposition that favors the progression of change observed here, as these reflexes can also be observed in the English monolinguals.

In particular, the results revealed that the bilinguals used vocalized and non-vocalized variants of postvocalic /r/ in both of their languages, and thereby differ from the English as well as German monolingual controls in both languages. In their L1, the bilinguals vocalized post-vocalic /r/ more frequently than the American English monolingual controls, leading to non-convergence with the monolingual norm in their L1, English. In their L2, the bilinguals failed to vocalize post-vocalic /r/ in their L2 categorically across the board, leading to a non-targetlike production of L2 rhoticity. Rhoticity in the bilinguals' L1, English, can be said to show the emergence of non-monolingual-like non-rhoticity, while their L2 German exhibits non-targetlike residual rhoticity. However, the bilinguals exhibited degrees of /r/-vocalization across the subcategories in both structural contexts (pre-rhotic vowel and syllable structure) which follow positional and contextual distributions also observed in the monolingual controls in both of their languages. That is to say, emergent non-rhoticity in the bilingual group's L1 (English) follows positional constraints also present in the English monolingual controls, whereas the residual rhoticity in the bilinguals' L2 (German) can be taken to reflect the monolingual German control group's lack of sensitivity to structural constraints, although naturally, the lack of significances does not provide evidence of the lack of effect.[66]

Let us account for the English data first. The results above revealed that emergent non-rhoticity in the L1 of the bilingual group was shown to be sensitive to structural variables, and some of the subcategories within the structural variables (quality of the pre-rhotic vowel and morpho-phonological environment respectively) were shown to trigger the emergence of non-rhoticity; (27) and (28) below illustrate the likelihood of r-dropping across individual subcategories across the structural variables pre-rhotic vowel and morphophonological context respectively.

(27) Likelihood of /r/-dropping in English across sub-levels of the variable pre-rhotic vowel, from left to right: least /r/-dropping to most /r/-dropping.

(27a) Bilinguals:

NURSE < START < NEAR < SQUARE < NORTH < SCHWA

(27b) Monolinguals:

START, NURSE < NEAR < NORTH < SQUARE < SCHWA

[66] Note that this interpretation, although not evident in the analyses due to a missing interaction between Group and Vowel, is in line with sociolinguistic studies which typically base those hierarchies on observable tendencies in the data rather than statistical interactions.

(28) Likelihood of /r/-dropping in English across morpho-phonological environments, from left to right from least /r/-dropping (left edge) to most /r/-dropping (right edge).

(28a) Bilinguals:

Pause < Morpheme-internal < Morpheme-final, word-internal < Word-final

(28b) Monolinguals:

Pause < Morpheme-final, word-internal < Morpheme-internal < Word-final

This pattern is reminiscent of distributional patterns also observed diachronically as well as in the synchronic variation of postvocalic /r/ in English, suggesting that historical /r/-loss in English was subject to similar structural constraints.[67] Synchronic variation, in particular, provides valuable insights; for example, semi-rhotic varieties of English have been shown to favor rhoticity in a number of structural contexts (e.g., when a NURSE vowel precedes postvocalic /r/, or when a pause follows postvocalic /r/) and disfavor rhoticity in others (e.g., when SCHWA precedes postvocalic /r/ or when postvocalic /r/ is located at a word boundary which is followed by a consonant in the next word).

Nevertheless, the similarities between monolinguals and bilinguals across the distributional contexts suggest that the increase of /r/-dropping under L1 attrition is not governed by the L2; it implies that the grammatical constraints which regulate the likelihood of /r/-vocalization in the L1 phonological grammar of the bilinguals are active. Crucially, the L1 constraints do not seem to be subject to genuine L2-induced re-arrangement of the L1 phonological grammar. Instead, the results suggest that the effect of these constraints is masked by full rhoticity in monolingual speakers; nevertheless, they resurface and manifest themselves in the grammar of bilinguals under L1 attrition. Thus, the bilingual group shows quantitative non-convergence with the L1 norm as implied by the increased rate of rhoticity rather than qualitative non-convergence, i.e., in terms of distributional differences.

Finally, the analysis of the English data also showed that the rate of rhoticity was subject to significant task effects. Unexpectedly, text and conversation, i.e., the most formal and the least formal task, did not differ significantly in either group. The grocery map task however which was intended to elicit semi-formal speech differed robustly from the two other

[67] That is to say, historical /r/-loss was arguably also subject to constraints such as the quality of the pre-rhotic vowel and the morpho-phonological environment of /r/, although the exact nature of these is unknown.

tasks. Such a distribution is unattested in previous literature, and there is no straightforward explanation which can account for a distribution of /r/-dropping that shows an inverse U-curve on a continuum from low to high formality. Instead, the effect might be rooted in several properties related to the task. Firstly, the bilinguals and monolinguals alike perceived the task as challenging, which was also evident in their behavior during task preparation and the task itself. For example, most speakers requested additional preparation time and task time itself, and this was also reflected in the considerably shorter duration in the pilot tests, which lacked the pressure to perform well: the average time speakers needed to finish was ~15 minutes in the pilot test and ~30 minutes in the actual test. This indicates that all speakers were anxious to perform well, which potentially triggered greater awareness of their speech patterns and the formality of the test situation.

Recall also that the speaker's test items were distributed across four lists, each of which was assigned to a fictional character to elicit the test items embedded in full sentences rather than in a single word reading style. Here, a referee effect (Bell, 1984), i.e., a form of speech accommodation in which speakers accommodate to an imagined audience. Here, character names may have been a potential trigger: Although language-neutral and frequent names were chosen, the speakers consistently used the English pronunciation variant, indicating that the characters were consistently imagined as speakers of English.[68] Thus, it is possible that the bilingual group accommodated to an imagined English-speaking audience and therefore adjusted the frequency of /r/-dropping to match the imagined monolinguals.

To investigate the contribution of and relationship between L2 acquisition and L1 attrition, the German data will be accounted for next. The results for German postvocalic /r/ revealed that the monolingual German controls were categorically non-rhotic, a result consistent with earlier suggestions that Modern German speakers strongly favor vocalization of postvocalic /r/ (e.g., Wiese, 2000), and indeed most speakers are categorically non-rhotic.

The bilinguals, in contrast, failed to suppress rhoticity in their German and were rhotic in 27.56% of the tokens. Thus, bilinguals produced a pattern which may be referred to as residual rhoticity, and which falls out from L1 influence on the bilinguals’ L2. Despite the

[68] Speakers used an English pronunciation even when they mentioned German friends and acquaintances with the same name, or when they identified a German store they believed to recognize in the store layout on the map. Both of these factors may have induced a shift towards a more German mode. Note, however, that the map was designed in a way that did not specifically resemble German or American grocery stores; speakers also differed from each other in their store suggestions.

clear evidence of L1 influence, the pattern observed here in L2 rhoticity is not subject to the same structural constraints that modulate the positional differences of /r/ in the bilinguals' English. In particular, none of the structural variables shown to impact rhoticity in the bilinguals' L1 had a significant impact on rhoticity in their L2 which may result from the lack of structural differences in German and furthermore a monolingual-like L2 grammar in the late bilinguals. However, such conclusions are difficult to draw based on the lack of significant effects.

The results revealed that the bilinguals vocalized postvocalic /r/ in both of their languages but differ from the English and German monolingual controls in both of their languages: In their L1, the bilinguals vocalized post-vocalic /r/ at a higher frequency than American English monolingual controls; the bilinguals also failed to categorically vocalize post-vocalic /r/ in their L2, German. Their L1 English is therefore subject to the emergence of non-monolingual-like non-rhoticity, while their L2 German exhibits non-targetlike residual rhoticity.[69] However, the bilinguals exhibited degrees of /r/-vocalization across the subcategories in both structural contexts (pre-rhotic vowel and morpho-phonological context) which follow distributional restrictions also observed in the monolingual controls in both of their languages, i.e., emergent non-rhoticity in the bilingual group's L1 (English) follows similar positional hierarchies as (albeit infrequent) non-rhoticity of the English monolingual controls, whereas the residual rhoticity in the bilinguals' L2 (German) can be taken to reflect the monolingual German control group's lack of sensitivity to structural constraints.

The auditory study showed that in the acquisition of their L2, the bilingual group acquired a native-like L2 distributional hierarchy of (non-)rhoticity while maintaining a non-nativelike degree of rhoticity. Crucially, the English attrition data did not exhibit characteristics of transfer of the L2 hierarchy governed by structural constraints, and instead consistently applied constraints which reflect hierarchies also underlyingly present in their L1.

Additionally, bilinguals rarely produced /r/ in each language by a categorical replacement of the rhotic for the rhotic in the other language, which provides additional evidence that the bilinguals operate in separate phonological grammars in each respective language.

[69] I use the terms *residual* and *emergent* similar to the way it is used by Sorace (2011), but do not intend to refer to the implications of Sorace's Interface Hypothesis.

Taken together, the results of the English attrition and the German acquisition data show that late bilinguals operate in phonological grammars which are connected, albeit to a limited degree. More precisely, the constraints strongly affected by the restructuring process in L2 acquisition seem to be those that exhibit the most pervasive residual variability. Taken together, the results provide evidence that the late bilinguals operate in a distinct L2 grammar which differs from their L1 grammar in qualitative ways such as hierarchical constraint orders, but nevertheless remains connected to and interacts with their L1.

6.5 Results: Acoustic properties of /r/

As shown in the analysis of the categorical presence and absence of postvocalic /r/ in Chapter 6.3, bilinguals differed from monolinguals in terms of the degree of perceivable rhoticity in [Vr]-sequences with underlying post-vocalic /r/. This implied that L1 attrition affected the late bilinguals' phonological grammar, but that L2 influence on the L1 grammar was not unconstrained, and instead strongly modulated phonological constraints also active in English monolinguals. The acoustic analysis aims to determine the relationship between changes in L1 phonological grammars and L1 phonetic attrition. In particular, it investigates phonetic attrition of rhoticity in the L1 as well as the acquisition of non-rhoticity in the L2 to evaluate the relationship between both languages in the bilinguals' mind as well as the impact of the L2 on L1 phonetic attrition.

6.5.1 Acoustic properties of English rhoticity in rhotic sequences

For the following acoustic analyses, the categorical judgment was used as a basis for the creation of multiple subsets of the data. For the analysis of English rhoticity, the test items which were coded as non-rhotic in the auditory judgment in Chapter 6.3 were removed from the dataset, resulting in a rhotic-only subset of the data. The analysis of the rhotic-only subset thus investigates whether the decrease of perceivable rhoticity in the bilinguals' L1 is limited to categorical change, or whether gradient and gradual phonetic change in /r/ itself can be observed, and, by extension, whether phonetic change precedes phonological change in the bilingual grammars. In other words, the aim of the following section is to determine whether bilinguals deviate from the monolingual norm in the phonetic properties of tokens in which a consonantal /r/ was overtly realized. As described in Chapter 2 of this dissertation, rhoticity is characterized by a variety of acoustic cues such as the decrease of the third formant (F3). The very low F3 of English /r/ itself is characterized by strong coarticulatory and anticipatory forces, which cause F3-lowering in multiple syllables before the syllable with a post-vocalic /r/. Therefore, the following analysis focuses both on F3 in the pre-rhotic vowel, and in the consonantal /r/ itself. This allows a holistic observation of potential changes of rhoticity in late bilinguals.

6.5.1.1 Acoustic properties of rhotic [Vr]-sequences

To analyze the phonetic properties of rhotic influence on the pre-rhotic vowel, the rhotic dataset was modeled in a LMM. Here, the distance between Z3 and Z2 (in Bark) at the time of the F3 maximum and its respective F2 value in the pre-rhotic vowel, which results in the variable Z3-Z2Distance(Vowel) was used as the dependent variable. SYLLABLE, VOWEL, TASK, and GROUP were used as fixed effects, and WORD and SPEAKER were used as random effects.

Subsequent model comparisons revealed that while SYLLABLE did not significantly improve model fit, the presence of a significant three-way-interaction between GROUP, VOWEL, and TASK constituted an improvement to the model. The final model is shown in Table 6.5. The interaction between GROUP, VOWEL, and TASK is plotted in Figure 6.12, which shows Z3-Z2 values by GROUP, VOWEL, and TASK.

To explore the interaction, pairwise comparisons with Bonferroni correction were conducted. These revealed that the bilinguals differed from monolinguals in the text task on the vowels NORTH ($p < 0.0001$), NURSE, SCHWA, and START (all $p < 0.001$). In the grocery map task, bilinguals differed from monolinguals on all vowels except NEAR (SQUARE $p < 0.01$; NORTH, NURSE, SCHWA, and START all $p < 0.0001$). Finally, in the conversation task, all vowels reached significance between bilinguals and monolinguals (SQUARE $p < 0.03$; START and NEAR $p < 0.001$; NORTH, NURSE, and SCHWA $p < 0.0001$).

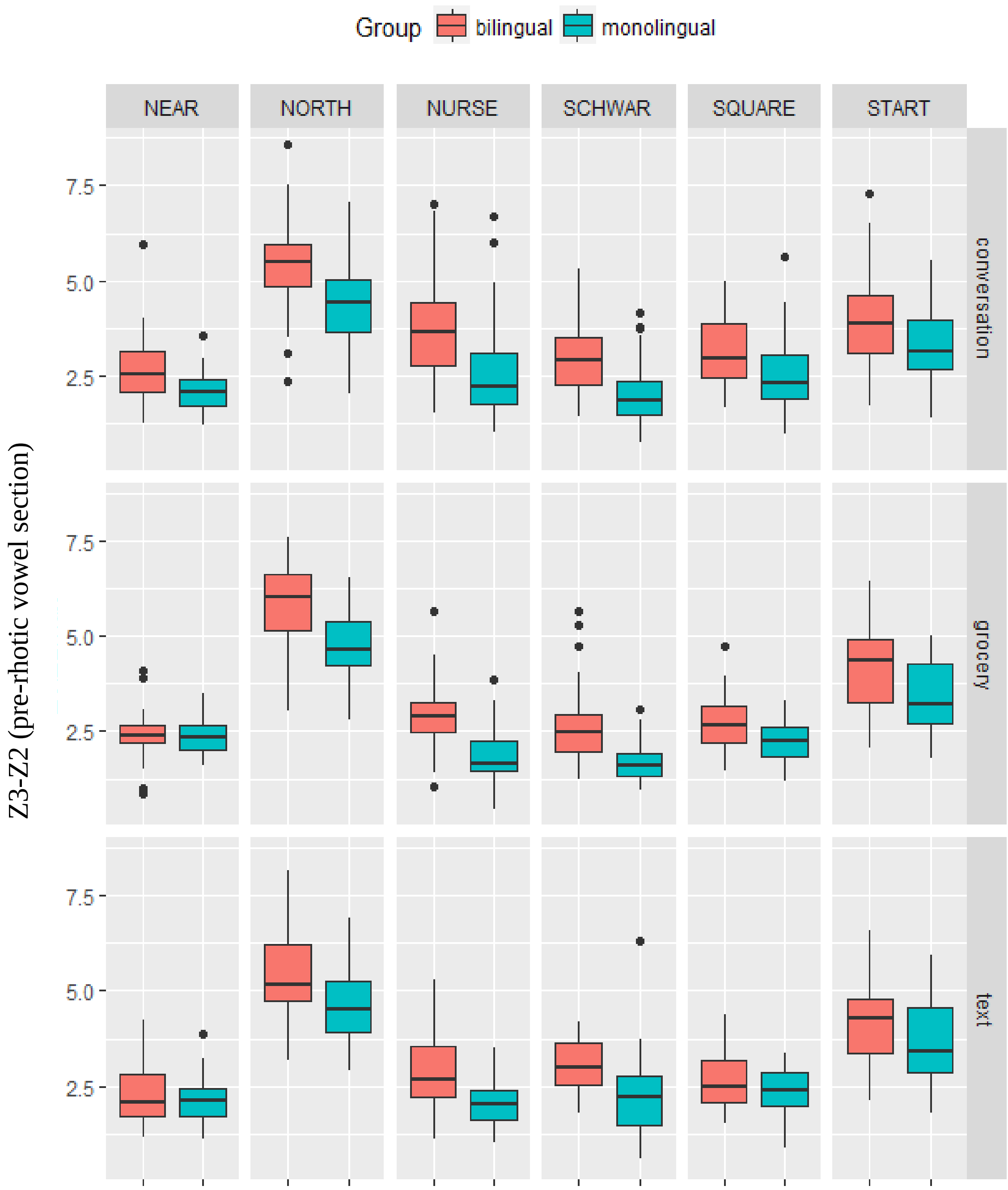

Figure 6.12: Z3-Z2 values in the pre-rhotic vowel for the three-way-interaction of Vowel, Group and Task.

Table 6.5: Linear mixed-effects model for Z3-Z2 in the pre-rhotic vowel, showing a three-way-interaction between Group, Vowel and Task.

Random effects:					
Groups	Name		Variance		Std. Dev.
Context	(Intercept)		0.18356		0.4284
Speaker	(Intercept)		0.08454		0.2908
Residual			0.58061		0.7620
Number of obs: 1712, groups: Context 220; Speaker 24					
Fixed effects:					
	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	2.64210	0.24606	173.80000	10.738	<2e-16***
Vowel (NORTH)	2.85249	0.27476	201.60000	10.382	<2e-16***
Vowel (NURSE)	0.98051	0.27497	182.40000	3.566	0.000463***
Vowel (SCHWA)	0.34924	0.28436	225.50000	1.228	0.220655
Vowel (SQUARE)	0.21131	0.29950	225.40000	0.706	0.481215
Vowel (START)	1.34553	0.27217	183.80000	4.944	1.72e-06***
Group (Monolingual)	-0.65168	0.19908	138.80000	-3.274	0.001341**
Task (Grocery)	-0.20323	0.39670	68.40000	-0.512	0.610101
Task (Text)	-0.41054	0.31881	100.00000	-1.288	0.200823
Vowel (NORTH): Group (Monolingual)	-0.38706	0.23745	1468.70000	-1.630	0.103300
Vowel (NURSE): Group (Monolingual)	-0.40143	0.21977	1654.70000	-1.827	0.067942.
Vowel (SCHWA): Group (Monolingual)	-0.26557	0.25356	1362.70000	-1.047	0.295101
Vowel (SQUARE): Group (Monolingual)	0.15608	0.26046	1645.00000	0.599	0.549077
Vowel (START): Group (Monolingual)	-0.10610	0.22378	1653.90000	-0.474	0.635488
Vowel (NORTH): Task (Grocery)	0.31701	0.51744	87.90000	0.613	0.541684
Vowel (NURSE): Task (Grocery)	-0.52513	0.53465	66.70000	-0.982	0.329563
Vowel (SCHWA): Task (Grocery)	-0.19492	0.53916	69.90000	-0.362	0.718801
Vowel (SQUARE): Task (Grocery)	0.06059	0.53194	83.60000	0.114	0.909585
Vowel (START): Task (Grocery)	0.38405	0.53222	65.90000	0.722	0.473093
Vowel (NORTH): Task	0.25842	0.39920	130.60000	0.647	0.518542

(Text)					
Vowel (NURSE): Task (Text)	-0.45541	0.36904	152.10000	-1.234	0.219098
Vowel (SCHWA): Task (Text)	0.46967	0.43615	144.70000	1.077	0.283342
Vowel (SQUARE): Task (Text)	0.28164	0.41323	143.30000	0.682	0.496627
Vowel (START): Task (Text)	0.57259	0.37414	153.60000	1.530	0.127972
Group (Monolingual): Task (Grocery)	0.59145	0.22561	1556.10000	2.622	0.008837**
Group (Monolingual): Task (Text)	0.55762	0.21653	1564.20000	2.575	0.010107*
Vowel (NORTH): Group (Monolingual): Task (Grocery)	-0.67520	0.33622	1654.80000	-2.008	0.044783*
Vowel (NURSE): Group (Monolingual): Task (Grocery)	-0.56634	0.32010	1595.60000	-1.769	0.077039.
Vowel (SCHWA): Group (Monolingual): Task (Grocery)	-0.57458	0.34047	1639.00000	-1.688	0.091679.
Vowel (SQUARE): Group (Monolingual): Task (Grocery)	-0.57808	0.34380	1642.80000	-1.681	0.092871.
Vowel (START): Group (Monolingual): Task (Grocery)	-0.62948	0.31790	1610.40000	-1.980	0.047863*
Vowel (NORTH): Group (Monolingual): Task (Text)	-0.32509	0.31610	1651.30000	-1.028	0.303901
Vowel (NURSE): Group (Monolingual): Task (Text)	-0.24037	0.30160	1608.50000	-0.797	0.425589
Vowel (SCHWA): Group (Monolingual): Task (Text)	-0.37252	0.36182	1649.50000	-1.030	0.303366
Vowel (SQUARE): Group (Monolingual): Task (Text)	-0.34618	0.33358	1648.50000	-1.038	0.299537
Vowel (START): Group (Monolingual): Task (Text)	-0.41113	0.30503	1619.70000	-1.348	0.177908

6.5.1.2 Acoustic properties of the consonantal section

The analysis of the consonantal section, i.e., /r/ proper, is shown in Table 6.6. The model comparison revealed a significant three-way-interaction between GROUP, VOWEL, and

TASK. Post-hoc tests revealed that bilinguals and monolinguals differ significantly for the NORTH and START vowel in the text task ($p < 0.01$ and $p < 0.03$ respectively), as well as in the grocery map task ($p < 0.001$ and $p < 0.02$ respectively). In the conversation task, bilinguals differ from monolinguals significantly on NORTH, NURSE and SCHWA ($p < 0.0001$, $p < 0.01$, and $p < 0.01$ respectively), while START does not reach significance ($p = 0.51$). Figure 6.13 demonstrates the interaction for F3 of the consonantal section across GROUP, VOWEL, and TASK.

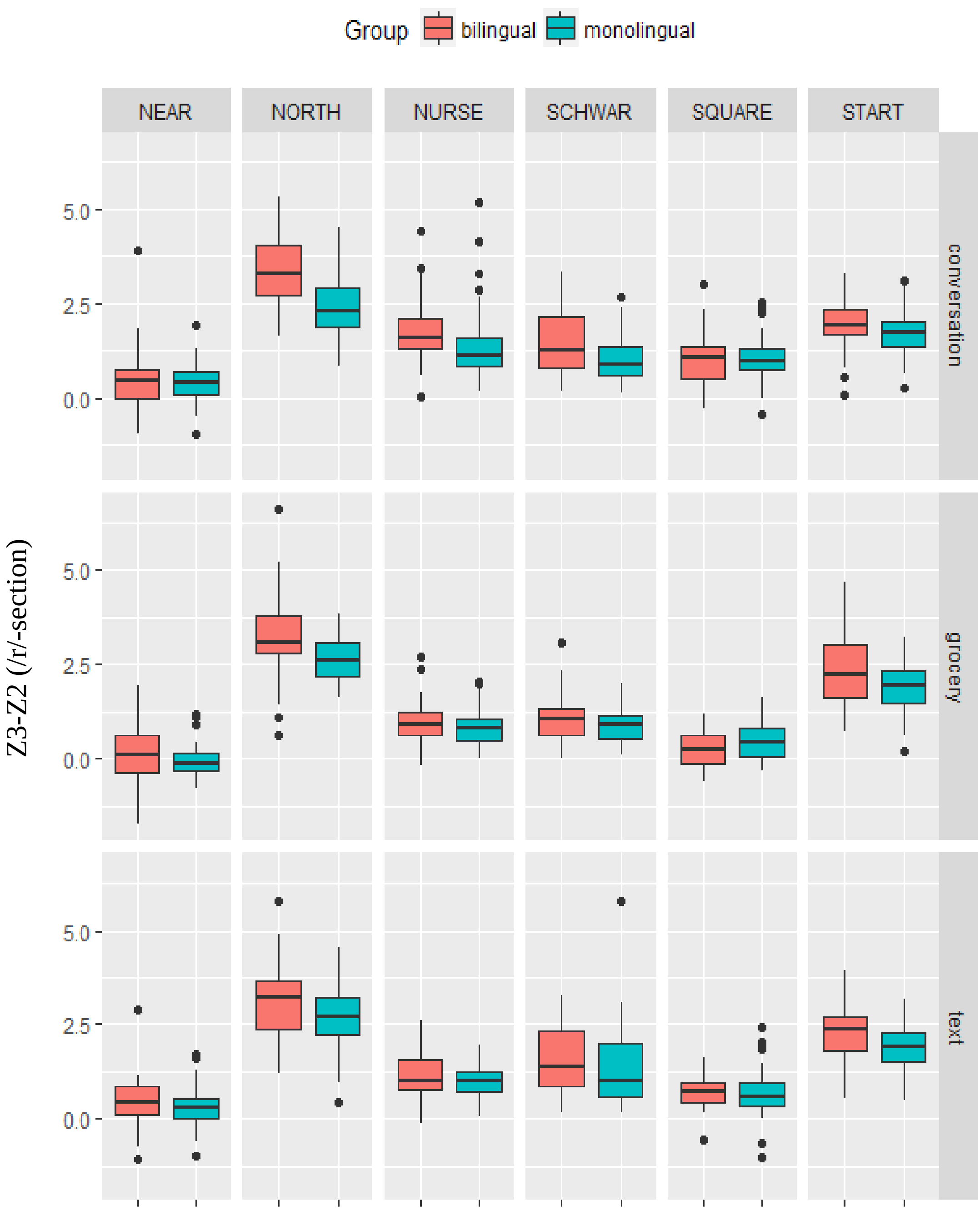

Figure 6.13: Three-way-interaction of Task, Vowel and Group for F3 in the /r/-section.

Table 6.6: Linear mixed-effects model for Z3-Z2 of the consonantal section, showing a three-way-interaction between Group, Vowel and Task.

Random effects:					
Groups	Name	Variance	Std.Dev.		
Context	(Intercept)	0.12897	0.3591		
Speaker	(Intercept)	0.05203	0.2281		
Residual		0.37589	0.6131		
Number of obs: 1712, groups: Context 220; Speaker 24					
Fixed effects:					
	Estimate	Std.Error	df	tvalue	Pr(>|t|)
(Intercept)	0.46418	0.20115	162.50000	2.308	0.02228*
Vowel (NORTH)	2.90426	0.22519	187.80000	12.897	<2e16***
Vowel (NURSE)	1.25692	0.22557	170.70000	5.572	9.64e08**
Vowel (SCHWA)	0.99825	0.23283	209.40000	4.288	2.76e05**
Vowel (SQUARE)	0.64406	0.24522	210.60000	2.626	0.00926**
Vowel (START)	1.52316	0.22326	171.30000	6.822	1.48e10**
Task (Grocery)	-0.35576	0.32930	64.90000	-1.080	0.28399
Task (Text)	-0.01660	0.26329	93.60000	-0.063	0.94986
Group (Monolingual)	-0.08789	0.15890	146.60000	-0.553	0.58102
Vowel (NORTH): Task (Grocery)	0.31655	0.42797	84.30000	0.740	0.46157
Vowel (NURSE): Task (Grocery)	-0.42440	0.44400	63.30000	-0.956	0.34277
Vowel (SCHWA): Task (Grocery)	-0.03153	0.44743	66.10000	-0.070	0.94403

Vowel (SQUARE): Task (Grocery)	-0.36950	0.44027	80.00000	-0.839	0.40383
Vowel (START): Task (Grocery)	0.66391	0.44205	62.60000	1.502	0.13815
Vowel (NORTH): Task (Text)	-0.27802	0.32861	123.00000	-0.846	0.39918
Vowel (NURSE): Task (Text)	-0.45270	0.30330	142.00000	-1.493	0.13777
Vowel (SCHWA): Task (Text)	0.09846	0.35866	134.30000	0.275	0.78410
Vowel (SQUARE): Task (Text)	-0.37573	0.33982	134.60000	-1.106	0.27084
Vowel (START): Task (Text)	0.07654	0.30746	143.50000	0.249	0.80377
Vowel (NORTH): Group (Monolingual)	-0.77534	0.19188	1458.00000	-4.041	5.61e-05***
Vowel (NURSE): Group (Monolingual)	-0.31719	0.17721	1654.20000	-1.790	0.07364.
Vowel (SCHWA): Group (Monolingual)	-0.36837	0.20504	1336.50000	-1.797	0.07263.
Vowel (SQUARE): Group (Monolingual)	-0.02324	0.21013	1648.80000	-0.111	0.91195
Vowel (START): Group (Monolingual)	-0.22011	0.18048	1654.70000	-1.220	0.22279
Task (Grocery): Group (Monolingual)	-0.10130	0.18164	1541.50000	-0.558	0.57715
Task (Text): Group (Monolingual)	-0.04416	0.17434	1550.10000	-0.253	0.80008
Vowel (NORTH): Task (Grocery): Group (Monolingual)	0.38568	0.27111	1654.80000	1.423	0.15505
Vowel (NURSE): Task (Grocery): Group (Monolingual)	0.37411	0.25781	1585.90000	1.451	0.14694
Vowel (SCHWA): Task (Grocery): Group (Monolingual)	0.35004	0.27471	1636.60000	1.274	0.20277

Vowel (SQUARE): Task (Grocery): Group (Monolingual)	0.44436	0.27706	1638.10000	1.604	0.10893
Vowel (START): Task (Grocery): Group (Monolingual)	0.05231	0.25608	1603.10000	0.204	0.83816
Vowel (NORTH): Task (Text): Group (Monolingual)	0.53056	0.25497	1651.40000	2.081	0.03760*
Vowel (NURSE): Task (Text): Group (Monolingual)	0.24153	0.24295	1600.00000	0.994	0.32029
Vowel (SCHWA): Task (Text): Group (Monolingual)	0.44039	0.29187	1648.70000	1.509	0.13153
Vowel (SQUARE): Task (Text): Group (Monolingual)	0.10602	0.26885	1644.80000	0.394	0.69338
Vowel (START): Task (Text): Group (Monolingual)	0.03122	0.24574	1613.50000	0.127	0.89891

6.5.2 Acoustic properties of German non-rhoticity

The purpose of the following analysis is to find whether the American English-German bilinguals produce German non-rhotic sequences in a target-like fashion. The basis for the analysis is thus the non-rhotic subset of the tasks conducted in German for comparison with the German monolingual control group.

6.5.2.1 Acoustic properties of the pre-rhotic vowel in German

A LMM was built using Z3-Z2 of the vowel section as dependent variable. The model included VOWEL, SYLLABLE, TASK, and GROUP as fixed effects, and SPEAKER and WORD as random effects. Model comparison revealed that the optimal model excludes SYLLABLE both as a main effect and in interactions with other variables, which reveals that SYLLABLE does not constitute a significant predictor of Z3-Z2 distance. Furthermore, the optimal model included two interactions, VOWEL*GROUP ($p < 0.001$) and TASK*GROUP ($p < 0.005$). Table 6.7 shows the final model.

Table 6.7: Linear mixed-effects model for Z3-Z2 distance in the German non-rhotic pre-rhotic vowel section.

Random effects:					
Groups	Name	Variance	Std.Dev.		
Context	(Intercept)	0.1563	0.3953		
Speaker	(Intercept)	0.1124	0.3352		
Residual		0.4415	0.6645		
Number of obs: 964, groups: Context, 232; Speaker 24					
Fixed effects:					
	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	3.26496	0.14612	80.60000	22.345	<2e-16***
Vowel (START)	1.87864	0.14510	166.50000	12.947	<2e-16***
Vowel (NORTH)	2.85263	0.14328	166.10000	19.910	<2e-16***
Vowel (SQUARE)	0.47444	0.14205	177.00000	3.340	0.00102**
Vowel (SCHWA)	1.33411	0.13764	204.70000	9.693	<2e-16***
Group (Bilingual)	-0.36740	0.18412	57.50000	-1.995	0.05075.
Task (Text)	-0.06065	0.09874	105.00000	-0.614	0.54037
Vowel (START): Group (Bilingual)	0.29520	0.15135	885.70000	1.950	0.05143.
Vowel (NORTH): Group (Bilingual)	0.39559	0.15816	866.50000	2.501	0.01256*
Vowel (SQUARE): Group (Bilingual)	-0.17864	0.14810	896.20000	-1.206	0.22807
Vowel (SCHWA): Group (Bilingual)	-0.44434	0.14930	916.60000	-2.976	0.00299**
Group (Bilingual): Task (Text)	-0.28104	0.09597	925.60000	-2.928	0.00349**

To examine the significant interactions in detail, pairwise comparisons with Bonferroni corrections were conducted using the lsmeans package. The pairwise comparisons revealed significant differences between monolinguals and bilinguals in the vowels SQUARE ($p < 0.01$) and SCHWA ($p < 0.0001$), and did not differ in NEAR, NORTH and START.

6.5.2.2 Acoustic properties of the non-rhotic /r/-section in German

To examine whether bilinguals displayed deviant acoustic properties in the position of the vocalized or dropped historical /r/ in German as reflected in residual drops of F3 expressed in a lower Z3-Z2 difference, the lowest position of F3 in the vocalized (non-rhotic) section of the sequence was identified. A model was fit to include Z3-Z2 as the dependent variable. As in the previous analyses, VOWEL, SYLLABLE, TASK, and GROUP were added as fixed effects, and WORD and SPEAKER were added as random effects. Model comparison revealed that Syllable did not significantly improve the model, and neither did the interaction SYLLABLE*GROUP. Thus, both were excluded from the final model. While TASK was significant as the main effect, the TASK*GROUP interaction was not. Finally, the final model includes a significant interaction for VOWEL*GROUP. This model is shown in Table 6.8.

Table 6.8: Linear mixed-effects model for Z3-Z2 in the German non-rhotic /r/ section.

<table>
<tr><td colspan="6">Random effects:</td></tr>
<tr><td>Groups</td><td>Name</td><td colspan="2">Variance</td><td colspan="2">Std. Dev.</td></tr>
<tr><td>Context</td><td>(Intercept)</td><td colspan="2">0.1797</td><td colspan="2">0.4239</td></tr>
<tr><td>Speaker</td><td>(Intercept)</td><td colspan="2">0.1564</td><td colspan="2">0.3954</td></tr>
<tr><td>Residual</td><td></td><td colspan="2">0.5691</td><td colspan="2">0.7544</td></tr>
<tr><td colspan="6">Number of obs: 964, groups: Context, 232; Speaker 24</td></tr>
<tr><td colspan="6">Fixed effects:</td></tr>
<tr><td></td><td>Estimate</td><td>Std. Error</td><td>df</td><td>t value</td><td>Pr(>|t|)</td></tr>
<tr><td>(Intercept)</td><td>2.44959</td><td>0.16484</td><td>71.50000</td><td>14.861</td><td><2e-16***</td></tr>
<tr><td>Vowel (START)</td><td>1.82205</td><td>0.16025</td><td>200.20000</td><td>11.370</td><td><2e-16***</td></tr>
<tr><td>Vowel (NORTH)</td><td>2.78644</td><td>0.15814</td><td>200.50000</td><td>17.620</td><td><2e-16***</td></tr>
<tr><td>Vowel (SQUARE)</td><td>0.43008</td><td>0.15701</td><td>212.20000</td><td>2.739</td><td>0.006684**</td></tr>
<tr><td>Vowel (SCHWA)</td><td>1.63559</td><td>0.15242</td><td>244.80000</td><td>10.731</td><td><2e-16***</td></tr>
<tr><td>Group (Bilingual)</td><td>-0.83420</td><td>0.20461</td><td>46.00000</td><td>-4.077</td><td>0.000179***</td></tr>
<tr><td>Task (Text)</td><td>-0.24386</td><td>0.10121</td><td>97.30000</td><td>-2.409</td><td>0.017857*</td></tr>
<tr><td>Vowel (START): Group (Bilingual)</td><td>0.39538</td><td>0.17129</td><td>900.80000</td><td>2.308</td><td>0.021211*</td></tr>
<tr><td>Vowel (NORTH): Group (Bilingual)</td><td>0.63345</td><td>0.17851</td><td>889.30000</td><td>3.548</td><td>0.000408***</td></tr>
<tr><td>Vowel (SQUARE): Group (Bilingual)</td><td>-0.06788</td><td>0.16757</td><td>908.60000</td><td>-0.405</td><td>0.685487</td></tr>
<tr><td>Vowel (SCHWA): Group (Bilingual)</td><td>-0.26502</td><td>0.16880</td><td>923.30000</td><td>-1.570</td><td>0.116757</td></tr>
</table>

Subsequent pairwise comparisons with Bonferroni correction for the VOWEL*GROUP interaction revealed that the bilingual group differed from the monolinguals in the vowels NEAR ($p < 0.008$), SQUARE, and SCHWA (both $p < 0.0001$).

6.5.3 Comparison of the bilingual productions in both languages

To investigate the source of phonetic attrition more closely, the following analysis tests whether the bilinguals produced phonetically distinct [Vr]-sequences in German and English. The analysis therefore investigates whether phonetic attrition in the L1 is induced by target-like phonetic acquisition in the L2. Here, the bilingual data of both languages, German and English, were pooled into a single dataset, i.e., both rhotic and non-rhotic tokens produced by bilinguals in both languages. The variable RHOTICITY (divided into the levels *rhotic* and *non-rhotic*) was then coded to distinguish the tokens perceived as rhotic from those perceived as non-rhotic.

6.5.3.1 Comparison of the pre-rhotic vowel in bilingual English and German

Figure 6.14 shows the Z3-Z2 difference in the pre-rhotic vowel section between the bilinguals' two languages.

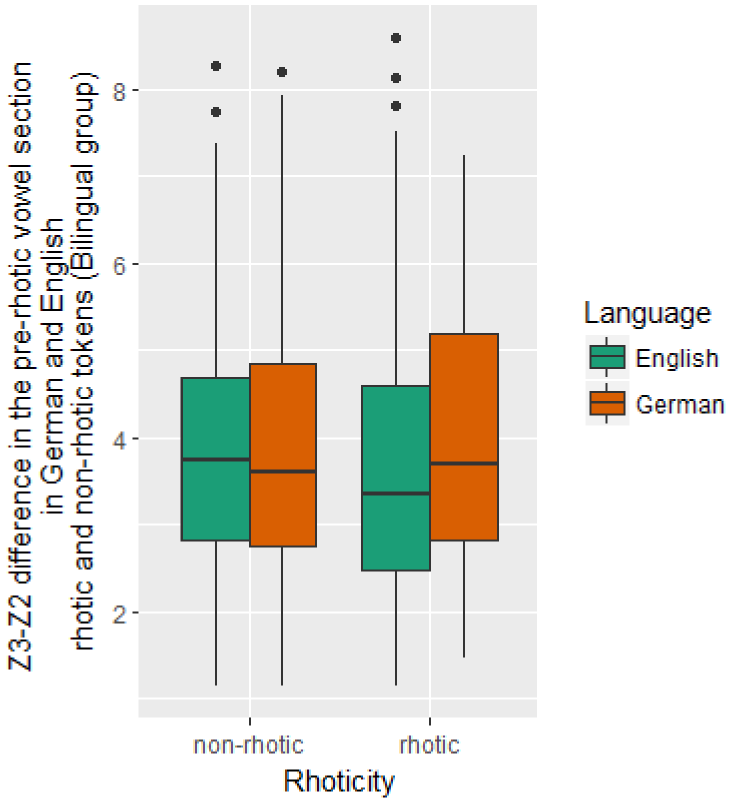

Figure 6.14: Acoustic quality of the pre-rhotic vowel in rhotic and non-rhotic tokens in bilinguals German and English.

A LMM was built using the Z3-Z2 difference in the pre-rhotic vowel was used as the dependent variable. Random Effects were WORD and SPEAKER. VOWEL, SYLLABLE, TASK, RHOTICITY, and LANGUAGE were used as fixed effects, and an interaction for RHOTICITY*LANGUAGE was included to determine whether bilinguals produced acoustically distinct rhotic and non-rhotic [Vr]-sequences in their German and English. The basic model revealed significant main effects for VOWEL, RHOTICITY, and LANGUAGE (all ps < 0.0001), as well as the significance of the RHOTICITY*LANGUAGE interaction ($p < 0.0001$). TASK and SYLLABLE did not reach significance as shown by model comparison ($p = 0.56$ and $p = 0.55$ respectively).

Model comparison was used to determine optimal model fit. The final model included VOWEL, TASK, RHOTICITY, and LANGUAGE as main effects, which were all shown to significantly improve model fit to the data. Furthermore, model comparison revealed significant interactions between TASK and LANGUAGE, and RHOTICITY and LANGUAGE. SYLLABLE remained non-significant as main effect or in interactions and was excluded from the final model, which is shown in Table 6.9.

Table 6.9: Final model for the Z3-Z2 difference in the pre-rhotic vowel in bilinguals' both languages.

Random effects:					
Groups	Name	Variance	Std.Dev.		
Word	(Intercept)	0.1474	0.3840		
Speaker	(Intercept)	0.1013	0.3183		
Residual		0.6222	0.7888		
Number of obs: 1071, groups: Word, 254; Speaker, 12					
Fixed effects:					
	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	2.25350	0.15570	63.30000	14.473	<2e-16***
Rhoticity (non-rhotic)	0.44525	0.08882	1044.20000	5.013	6.30e-07***
Vowel (NORTH)	3.18002	0.13817	114.90000	23.015	<2e-16***
Vowel (SCHWA)	0.82119	0.13220	128.10000	6.212	6.78e-09***
Vowel (SQUARE)	0.37334	0.13682	112.80000	2.729	0.00738**
Vowel (START)	2.05769	0.13505	117.80000	15.236	<2e-16***
Task (Text)	-0.01471	0.10363	205.10000	-0.142	0.88724
Language (German)	0.58586	0.12004	534.90000	4.881	1.40e-06***
Rhoticity (non-rhotic): Language (German)	-0.36434	0.1256	1047.50000	-2.904	0.00376**
Task (Text): Language (German)	-0.32616	0.15306	146.30000	-2.131	0.03477*

The interaction between TASK and LANGUAGE seems to be an artifact of the data structure: Recall that the dataset includes both rhotic and non-rhotic tokens. The categorical analysis of English rhoticity showed that the difference between conversation and text was minor. While this task difference was also not significant in the German data, the difference in frequency of rhoticity was larger between the two tasks in German, leading to a larger TASK difference in Z3-Z2 values in German as compared to English. This is further supported by the lack of a significant three-way-interaction between TASK, LANGUAGE, and RHOTICITY which did not improve model fit of the model shown in Table 6.9. The two-way-interaction between TASK and LANGUAGE is therefore negligible and was not unpacked further.

Pairwise comparisons of the significant interaction between LANGUAGE and RHOTICITY (which can also be observed in Figure 6.15 below) were conducted via pairwise comparisons of rhotic and non-rhotic tokens in both languages using Bonferroni-correction. The comparisons showed that the Z3-Z2 difference of the pre-rhotic vowel differed significantly between rhotic and non-rhotic tokens in the bilinguals' English ($p < 0.0001$), where rhotic tokens were produced with a smaller Z3-Z2 difference in the pre-rhotic vowel as compared to rhotic tokens. Rhotic and non-rhotic tokens do not differ significantly in the bilinguals' German. The comparison of rhotic and non-rhotic tokens across languages both showed that the Z3-Z2 difference of the pre-rhotic vowel in rhotic tokens differs significantly between the bilinguals' English and their German ($p < 0.0001$), while it does not differ for non-rhotic tokens across the bilinguals' languages.

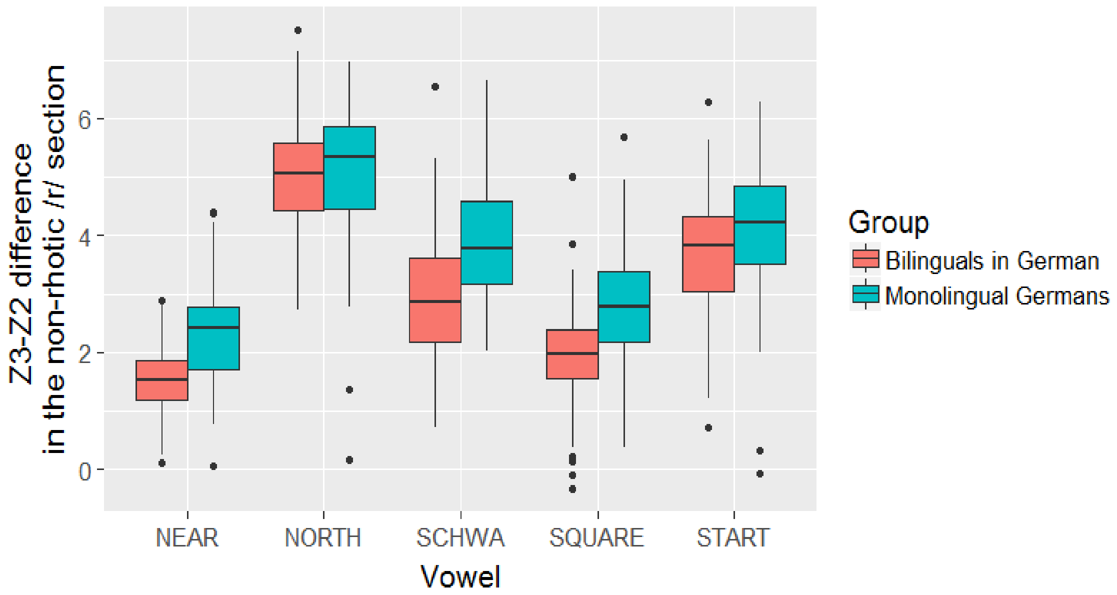

Figure 6.15: Z3-Z2 differences of the non-rhotic /r/-section across vowel contexts in German in the monolingual and bilingual group.

6.5.3.2 Comparison of the rhotic and non-rhotic /r/-section in bilingual English and German

Figure 6.16 illustrates the acoustic properties of the /r/-section in German and English for both rhotic and non-rhotic tokens in bilinguals.

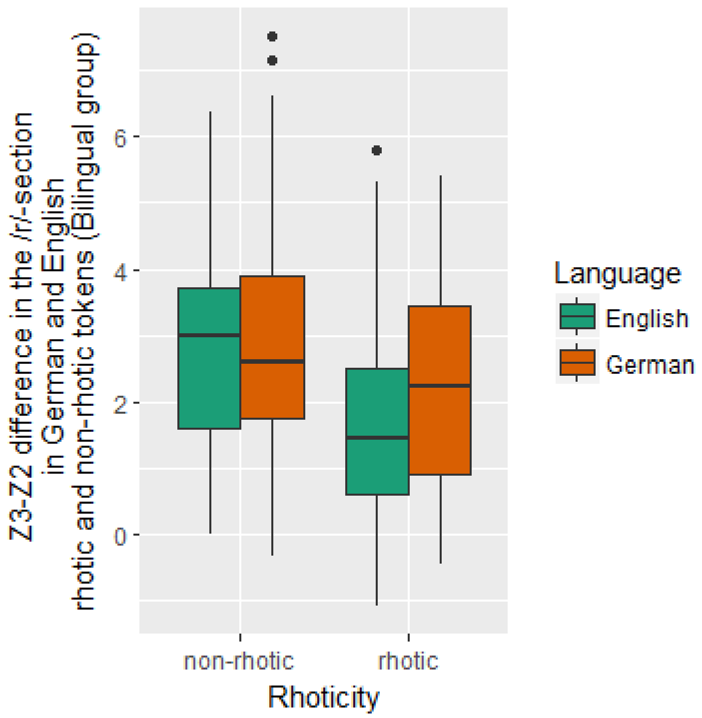

Figure 6.16: Acoustic quality of the /r/-section in rhotic and non-rhotic tokens in bilingual German and English.

As in the analysis above, a LMM was fitted to the full bilingual dataset containing rhotic and non-rhotic tokens in German and English. To analyze whether the bilinguals merged the /r/ section itself in both languages, the Z3-Z2 difference in the /r/-section was used as the dependent variable, again with WORD and SPEAKER as random Effects. As above, the fixed Effects were VOWEL, SYLLABLE, TASK, RHOTICITY, LANGUAGE, as well as an interaction RHOTICITY*LANGUAGE. Model comparison revealed that the optimal model included VOWEL, TASK, RHOTICITY and LANGUAGE as main effects, and a significant three-way-interaction between RHOTICITY, VOWEL, and LANGUAGE. Again, SYLLABLE was not significant either as a main effect or in interactions. The final model is shown in Table 6.10.

Table 6.10: Final model for Z3-Z2 difference in the /r/-section in bilinguals' both languages.

Random effects:					
Groups	Name	Variance	Std. Dev.		
Word	(Intercept)	0.1689	0.4109		
Speaker	(Intercept)	0.0407	0.2017		
Residual		0.5814	0.7625		
Number of obs: 1071, groups: Word, 254; Speaker, 12					
Fixed effects:					
	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	0.61151	0.18399	103.20000	3.324	0.00123**
Rhoticity (non-rhotic)	0.38593	0.20278	877.00000	1.903	0.05735.
Vowel (NORTH)	2.68097	0.21020	112.80000	12.754	<2e-16***
Vowel (SCHWA)	0.90415	0.21847	146.80000	4.138	5.87e-05***
Vowel (SQUARE)	0.32856	0.22645	99.50000	1.451	0.14994
Vowel (START)	1.46488	0.21317	102.40000	6.872	5.06e-10***
Task (Text)	-0.16272	0.07861	158.90000	-2.070	0.04007*
Language (German)	0.32529	0.26090	180.40000	1.247	0.21410
Rhoticity (non-rhotic): Vowel (NORTH)	0.88617	0.27317	940.10000	3.244	0.00122**
Rhoticity (non-rhotic): Vowel (SCHWA)	1.00891	0.25131	927.40000	4.015	6.44e-05***
Rhoticity (non-rhotic): Vowel (SQUARE)	0.75358	0.29346	913.00000	2.568	0.01039*
Rhoticity (non-rhotic): Vowel (START)	0.95296	0.31676	924.00000	3.008	0.00270**
Rhoticity (non-rhotic): Language (German)	0.26639	0.27385	913.20000	0.973	0.33093
Vowel (NORTH): Language (German)	0.43783	0.34022	229.90000	1.287	0.19942
Vowel (SCHWA): Language (German)	0.31091	0.34470	279.30000	0.902	0.36785
Vowel (SQUARE): Language (German)	0.11730	0.35184	212.00000	0.333	0.73917
Vowel (START): Language (German)	0.98113	0.33886	221.90000	2.895	0.00417**
Rhoticity (non-rhotic): Vowel (NORTH): Language (German)	-0.65799	0.37641	959.60000	-1.748	0.08078.
Rhoticity (non-rhotic): Vowel (SCHWA): Language	-0.90626	0.35875	966.50000	-2.526	0.01169*

(German)					
Rhoticity (non-rhotic): Vowel (SQUARE): Language (German)	-0.74376	0.38691	934.30000	-1.922	0.05487.
Rhoticity (non-rhotic): Vowel (START): Language (German)	1.13312	0.41067	975.20000	-2.759	0.00590**

The three-way-interaction was subsequently explored via pairwise comparisons using Bonferroni correction. The results show that differences of the Z3-Z2 difference of the /r/-section are limited to rhotic tokens, and within the rhotic tokens, significant differences emerged only in NORTH ($p < 0.003$), SCHWA ($p < 0.03$) and START ($p < 0.0001$). The interaction is shown in Figure 6.17.

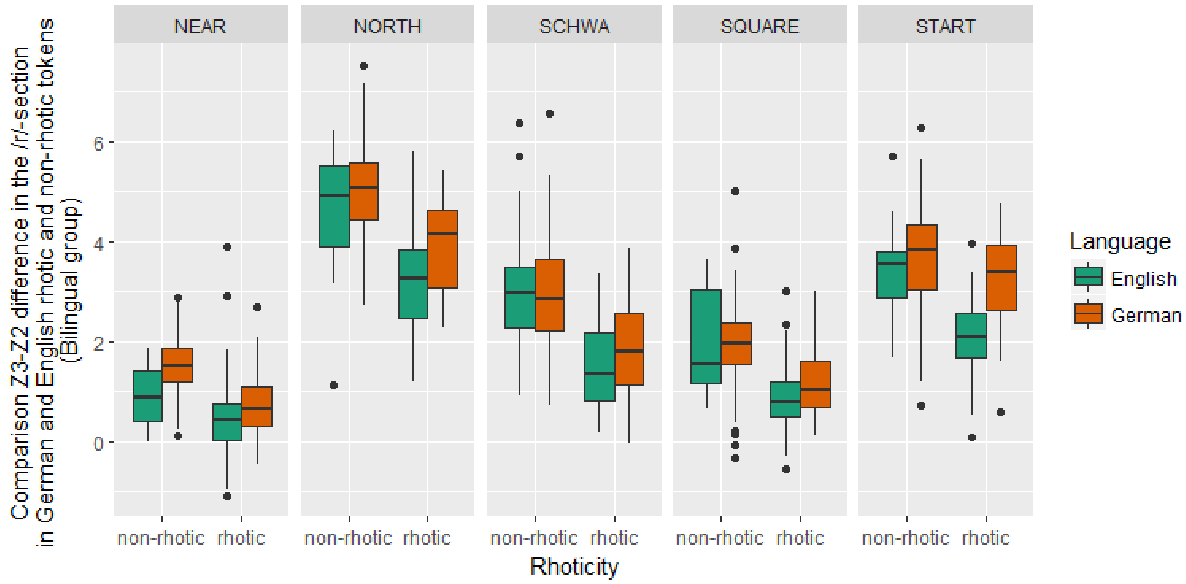

Figure 6.17: Acoustic quality of the /r/-section in rhotic and non-rhotic tokens in bilinguals German and English across vowel contexts.

6.5.4 Assessing the reliability of the auditory judgment

Finally, let us return to the categorical analysis of the presence and absence of post-vocalic /r/ presented in Chapter 6.3 and assess the validity and reliability of the auditory judgments presented there.

As rater judgments are known to add confounds by external variables inherent to the rater's individual experience and attitudes (e.g., previous experience, bias, and so forth), a

LMM was used to determine whether the variable PERCEIVED RHOTICITY is a significant predictor height of F3 (in Hz), which is known to coincide with the perceptual judgments of rhoticity. Here, the full dataset was modeled, using Z3-Z2 difference in the /r/-section as the dependent variable. The independent variables were SYLLABLE, VOWEL, TASK, and GROUP, and random effects were WORD and SPEAKER, as will also be in the analysis of absence and presence of /r/. Additionally, PERCEIVED RHOTICITY which was operationalized via binary judgment of rhoticity (i.e., whether a token was heard as rhotic or non-rhotic by the raters), was an independent variable. Thus, keeping all structural variables constant in this and all following models, PERCEIVED RHOTICITY should reach significance as a predictor for the Z3-Z2 difference of the /r/ portion if the auditory judgment produced reliable data. That is to say; if PERCEIVED RHOTICITY is a significant predictor of acoustic properties known to be present in rhoticity, the auditory analysis can be taken to be a reliable measure of (non-)rhoticity in the sample; the output of the model is shown in Table 6.11.

Table 6.11: Reliability of the auditory judgment.[70]

Random effects:					
Groups	Name	Variance	Std. Dev.		
Word	(Intercept)	0.15955	0.3994		
Speaker	(Intercept)	0.04989	0.2234		
Residual		0.43710	0.6611		
Number of obs: 1892, groups: Word 232, Speaker 24					
Fixed effects:					
	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	0.51084	0.14335	114.50000	3.564	0.000534***
Vowel (NORTH)	2.53983	0.14663	103.90000	17.321	<2e-16***
Vowel (NURSE)	1.02597	0.15443	100.70000	6.644	1.59e-09***
Vowel (SCHWA)	0.96092	0.14458	109.40000	6.646	1.22e-09***
Vowel (SQUARE)	0.54961	0.15972	94.30000	3.441	0.000865***

70 Note that the number of observations here is *lower* in the acoustic data than in the auditory judgement analysis. Some tokens were clearly audible, but the formants could not be analyzed in Praat due to issues with formant tracking, such as unresolvable formant mergers of F1 and F2, or various issues in tracking F3, such as the use of creaky voice. These tokens could be clearly assessed auditorily and were included in the auditory analysis but had to be removed from all acoustic analyses.

Vowel (START)	1.55819	0.15448	99.60000	10.086	<2e-16***
Task (Grocery)	-0.20936	0.12223	86.50000	-1.713	0.090321.
Task (Text)	-0.13053	0.06886	340.10000	-1.896	0.058850.
Group (Monolingual)	-0.25487	0.09677	22.30000	-2.634	0.015047*
Perceived Rhoticity (non-rhotic)	1.08912	0.06367	1862.50000	17.106	<2e-16***

As the results of the model show, PERCEIVED RHOTICITY is indeed a significant predictor of phonetic properties of /r/, thereby confirming that the operationalization via auditory analysis accurately reflects acoustic properties as expected rather than external biases. Furthermore, GROUP remains a significant main effect, pointing towards additional differences in acoustic properties of /r/ between monolinguals and bilinguals beyond categorical /r/-lessness. Indeed, this was confirmed by the analyses presented in 6.3. Finally, an interaction between GROUP and RHOTICITY was added to explore whether the perceptual judgment was biased towards more lenient judgments of non-rhoticity in the bilingual data, i.e., whether a bias towards judging bilinguals less rhotic in tokens in which Z3-Z2 difference falls into the gradient acoustic borderlands between rhotic and non-rhotic. Model comparison revealed that this interaction did not contribute to model fit, thereby demonstrating no significant difference in rater behavior across groups.

6.6 Summary of acoustic data

The analyses of the acoustic data revealed that bilinguals deviate from the monolingual norm in their productions of both the degree of r-coloring in the pre-rhotic vowel, as well as in /r/ itself. However, some important interaction effects emerged in the comparisons, yielding potential answers for (i) why rhoticity in the context of certain types of vowels are more susceptible to variation in my study (as well as in previous observations), (ii) which acoustic property is the driving force of non-rhoticization.

Firstly, the changes were strongly affected by the quality of the potentially rhotic vowel and the quality of the pre-rhotic vowel, respectively. Here, back vowels (NORTH and START) showed robust differences across tasks in both analyses, whereas front vowels, i.e., NEAR and SQUARE, were highly resistant to acoustic variation. I take this pattern to be phonetically motivated and suggest that it emerges because of the intrinsic acoustic properties of the vowels, as well as their interaction with immediately adjacent rhotics in coda position. In particular, front vowels have a naturally higher F2, which puts a restraint on F3 to drop by a large degree. Thus, the intrinsic height of F2 in front vowels may be responsible for holding F3 close to its neutral position. As a result, further increases of F3 are not expected, as this would lead to an F3 that exceeds the neutral configurations, resulting in an acoustic profile that would yield unnatural acoustic specifications for both the bilinguals' L1 and L2. For back vowels, however, F2 is naturally lower, more so in NORTH as compared to START. Here, the trigger to a rhotic percept requires F3 to drop very low, which typically results in a F3 that is lower than average throughout the vowel+/r/ sequence, resulting in r-coloring. This lower than default position of F3 then may render back vowels generally more susceptible to acoustic variation, as more acoustic space is available. These acoustic changes, however, do not express that the change is also perceptually relevant, as a comparatively high F3 can still trigger a rhotic percept (Hagiwara, 1995). Indeed, the derhotacization tendency of back vowels as compared to front ones has been expressed previously by Feagin (1990) in her auditory analysis of rhoticity in Alabama, although she did not interpret this as a function of acoustic properties.

Secondly, the analyses above show that r-coloring, as expressed by F3 of the rhotic vowel, yields more variation as compared to the F3 of the /r/ portion alone. This is shown by the high proportion of statistically significant differences for the vowel portion as compared to the /r/-portion. I suggest that these more pervasive changes in the vowel section can form an intermediate stage in the drift towards categorical non-rhoticity (i.e., its complete absence). This is especially evident in the reduction of acoustic similarity of F3 between the vowel and the /r/-portion, which renders the [Vr]-sequence more difficult to articulate. That is to say, considering that the value of F3 is reflective of oral closure, the transition between a vowel with a high F3 and a low F3 in /r/ suggests that the articulation of such a transition may be more demanding and therefore disfavored. The switch to categorical non-rhoticity, then, offers a more optimal mechanism to resolve the more complex articulation process than a gradual movement of F3 in /r/ into higher regions would. Indeed, the decrease in F3 in the pre-rhotic vowel produced by American English monolinguals constitutes an anticipatory pattern, which readily supplies an acoustic cue to following rhoticity. Furthermore, an early decrease in F3 serves as an acoustic cue to following rhoticity across multiple syllables. The loss of these cues in the vowel portion may therefore lead to a more abrupt process of derhoticization. More precisely, the lack of proper acoustic cues to rhoticity may lead to sound change à la Ohala (1981), where misperceptions on the side of the listener may lead to a variety of sound changes, including the loss of segments. Although little is known about the perceptibility of rhoticity, Storme (2018) showed that in Haitian French, post-vocalic /r/ is significantly more difficult to perceive than post-vocalic /l/, which lends evidence to the interpretation that sound change in post-vocalic /r/ is closely related to the segment itself, but also to positional context and acoustic cues of the segmental environment. The absence of a significant SYLLABLE effect in the acoustic analysis, as opposed to the auditory analysis, also speaks for the account above. More specifically, a combination of both high F3 in the pre-rhotic vowel and disfavorable syllable environments (i.e., weak environments) may negatively affect the perceptibility of post-vocalic /r/. This may have increased the likelihood of categorical dropping due to a lack of perceptibility or due to the articulatory effort, leading to disfavorable structures suffering a sudden categorical collapse rather than gradient acoustic weakening.

Thirdly, it should be recalled that there was a strong asymmetry between vowel qualities in the auditory judgement, where START was shown to be almost unaffected by perceivable non-rhoticity as compared to NORTH. This asymmetry is potentially rooted in the closer proximity of F2 and F3 in START as compared to NORTH – an F2-F3 difference of 1189 Hz and 1541 Hz respectively. As outlined in Chapter 3, the percept of American English /r/ - and rhoticity in general – is induced by a close (relative) proximity of F2 and F3 (reflected in Z2-Z3 in the analyses above). It stands to reason that if the same degree of acoustic change occurred in both, F3 in NORTH would bear a higher potential to escape the forces of F2 (which would lead to perceivable rhoticity) and subsequently lose its rhotic quality at an earlier stage as compared to START.

Finally, the degree of non-targetlikeness of the bilinguals was strongly affected by task type, with more formal tasks eliciting more rhotic productions from the bilinguals in both the vowel and the /r/ section, but also from the monolinguals. This result is in line with previous observations, where rhoticity is (among others) shown to be moderated by task type, yielding higher degrees of rhoticity in more formal tasks. Importantly the acoustic analyses also revealed robust phonetic differences between monolinguals and bilinguals across all tasks in both the pre-rhotic vowel and the /r/-section in at least two vowel contexts, although more differences were found in informal tasks. This tendency contrasts with the outcome of the auditory analysis, where the grocery map task yielded full rhoticity across both groups, whereas the text reading and the conversation did not. Here, it can be argued that phonetic change is more pervasive than (categorical) phonological change as the former seemed to be restricted to the less formal tasks.

The analysis of German non-rhoticity, which aimed to investigate whether the bilingual group produced non-rhoticity differently from the German monolinguals, on the other hand, showed that bilinguals did indeed produce residual rhoticity in their L2. However, the bilinguals did not show sensitivity to contextual constraints as they did in their L1. This can be taken to show that L1 transfer is limited to rhoticity per se and that the more fine-grained structural differences are not transferred.

The comparison of the bilinguals in both of their languages finally revealed that the bilinguals produced a robust acoustic difference between their languages which was consistent across various positions and structural contexts. For Z2-Z1 in the pre-rhotic vowel, no significant interactions beyond RHOTICITY*LANGUAGE were found, which implies that bilinguals differ in the precise acoustic properties across their languages per se, and that structural properties in which coda-/r/ occurs do not affect their languages differently. The /r/-portion itself, however, was shown to be subject to influence of structural variables, where the variable VOWEL moderated differences between the bilinguals' languages as expressed by the three-way-interaction. More precisely, bilinguals differed acoustically between their L1 and L2 only in tokens which were produced with a consonantal /r/ in both languages, i.e., the target-like tokens in English and the non-target-like tokens in German. Here, bilinguals produced the post-vocalic /r/s which followed START, NORTH and SCHWA with distinct acoustic qualities in their languages. In the case of SCHWA, this can be argued to be a symptom of a more general difference in the phonemic inventories of both languages, where German lacks an equivalent to the English rhoticized unstressed SCHWA, which may lead the bilinguals to produce different acoustic categories in both languages. In the case of NORTH and START, the cause of cross-language distinction was less clear. More conspicuously, NORTH and START were also shown to be subject to phonetic L1 attrition in the bilinguals' English. This result stands in contrast with previous assumptions about the nature of phonetic attrition, which is believed to be induced, among others, by merging L1 and L2 phonetic categories. My study, however, showed that attrition was more pervasive in contexts in which cross-language category separation between the L1 and the L2 was present.

Chapter 7

Analyses and results: Laterals

7.1 Acquisition and attrition of laterals

In this chapter, laterals will be analyzed phonetically to determine the quality of the laterals and whether the allophonic pattern of the bilinguals' laterals has changed. Note that, unlike in the rhotic analysis, laterals will be not analyzed auditorily. While rhotics can be categorized using a binary distinction, laterals fall into a continuum from light to dark; in this way, creating an artificial distinction cannot properly capture any potential change. Therefore, changes to lateral allophony will be analyzed phonetically as described in Chapter 7.1.3.

7.1.1 Materials and participants

The same dataset and the same tasks (which were designed to also include target items for laterals) were used for the analysis of laterals.

7.1.2 Acoustic analysis of lateral quality

Acoustic measurements of laterals are arguably challenging (e.g., Recasens, 2012). For instance, the acoustic onset of coda laterals is often obscure and difficult to determine (if possible at all) due to the presence of a gradient acoustic transition from the vowel in the syllable nucleus to the lateral in the coda. These gradient transitions are known to cause a variety of problems regarding the comparability of formant measurements even within a dataset. To reduce such noise in the data and to generate a more reliable index of clarity and darkness of laterals, several acoustic characteristics were used to aid and improve the auditory identification of the lateral segments, which I will describe in the following.

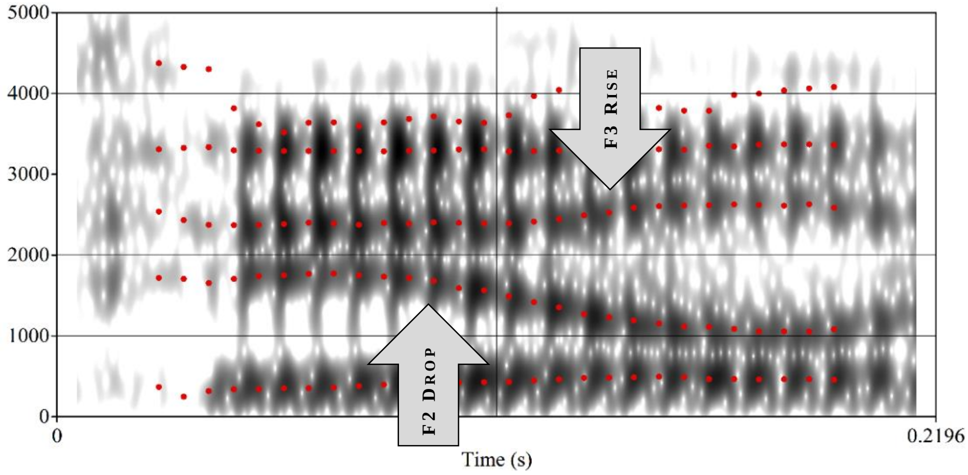

Figure 7.1: Spectrogram of 'feel' (male speaker).

Coda laterals are often characterized by a visible change of Hertz-frequency in F2 in a spectrogram as indicated by the arrow labelled ‘F2 Drop’ in Figure 7.1. Depending on the F2 of the adjacent vowel, the change in F2 emerges either as a rise or drop: front vowels are expected to result in a steeper drop in F2 toward the (typically dark) coda lateral as compared to coda laterals following back vowels, which usually show limited drops in F2 and, especially after high back vowels, may even lead to transitions characterized by level F2 or subtle rises of F2. Thus, F2 is not a reliable indicator whenever a back vowel precedes a velarized lateral.

Also, F3 was used to aid the identification of the lateral: English laterals have higher F3 frequencies (e.g., as compared to most vowels; see also Chapter 2) which leads to a noticeable and comparatively steep rise of F3 at the onset of the lateral, which is indicated by arrow labelled ‘F3 Rise’ in Figure 7.1.

Finally, a visible decrease in acoustic energy – indicated by a lighter shade of the formant bands – in a coda lateral after a vowel; onset laterals following a consonant-final word, on the other hand, are characterized by an increase of acoustic energy. Figure 7.2 shows an onset lateral, and the increase of acoustic energy is indicated by the arrow labelled ‘Lateral onset’ in Figure 7.1. It is worth noting that the degree of /l/-vocalization is expected to increase the acoustic energy of the lateral as no obstruction in the oral cavity is necessary during vowel production.

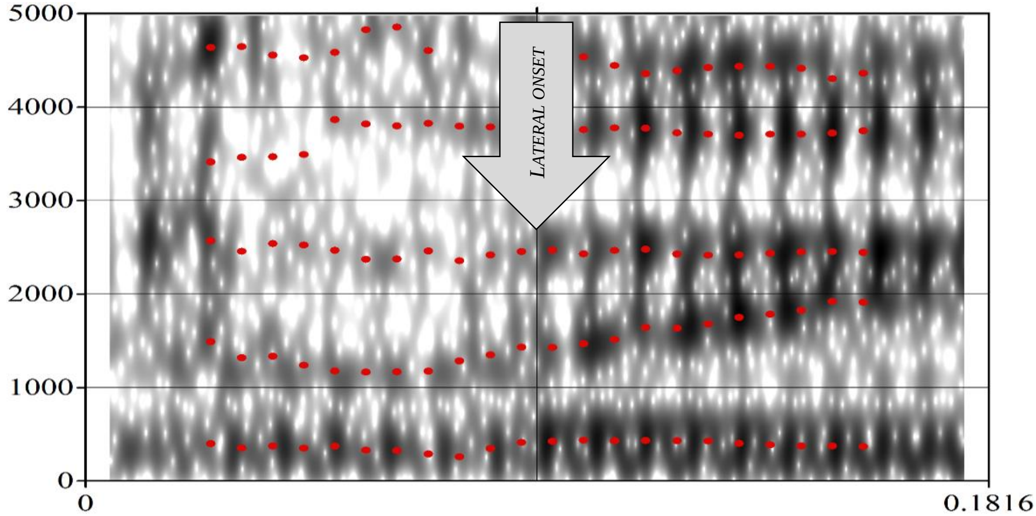

Figure 7.2: Spectrogram of 'leaned' (male speaker).

A second challenge in measuring laterals is the position of measurement for F1 and F2. Here, several options have been used previously, for example the midpoint of the lateral (e.g., Solon, 2017), or a fixed time point determined using the end of the lateral (e.g., 30 ms before the lateral offset, see de Leeuw, Opitz, & Lubińska, 2013). However, the duration of laterals has been shown to differ due to phonetic and external variables such as speech rate and previous vowel and thus inserting a fixed time point may indeed not measure the same position within the lateral segment. Likewise, midpoint measurements may lead to inconsistent acoustical measures and can also reflect individual articulatory differences in the overall formant structure layout.

Midpoint measurements are even more problematic with coda laterals as the onset of the lateral can be exceptionally difficult to determine, if possible at all. Especially if the lateral is velarized and preceded by a high back vowel, identification of the lateral onset is virtually impossible as a very low F2 characterizes both high back vowels and velarized laterals. As midpoint measurements crucially depend on consistency in onset and offset labeling, they are vulnerable to variation and cannot be considered to reflect the same measurement point across the data. That means individual measurements are subject to variation of the actual measurement point due to token-based differences in the perceived onset of the lateral.

The measurement point of F2 adopted in the present analysis was the F2 dip within the lateral, as also suggested in previous studies (Espy-Wilson, 1992; see also Lee-Kim, Davidson, & Hwang, 2013). As described in Chapter 2, the degree of velarization of laterals is associated with the height of F2, where lower F2 values indicate a higher degree of velarization of the lateral. Arguably, F2 at the lowest F2 dip reflects the strongest degree of velarization produced by a speaker – i.e., the most /ł/-like point. This measurement point is robust against inter-speaker variation in the duration and articulatory layout of the lateral, and more resistant to coarticulatory effects, especially if such coarticulatory processes show inter-speaker variability with regard to the timing of and the extent of coarticulatory changes in the lateral. That is to say, the lowest F2 dip is resistant to individual differences in the duration of the transition from the vowel to a coda lateral and how far into the lateral significant coarticulation with the preceding vowel or the following vowel are maintained or set in. Moreover, the lowest point of the F2 dip can be detected using a combination of automatic extraction and manual correction, rendering the method resistant to the inconsistencies resulting from exclusive use of manual or automatic detection. This is especially advantageous in coda laterals, where inconsistent onset placements would affect the location of the measurement point in a midpoint measurement. Similarly, inconsistencies in the identification of the offset affect measurements in offset-based methods, as do stylistic differences. Both pitfalls can be avoided by resorting to the lowest F2 dip which is independent of temporal or transitional characteristics of the lateral.

Thus, laterals were measured as follows. First, the lateral segment was visually and auditorily identified using Praat and annotated in a Textgrid file. Markers were placed at the onset of the lateral if the lateral was in the onset, and at the estimated end of the transition from the vowel to the lateral if the lateral was in the coda. The measurement point, the lowest F2 dip in the segment marked in the previous step, was identified automatically using a Praat script. Then the measurement point was inserted by first visually identifying the lowest F2 within the marked lateral segment, followed by manual insertion of the measurement marker in a position of the lateral segment that matched the minimal F2 value (+/-10 Hz) from the automatic detection. Tokens were excluded from analysis if multiple points roughly matched the automatic value, which was the case in some tokens where a coda lateral followed a back vowel. Tokens were also excluded if the automatically detected value was clearly incorrect, e.g., due to an outlier in Praat's formant tracker that did not align with the visible spectrogram. Again, the latter also mostly affected coda laterals following back vowels. Issues with coda laterals after back vowels were especially prevalent in some tall male speakers whose F1 and F2 in back vowels approximated one another so closely that Praat's formant tracker identified a single formant in the region of F1 and F2. When this happens, the formant tracker incorrectly identifies a value intermediate to F1 and F2 as F1, and subsequently incorrectly labels F3 as F2. If these issues could not be resolved by adjusting Praat's tracking settings as described in the next paragraph, the item was excluded from analysis.

After auditory confirmation that the inserted measurement marker was indeed located in the lateral, Hertz-values for F1, F2 and F3 were extracted by hand using the LPC algorithm. The settings were left in Praat's standard settings unless the LPC tracker did not track the formants accurately (e.g., if two formants were visible, but the tracker found only one formant). In general, tracking issues may occur in male speakers who produce F1 and F2 near to each other. This frequently occurs in strongly velarized laterals which naturally have a small F1-F2 distance. In these cases, the number of formants was increased to six to improve tracking. If this did not correctly track the formants as visible in the spectrogram, the token was discarded.

The lateral formant data was normalized via a modified version of the Bark Difference Metric (Syrdal & Gopal, 1986) using the vowels package (Kendall & Thomas, 2009) in R (R Core Team, 2017). For the Bark Difference Metric, F1, F2, and F3 are first converted into Bark values using the Traunmüller (1990) formula, resulting in Z1, Z2, and Z3 respectively. The distance between Z2 and Z1 (henceforth 'Z2-Z1') was calculated by subtracting Z1 from Z2. As Z1 and Z2, (which correspond to F1 and F2) are the two central acoustic parameters of velarization in laterals, Z2-Z1 can be taken to capture gradience in clarity or darkness of laterals appropriately.

7.1.3 Analyses of lateral allophony

While the data analyses above aim to shed light on changes to the acoustic quality of laterals in various conditions in the late bilinguals' mind, another set of analyses were aimed to investigate whether the bilinguals' allophonic pattern in the L1 had changed as well. Unlike rhotics above, an auditory analysis of velarization can be argued to be less suitable due to the inherent gradience (both acoustically and perceptually) of laterals. That is to say, while there is evidence for a natural boundary (albeit fuzzy) of perceivable rhotic quality (see Hagiwara, 1995), there is no evidence for the presence of such a boundary in velarization. To reveal whether the bilinguals' allophonic pattern changed, the analyses below instead resort to the acoustic data in comparing the difference between Z2-Z1 in initial and final laterals. In particular, a decreased distance between initial and final laterals in English would indicate a loss of the allophonic distribution, i.e., the allophonic patterns and distances produced by the bilinguals in both languages in comparison to monolinguals. To do so, the average Z2-Z1 between initial and final laterals was calculated, which is indicative of the acoustic distance between initial and final allophones, respectively. Means for each speaker's Z2-Z1 were calculated separately for each condition, i.e., each speaker had a mean for initial vs. final in back vs. front conditions across the text and conversation task.[71] Lateral distance was calculated by subtracting each participant's Z2-Z1 in final laterals from the Z2-Z1 of initial laterals for each task and vowel context. For bilinguals, means were calculated for both languages, English and German. This resulted in the variable LATERALDISTANCE, i.e., the difference between Z2-Z1 in word-initial laterals and Z2-Z1 in word-final laterals.

Finally, I investigated whether the bilinguals merge laterals into the same category or produce distinct phonetic variants in German and English, Z2-Z1 was compared across the bilinguals' languages. As this analysis addresses a question relevant only for the bilingual data, the full dataset was reduced to exclude the monolingual data in both languages while the subset of the data containing the bilinguals' laterals in English and German were submitted to analysis.

7.2 Results: Phonetic change in English laterals

7.2.1 English laterals: Group comparison

To investigate whether the bilinguals in their L1 differed from the monolingual controls, a LMM was fitted to the English lateral dataset. The dependent variable was Z2-Z1 (in Bark); the independent variables were GROUP (monolingual vs. bilingual), POSITION (initial vs. final), VOWEL (back vs. front), and TASK (text, grocery map, and conversation). Finally, random effects were included for WORD and SPEAKER. Model comparisons revealed that a model with two significant two-way interactions, GROUP*POSITION and GROUP*TASK, provided the best fit to the data as compared to the simple model limited to main effects. Table 7.1 shows the results of the final model.

[71] Recall that the German part of the experiment did not include the map task. As the analyses in the previous Chapters showed, the map task differed markedly from the other tasks. For this reason, the map task was removed from the dataset, rather than pooled.

Table 7.1: Linear mixed-effects model for Z2-Z1 of laterals in bilingual and monolingual English.

Random effects:					
Groups	Name	Variance	Std.Dev.		
Context	(Intercept)	0.1619	0.4023		
Speaker	(Intercept)	0.2439	0.4938		
Residual		0.9543	0.9769		
Number of observations: 1201, groups: Context 131; Speaker 24					
Fixed effects:					
	Estimate	Std. Error	Df	t value	Pr(>|t|)
(Intercept)	3.52474	0.18539	49.70000	19.013	<2e-16***
Vowel (front)	1.04280	0.11613	59.20000	8.979	1.20e-12***
Position (initial)	1.55165	0.13162	95.90000	11.789	<2e-16***
Group (Monolingual)	-0.98403	0.22917	31.30000	-4.294	0.000157***
Task (map)	-0.38056	0.15867	117.60000	-2.398	0.018036*
Task (Reading)	0.38711	0.12507	323.10000	3.095	0.002140**
Position (initial): Group (Monolingual)	-0.57576	0.11934	1144.60000	-4.824	1.59e-06***
Group (Monolingual): Task (map)	0.48671	0.14497	1163.30000	3.357	0.000812***
Group (Monolingual): Task (Reading)	0.03893	0.13896	1164.70000	0.280	0.779402

The coefficients indicate the direction of the effect where a negative coefficient indicates a smaller Z2-Z1 (which corresponds to darker laterals), and a positive coefficient indicates a larger Z2-Z1 (which corresponds to clearer laterals). Figure 7.3 shows the interaction between Group and Position.

As visible in Figure 7.3, the late bilinguals produced laterals in word-initial position with a larger Z2-Z1 as compared to word-initial laterals produced by monolinguals. It furthermore shows that the Z2-Z1 between initial and final laterals produced by the bilingual group is larger than between word-initial and -final laterals produced by the monolingual

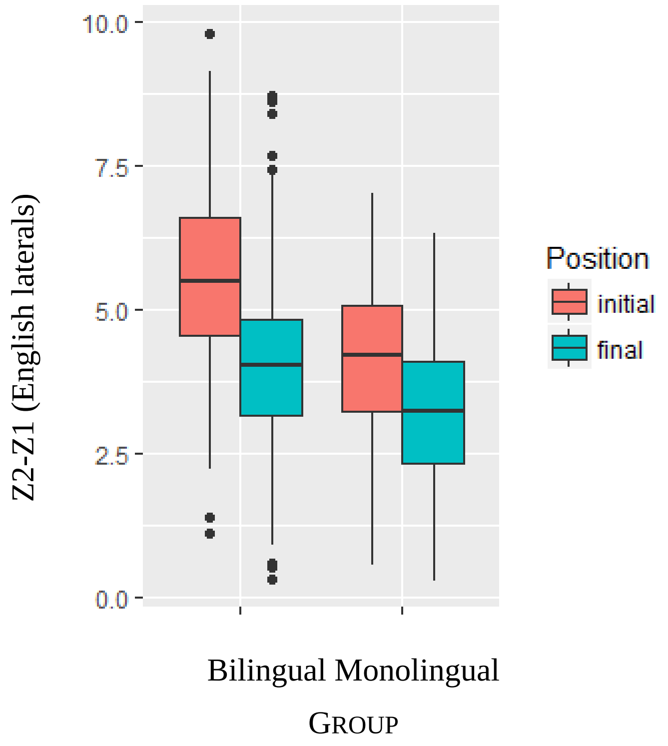

Figure 7.3: Z2-Z1 in bilingual and monolingual English by Position.

controls. In other words, the result shows that laterals in word-initial position show a more substantial increase of Z2-Z1. To explore the interaction, pairwise comparisons with Bonferroni correction were used. The comparisons confirm that bilinguals differ from monolinguals across position. Indeed, all pairwise comparisons within Group*Position except one were significant: The non-significant comparison, bilinguals in final position vs. monolinguals in initial position, although a negligible effect supports that bilinguals shifted with regard to the phonetic properties of their laterals in final position and approximate the laterals in initial position produced by the monolingual controls.

The second significant interaction, GROUP*TASK, is presented in Figure 7.4. Pairwise comparisons of the interaction revealed that the bilinguals significantly differed from monolinguals across tasks, albeit not uniformly so. For the monolingual group, Z2-Z1 did not differ significantly between either the conversation and the grocery map task, or between the grocery map and text task (both $p < 0.5$), whereas conversation and text differed significantly ($p < 0.01$). In contrast, the bilinguals produced no significantly different Z2-Z1 between the conversation and grocery map tasks, but Z2-Z1 was significantly different between conversation and text ($p < 0.3$), and between grocery map and text ($p < 0.0001$).

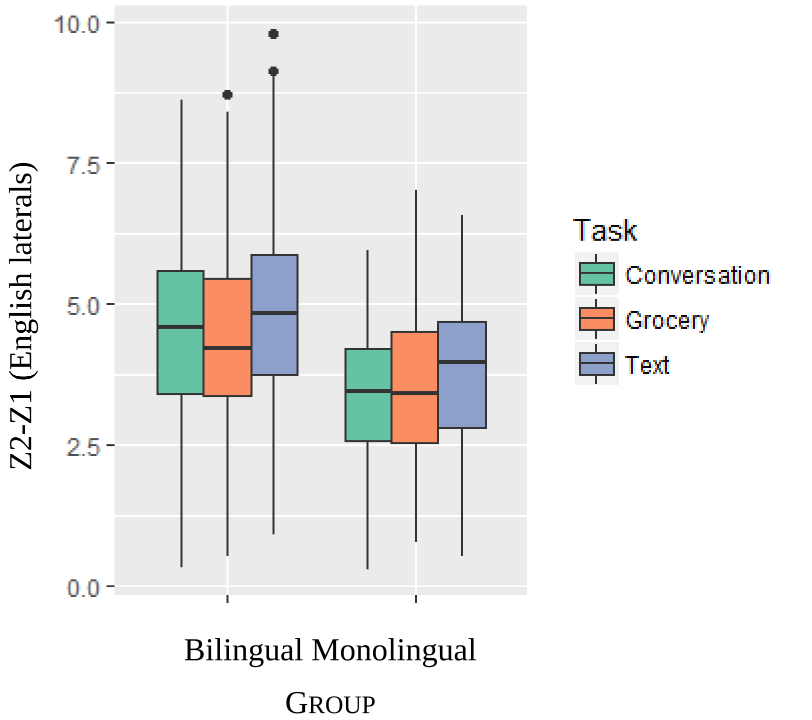

Figure 7.4: Z2-Z1 of English laterals across tasks in bilingual and monolingual English.

7.2.2 Effects of external variables on the bilinguals' production of laterals

To investigate the effect of social and individual background variables on the late bilinguals' L1 laterals, a LMM was fit to the lateral data which included the full set of individual variables. In other words, just like the analysis of the impact of social and individual variables on rhotics in Chapter 6, L1C-TEST, L2C-TEST, L1 FLUENCY, L2 FLUENCY, LANGUAGEUSE, and AFFILIATION were included in the full model. The full model featuring all individual variables as main effects showed that none of the individual variables had a significant effect. Subsequent model reduction and model comparisons revealed that none of the individual variables improved model fit to the data, indicating that none of the individual variables reliably predicted the changes in the laterals produced by late bilinguals. For the sake of completeness, the full model featuring the non-significant individual variables is given in Table 7.2.

Table 7.2: Linear mixed-effects model for Z2-Z1 of laterals in bilingual and monolingual English (structural variables not shown).

Random effects:					
Groups	Name	Variance	Std. Dev.		
Context	(Intercept)	0.1576	0.3970		
Speaker	(Intercept)	0.3704	0.6086		
Residual		1.0334	1.0165		
Number of observations: 600, groups: Context 96; Speaker 12					
Fixed effects:					
	Estimate	Std. Error	Df	T value	Pr(>|t|)
(Intercept)	3.49386	0.23136	9.67000	15.102	4.78e-08***
Position (initial)	1.51615	0.14185	40.34000	10.689	2.46e-13***
Vowel (front)	1.24170	0.13978	37.94000	8.883	8.36e-11***
Task (map)	-0.35082	0.17015	42.05000	-2.062	0.04543*
Task (Reading)	0.36132	0.13583	96.99000	2.660	0.00914**
L1 proficiency (C-Test)	-0.53029	0.44284	5.00000	-1.197	0.28478
L2 proficiency (C-Test)	0.04993	0.25226	4.99000	0.198	0.85089
L1 Fluency	-0.19039	0.29475	5.01000	-0.646	0.54676
L2 Fluency	0.06099	0.26693	5.02000	0.228	0.82828
Language use	-0.06387	0.20581	4.99000	-0.310	0.76884
Affiliation	0.09826	0.23815	5.00000	0.413	0.69700

7.3 Results: Phonetic acquisition of German laterals

7.3.1 German laterals: Group comparison

The boxplot in Figure 7.5 shows the Z2-Z1 in German laterals produced by bilinguals in German and by the monolingual German control group separated by POSITION. As can be seen in Figure 7.5, the bilingual group produces laterals in their L2 using separate phonetic variants in initial and in final position which resembles their L1 allophonic pattern for initial laterals and final laterals, respectively. The German monolingual controls produced laterals in initial and final position with almost identical Z2-Z1 values which means that, as expected, German monolinguals do not show allophony.

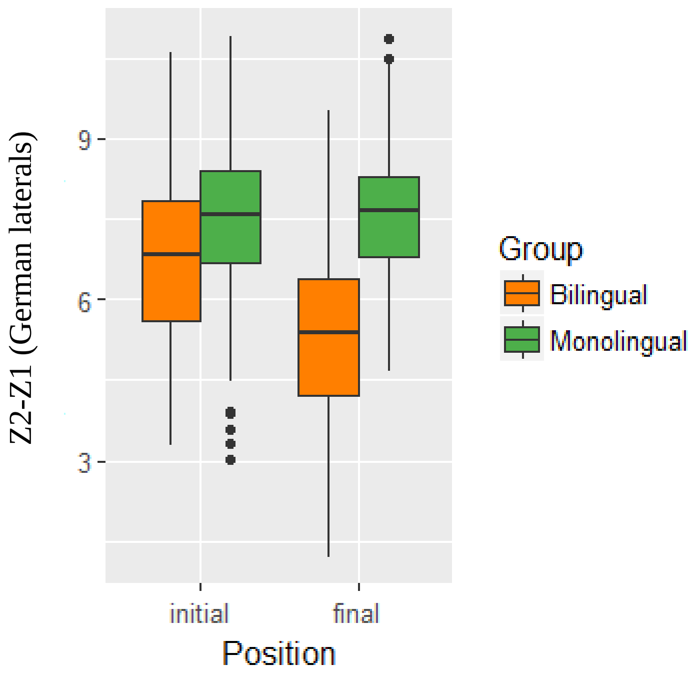

Figure 7.5: Z2-Z1 in German laterals produced by German monolinguals and bilinguals in German in initial and final position.

A LMM was fit to test group differences and the effect of structural variables in bilingual and in monolingual German. In the model, Z2-Z1 was the dependent variable; the independent variables were POSITION, VOWEL, GROUP and TASK and the random effects were WORD and SPEAKER. Subsequent model comparisons revealed the presence of two significant three-way-interactions, POSITION*VOWEL*GROUP and POSITION*TASK*GROUP. The final model including the interactions is shown in Table 7.3.

Table 7.3: Linear mixed-effects model for Z2-Z1 of laterals in bilingual and monolingual German.

Random effects:			
Groups	Name	Variance	Std. Dev.
Context	(Intercept)	0.4365	0.6607
Speaker	(Intercept)	0.4594	0.6778
Residual		0.7174	0.8470

Number of observations: 791, groups: Context, 195; Speaker, 24					
Fixed effects:					
	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	4.68043	0.25900	57.40000	18.071	<2e-16***
Position (initial)	1.16865	0.27700	275.60000	4.219	3.33e-05***
Vowel (front)	1.37602	0.20209	198.60000	6.809	1.14e-10***
Task (Reading)	-0.08404	0.17353	567.40000	-0.484	0.62833
Group (Monolingual)	1.98810	0.32166	35.90000	6.181	4.03e-07***
Position (initial): Vowel (front)	-0.42763	0.31786	231.80000	-1.345	0.17982
Position (initial): Group (Monolingual)	-1.27860	0.28758	663.20000	-4.446	1.03e-05***
Vowel (front): Group (Monolingual)	-0.39061	0.16269	690.30000	-2.401	0.01662*
Position (initial): Task (Reading)	0.52246	0.37094	110.70000	1.408	0.16180
Task (Reading): Group (Monolingual)	0.82514	0.16775	744.90000	4.919	1.07e-06***
Position (initial): Vowel (front): Group (Monolingual)	0.86862	0.28116	737.60000	3.089	0.00208**
Position (initial): Task (Reading): Group (Monolingual)	-0.88958	0.29191	741.60000	-3.047	0.00239**

The two significant interactions were subsequently analyzed further using pairwise comparisons with Bonferroni correction. Firstly, pairwise comparisons of the interaction POSITION*VOWEL*GROUP show that the laterals produced by the late bilinguals differ from those produced by monolinguals across positions (all $p < 0.05$) with one exception, namely laterals in initial position followed by back vowels which did not differ significantly between the groups ($p = 0.24$). The first of the two three-way-interactions, POSITION*VOWEL*GROUP, is shown in Figure 7.6.

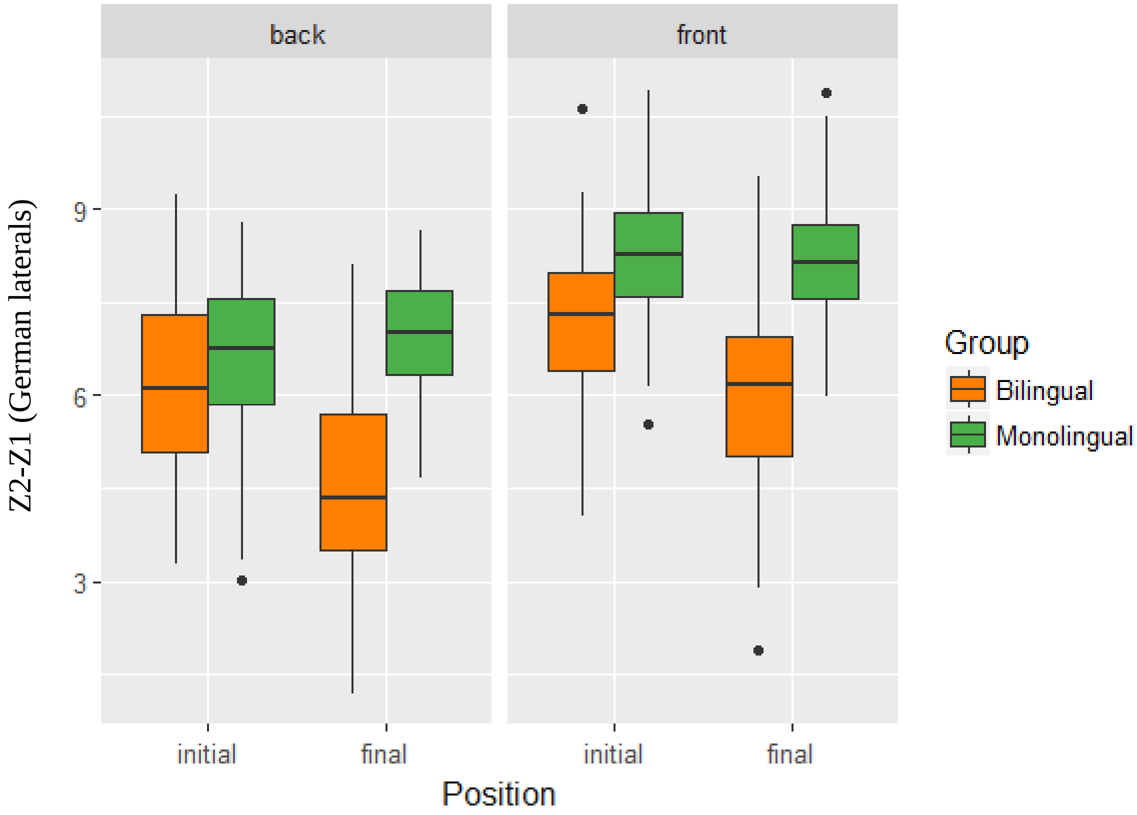

Figure 7.6: Comparison of German laterals across vowel contexts and positions across monolinguals and bilinguals.

Pairwise comparisons of the second interaction, POSITION*TASK*GROUP, show that the groups behaved significantly different across TASK and POSITION. The bilinguals' laterals in initial position differed from their laterals in final position across the tasks, i.e., both in text and in conversation (both ps < 0.001). The comparison of initial laterals between text and conversation revealed that initial laterals in text did not differ from initial laterals in conversation, and neither did final laterals in text and conversation (all ps > 0.05). In contrast, the monolingual group did not produce significantly different Z2-Z1 due to positional context, i.e., Z2-Z1 in initial laterals and Z2-Z1 in final laterals did not differ in either of the tasks. Furthermore, while initial laterals produced by German monolinguals did not differ between text and conversation (p > 0.05), final laterals differed across tasks (p < 0.0001). The second of the two three-way-interaction is shown in Figure 7.7.

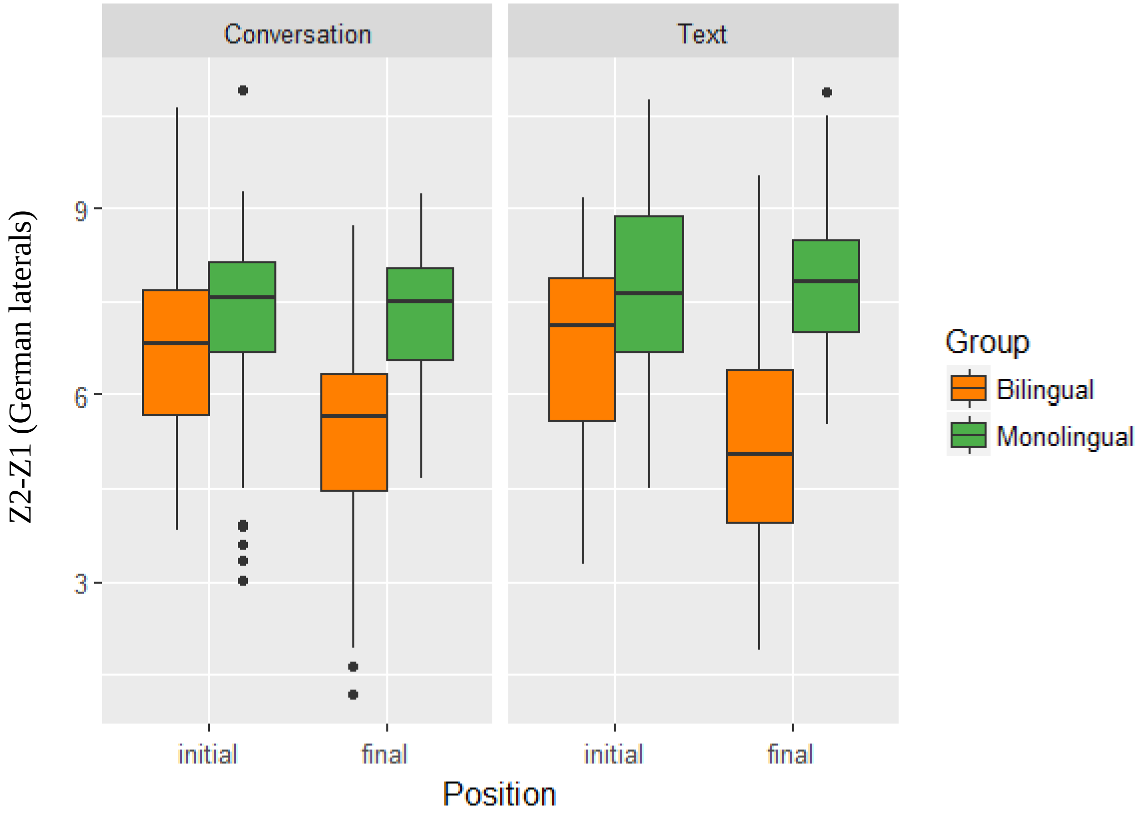

Figure 7.7: Lateral comparison across bilinguals' languages of German laterals across vowel contexts and tasks in both groups.

7.3.2 Effects of external variables on the bilinguals' German laterals

To explore the effects of external and individual characteristics on the production of laterals in the bilinguals' L2, German, a LMM was fit using both structural and external criteria as already done for the bilinguals' English laterals in 6.2.2 above. Here, too, the external variables included in the model were L1C-TEST, L2C-TEST, L1 FLUENCY, L2 FLUENCY, LANGUAGEUSE, and AFFILIATION. Model comparisons and model reduction showed that none of the external variables significantly influenced L2-targetlikeness in the German laterals produced by bilinguals. The full model including all (on-significant) external variables is provided in Table 7.4.

Table 7.4: Linear mixed-effects model for the effect of internal and external variables on Z2-Z1 of laterals in bilingual and monolingual German (structural variables not shown).[72]

Random effects:					
Groups	Name		Variance	Std. Dev.	
Context	(Intercept)		0.4459	0.6678	
Speaker	(Intercept)		0.7489	0.8654	
Residual			0.9701	0.9849	
Number of observations: 397, groups: Context, 116; Speaker, 12					
Fixed effects:					
	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	4.8091	0.3287	9.8100	14.633	5.49e-08***
Position (initial)	1.0238	0.1858	76.0300	5.511	4.69e-07***
Vowel (front)	1.3303	0.1949	72.7600	6.825	2.22e-09***
Task (Reading)	0.4142	0.1813	98.9000	2.285	0.0244*
L1 C-test	-1.3555	0.6248	4.9100	-2.169	0.0832.
L2 C-test	0.3049	0.3568	4.9500	0.855	0.4321
L1 Fluency	0.1585	0.4168	4.9600	0.380	0.7195
L2 Fluency	0.1522	0.3775	4.9800	0.403	0.7035
Language use	0.3435	0.2912	4.9600	1.180	0.2917
Affiliation	0.1764	0.3359	4.9000	0.525	0.6223

7.4 Results: Acquisition and attrition of lateral allophony

7.4.1 Comparison of the late bilinguals’ laterals in English and German

A LMM was fit to a subset of the data which included the bilingual data from both languages. Z2-Z1 was the dependent variable, WORD and SPEAKER were random effects, and POSITION, VOWEL, TASK and LANGUAGE independent variables. Figure 7.8 shows Z2-Z1 by POSITION, LANGUAGE and TASK.

[72] The external variables shown here were excluded from the final model shown previously.

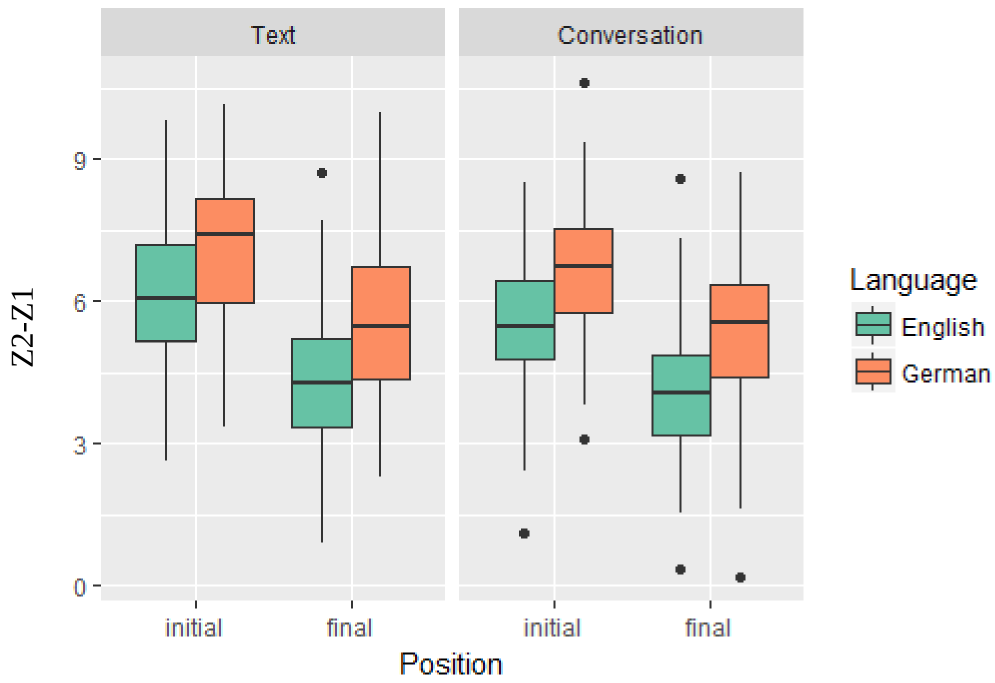

Figure 7.8: Z2-Z1 in the bilingual group across Position, Language and Task.

As visible in the graph, bilinguals produced phonetically separate laterals in each language, where their German shows a larger Z2-Z1, and English a smaller Z2-Z1. This observation is confirmed by an analysis via LMM (shown in Table 7.5), where Z2-Z1 was the dependent variable, and LANGUAGE, VOWEL, POSITION and TASK were independent variables. WORD and SPEAKER were added as random effects. The optimal model featured the variables as main effects only, and none of the interactions of interest were significant. Table 7.5 presents the final model for bilinguals' laterals in both languages.

Table 7.5: Linear mixed-effects model for the effect of internal and external variables on LateralDistance (Z2-Z1 between word-initial and word-final laterals) in the bilingual group in both languages.

Random effects:			
Groups	Name	Variance	Std.Dev.
Context	(Intercept)	0.3097	0.5565
Speaker	(Intercept)	0.3656	0.6046
Residual		1.1157	1.0563
Number of observations: 816, groups: Context, 205; Speaker, 12			

Fixed effects:					
	Estimate	Std.Error	df	T value	Pr(>|t|)
(Intercept)	5.2201	0.2392	32.6800	21.819	<2e-16***
Vowel (front)	1.2172	0.1293	118.0500	9.415	4.44e-16***
Position (final)	-1.2937	0.1275	128.3700	-10.145	<2e-16***
Language (German)	1.0167	0.1269	124.6000	8.013	6.85e-13***
Task (conversation)	-0.4546	0.1162	184.1500	-3.911	0.000129***

7.4.2 The loss of lateral allophony? - Comparisons of the distance between initial and final laterals in German and English across groups

A LMM was fit with LateralDistance as the dependent variable, and SPEAKER as random effect.[73] The fixed effects were VOWEL, LANGUAGE, TASK, and GROUP. Model comparisons revealed that an interaction between LANGUAGE and GROUP improved model fit significantly. TASK was neither significant as a main effect nor in interaction with other variables and therefore removed from the model. The final model is shown in Table 7.6.

Table 7.6: Linear mixed-effects model for group differences in LateralDistance (difference between word-initial and word-final laterals) across languages.

Random effects:					
Groups	Name	Variance	Std. Dev.		
Speaker	(Intercept)	0.08353	0.2890		
Residual		0.69243	0.8321		
Number of observations: 179, groups: Speaker 36					
Fixed effects:					
	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	1.50121	0.15899	66.58000	9.442	6.62e-14***
Language (German)	-0.10739	0.18404	149.20000	-0.584	0.56042
Vowel (front)	-0.07036	0.12476	149.15000	-0.564	0.57362
Group	-0.54158	0.20681	49.96000	-2.619	0.01166*

[73] The calculation of speaker averages for each lateral *context* naturally means that the more fine-grained data separation by *word* was merged into single context averages. Therefore, WORD was not part of the data distribution and could not be included as a random effect.

(Monolingual)					
Language (German): Group (Monolingual)	-0.92948	0.27745	117.25000	-3.350	0.00109**

To investigate the significant interaction in the model further, pairwise comparisons revealed that the LateralDistance bilinguals produce in their L1 English did not differ significantly from the LateralDistance in their L2 German. However, the bilinguals' German LateralDistance differs from the one produced by German monolinguals ($p < 0.0001$), and likewise the bilinguals' English LateralDistance differs from that produced by English monolinguals ($p < 0.04$). Figure 7.9 shows the interaction between LANGUAGE and GROUP for LateralDistance.

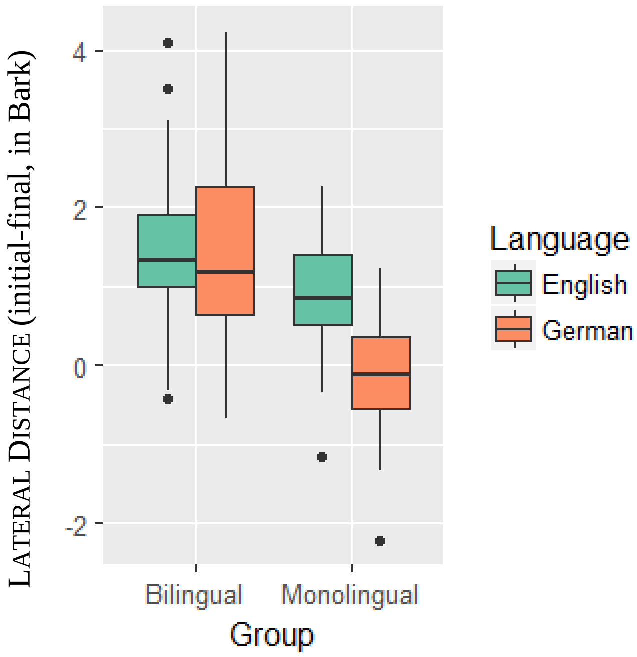

Figure 7.9: LATERAL DISTANCE for bilinguals in English and German as well as German and English monolingual controls.

7.5 Summary

The results above demonstrated a robust difference between the bilinguals and the monolingual control groups with regard to the phonetic realization of laterals, where the bilinguals produced laterals in their L1 as well as their L2 which are unlike those of the monolingual norms. Furthermore, the analyses did not reveal evidence for L2 phonological learning as showed by the analyses of LateralDistances.

Taken together, the analyses of the bilinguals' English laterals showed that the bilinguals produced their laterals with an increased Z2-Z1 in their L1, which indicates a shift towards their L2, German, where laterals are produced with a larger Z2-Z1 as compared to their L1. These effects however were not identical across the board. For example, the interaction between POSITION and GROUP for the Z2-Z1 of English laterals shows that the bilinguals' L2 does not fully determine the way in which an L1 will change as is expected via L2-based explanations often found in previous studies (see also Chapter 3). In particular, English word-initial laterals were shown to change more strongly than word-final laterals, which can be taken to indicate that English word-initial laterals are more susceptible to change in late bilinguals than word-final laterals are, as these seemed to be more resistant to attrition. As the analysis of the laterals produced by the German monolinguals showed, the bilinguals' English production pattern cannot come from the bilinguals' L2: In particular, monolingual German controls produced laterals with similar Z2-Z1 values across positions with a tendency for a larger Z2-Z1 in final laterals, albeit this slight difference was not significant. Thus, the attrition effect in the bilinguals' L1 seems to be closely related to the positional and phonetic properties of laterals observed across languages which were also reviewed in Chapter 2 of this dissertation. Here, cross-linguistic observations (Recasens, 2012) have shown that word-initial laterals are subject to greater acoustic variability within languages as compared to word-final laterals, which are more robust and show less acoustic scatter. Secondly, the clarity of laterals impacts their degree of variability, where clearer laterals exhibit more acoustic variability. Thus, word-initial laterals and clear laterals are more vulnerable to intra-language acoustic variation. This cross-language behavior of laterals accounts for the positional effect observed here. That is to say, the cross-linguistic trend for increased variability in word-initial, clear laterals is enhanced in the bilingual productions in this study.

The analyses of the bilinguals' German laterals showed that the bilinguals approximate their L2 from a phonetic perspective but fail to produce targetlike L2 laterals across the board, although the differences between the bilinguals in German and the German monolingual controls are larger in word-final laterals as compared to word-initial laterals, where the bilinguals are closer to the L2 target. This result reflects well-attested characteristics discussed in Chapter 2, whereby clear laterals and the word-initial position cause laterals to be acoustically more variable as compared to velarized, word-final laterals, a pattern well-attested across languages. This means that the late bilinguals approximate the L2 norm in both positional contexts but do so more strongly in clear laterals in initial position, the context and lateral quality more susceptible to variability and change than dark laterals in final position.

Secondly, the comparison of word-initial to word-final Z2-Z1 showed a significant interaction between GROUP and POSITION in English laterals which indicates that the phonetic change to the L1 of the bilinguals in word-initial laterals is more severe in word-initial laterals than word-final laterals. The analysis demonstrates that bilinguals exhibit a significantly increased distance between word-initial and word-final laterals in English. Additionally, the analyses showed that bilinguals exhibit an identical pattern in their L2, German, and that the bilingual German and the bilingual English pattern did not differ. Thus, bilinguals produced a non-nativelike pattern in both languages, both of which paradoxically favor smaller distances, German more so than English due to the lack of lateral allophony in German. The exceptionally large Z2-Z1 between initial and final laterals across both languages in bilinguals therefore suggests that the bilinguals have failed to acquire the phonological rule in their L2, which may explain the lack of change in their L1. The bilinguals also transfer allophony from their L1, but which is unlike that of English monolinguals: The asymmetry of the phonetic change to initial and final laterals enhances the distinctiveness of their lateral allophones which could be interpreted as a (potentially only temporary) strengthening of allophony. In this sense, paradoxically, a lack of allophony in the L2 does not cause the loss of L1 allophony and possibly even contributes to preserving it instead. Moreover, this effect implies that the late bilinguals did not establish separate phonological grammars for their languages. The lack of differentiation of the difference of Z2-Z1 in initial laterals and Z2-Z1 in final laterals between their languages strongly suggests that the same grammar operates in both languages.

Finally, the comparison of bilinguals' laterals in both of their languages revealed that bilinguals produce distinct phonetic realizations of laterals in both of their languages, each of which are closer to the respective monolingual norm. As such, this shows that bilinguals do not merge their lateral categories into a single phonetic realization but keep their languages phonetically distinct.

In sum, the results of the phonetic and the allophonic analyses of laterals indicate that bilinguals manipulate their acoustic space to accommodate the phonetic ranges of both languages in a single phonetic space, a result on par with the predictions of various models of phonetic learning (e.g., the SLM). In particular, the bilinguals increased the Z2-Z1 space available towards the clear end of the phonetic properties of laterals to accommodate the L2 lateral in a more targetlike fashion. Within the extended phonetic space, where the languages then occupy separate areas of the space, initial and clear laterals are more strongly affected by the extension than final dark laterals, which can be explained by the initial and clear laterals being more susceptible to large spans of phonetic variability across and within languages. Crucially, the phonological system remained unaltered, and therefore the same positional constraints apply within the modified phonetic space of bilinguals.

In addition, the degree of task formality was shown to influence the phonetic properties of laterals in bilingual English as well as the monolingual controls. In particular, the text reading task, a high formality task, triggered the largest Z2-Z1 difference in laterals in both groups, indicating that a high degree of formality leads to less strongly velarized laterals in general. This observation ties in with previous observations on the nature of velarization as a form of lenition. In this way, the result can be interpreted to indicate that speakers are more likely to deviate towards a lenited variant first in less formal styles, and less lenited forms in formal tasks. Furthermore, the lateral study showed a task difference for attrition, i.e., an interaction between Group and Task. This interaction indicates that bilinguals produce laterals differently from monolinguals depending on the formality of the task, and that the attrition of laterals is more pervasive in less formal tasks. Although attrition has been argued to be visible first in less formal tasks (Schmid, 2011), this idea is far from strong empirical support due to a lack of studies systematically comparing task differences in attrition, as already addressed in Chapter 3 of this dissertation. The results of the present study therefore contribute to this gap and show that attrition indeed surfaces first in less formal, conversational speech. The result that the smallest difference between bilinguals and monolinguals emerges in the grocery map task can be accounted for in the same way as the equivalent effect observed in rhotics earlier. Recall that the map tasks caused a potential audience effect in the bilingual group. The smaller Z2-Z1 distance in both word-initial and word-final laterals, then, may also be an expression of a better performance as a function of accommodating to an (albeit imagined) L1 audience. Unlike in the auditory analysis of rhotics, however, the effect here does not lead to a fully L1-like performance of the bilinguals, indicating that the effect of accommodation is also modulated by the segment.

Concerning the external variables, the analyses above did not show any of the individual variables to be significant predictors in L1 attrition or L2 acquisition of laterals. While the former result is clearly in line with previous studies as well as the analyses of rhotics in Chapter 6, the latter is somewhat more surprising. However, there is evidence that differences in the acquisition of laterals and lateral allophony due to L2 proficiency emerge only between groups with relatively large proficiency differences. For example, Solon (2017) showed that only the highest proficiency group in her sample differed significantly from the four low-proficiency groups. Likewise, attrition of phonetics and phonology could not be shown to be impacted by external variables, lending further support to the notion that the connection between external estimates such as proficiency and use is not as straightforward as assumed previously. Importantly, however, this result may simply fall out from a lack of differences between the bilingual participants in the sample as the proficiency differences between individual speakers in the study presented above may not have been not sufficiently large to yield a significant effect.

To sum up, bilinguals appear to use an intricately intertwined system for both of their languages, where attrition effects derive from a more global impact of L2 phonetics within the bilinguals' phonetic space rather than a direct, one-to-one phonetic effect of L1 and L2 sounds. This system is resistant to phonological change and remains in line with universal laws of phonetics.

Chapter 8

Discussion: Variability and change in the Dynamic Constraints Model

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8.1 Summary of the findings

The experiments presented in this dissertation showed that the L1 phonetic and phonological systems of late bilinguals remain susceptible to change across the life span. This change, however, is not exclusively guided by the L2 as often assumed (e.g., Keijzer, 2007). The experiments showed that the L1 productions of the late bilinguals deviate from those of the control monolinguals both in phonetic and phonological properties, but the properties of the bilinguals' L2, which are often presumed to be the intrinsic factors that trigger the non-convergence between bilinguals and monolinguals, can only account for a selection of changes. Although phonetic attrition clearly takes the direction of the L2 as predicted by models of phonetic L2 learning (e.g., Flege, 2007), change did neither affect the phonological patterns nor the different structural contexts under investigation in a unified manner. Instead, the changes in the bilinguals' L1 were subject to various contextual constraints also observed elsewhere (see Chapter 2): That is, phonetic properties of rhotics and laterals, typological tendencies in the unity and variation of /l/, and language-specific (in this case L1-specific) diachronic and synchronic behavior of /r/. While the bilinguals' L1 differs from their monolingual counterparts in degree of rhoticity produced across structural contexts, the distributional properties of /l/ in the bilinguals were not affected by the L2, where change was instead purely phonetic. Moreover, the data indicated that the bilinguals established an L2 grammar for German which crucially differs from the patterns observed in their L1. This may be taken to indicate that the bilinguals established separate grammars for the L1 and L2, respectively. As far as the changes in L1 are concerned, the findings suggest an important dichotomy: The direction of L1 change (rhoticity to non-rhoticity) and the non-L2-like structural patterns observed in that change (where non-rhoticity will be observed) have different sources. Crucially, the pattern observed in the /r/-dataset is highly reminiscent of the cases of synchronic variation of /r/ in variably rhotic monolinguals reported in Chapter 2, which implies that L2 influence may not need to arise in the precise patterns of the change that it has triggered. That is, the L2 only seems to *trigger* L1 change. The patterns that emerge in such change however, and the structural progression of the change are governed by constraint weights of the L1. Previous work in language attrition is known to suffer from a lack of frameworks with sufficient explanatory power. In this case, too, there is no current approach in L1 attrition that can account for these observations.

The remainder of this chapter will address the theoretical implications of the findings by developing a dynamic approach to L1 attrition which is informed both by psycholinguistic and phonological perspectives on variability. I will argue that phonetic and phonological change in L1 attrition is closely related to sound change in that L1 grammatical constraints undergo modifications in L1 attrition, and that the L2 triggers the onset of L1 attrition by increasing the noise also present in monolingual grammars, where it gives rise to variability in language. In this sense, the L2 neither induces a genuine restructuring of the L1 grammar nor does it control the developmental trajectory of sound change in L1 attrition; the L1 grammar instead becomes more variable but, although different from monolingual grammars, remains fully L1-like in that changes in attrition merely reflect underlying processes already present in the L1. To that end, I will suggest that an implementation of constraint-based approaches informed by a dynamic view of language development a la DST' can account for the data observed in the present study.

The following chapter is divided into two main sections. In the first, I will briefly review the arguably most advanced version of the DST in L1 attrition research, the DMM (Herdina & Jessner, 2002) and highlight several shortcomings of the DMM which fall out from the assumption that L1 attrition is fully guided by the impact of external variables, primarily by decreased L1 use. As we have seen in Chapters 3 and 4 as well as in the study presented here, the view of L1 use as the driving force in L1 attrition lacks empirical support and weakens the predictive power of the model. Moreover, the primacy of L1 use as an explanatory factor in the DMM also bears consequences for the model itself as it does not attend to mechanisms which can explain the differential outcomes of L1 change across different structural environments. For that reason, the DMM fails to account not only for the structural patterns which emerge in the L1 of the late bilinguals in this dissertation, but also L1 attrition in general.

The DMM's lack of powerful mechanisms which account for the effect of structural variables contrasts with other DST-based approaches to language. Most notably, this includes constraint-based grammars like OT (Prince & Smolensky, 2002) and its predecessor NHG (Legendre, Miyata, & Smolensky, 1990). Stochastic grammars like NHG offer tools which can model fine-grained variability in language and offer a promising approach to translate some of the DMM's assumptions into an approach drawing from insights to the behavior of the structures affected by L1 attrition from various strands of phonological research and based on phonological theory.[74]

The last chapter demonstrates modifications to constraint weight scaling to include bilinguals and to account for the data reported above. I will suggest modifications which adjust the weights of the phonological constraints in monolingual grammars to introduce variability in a way that reflects the patterns of L1 attrition as observed in the study presented here. The model is also in line with previous hypotheses on the processes believed to give rise to L1 attrition in general and can be extended to account for other processes of language change. In this way, I offer a unified account of L1 attrition informed both by phonological theory and models of bilingual phonological development.

8.2 A DST perspective on language development across the lifespan

8.2.1 Properties of dynamic linguistic systems: A DMM-perspective

The DST is an explanatory approach to complex interactions when two or more variables coexist in a single system, and in which, as de Bot, Lowie, and Verspoor (2007) argue, "all variables are interrelated, and therefore changes in one variable will have an impact on all other variables that are part of the system." (p. 8) Changes do not occur in isolation but permeates the entire system, a fundamental property of any dynamic system. This property is referred to as complete interconnectedness. In linguistic interpretations of DST, multiple languages coexist in a single mind, where they form a complex, non-linear dynamic system, and individual linguistic subdomains (e.g., phonological knowledge in the

[74] It is also worth noting here that the conjunction of both theoretical lines follows naturally as both the DMM and NHG originate from dynamical systems theory; NHG directly descends from harmony theory, "a mathematical framework for studying a class of dynamical stems that perform cognitive tasks" Smolensky (1986, p. 195).

L1 and L2) co-exist as separate but mutually interconnected subsystems. This view is achieved by the assumption that the linguistic system is nested such that the system branches into subsystems (e.g., subsystems consisting of different languages), which may branch into another, narrower set of subsystems (e.g., individual linguistic domains), and so forth. In this way, Herdina and Jessner (2002) argue that behaviors observed in bi- and multilingual speakers such as persistent non-nativelikeness in L2 learners, language attrition, and so forth, are not indicative of a failure of the learner to acquire an L2 or retain an L1 but emerge as natural, expected and inevitable consequences of language development.

In addition to interdependence and complexity, Herdina and Jessner (2002) argue that dynamic linguistic systems are further characterized by non-linearity, reversibility, stability, and change of quality (Herdina & Jessner, 2002). They suggest that language development does not progress linearly, i.e., in stepwise fashion along universal developmental stages and at a uniform growth rate; instead, language development progresses in curved fashion with phases of growth and phases of stagnation. Here, too, language development can take a positive (i.e., acquisition) or negative (i.e., loss) direction, and both remain reversible throughout the life span. Herdina and Jessner (2002) claim that such reversals are modulated by individual and external variables (e.g., language use, motivation, attitude). For example, language shift from dominance in the L1 to dominance in the L2 is known to result in an increase of proficiency in the L2 and decrease of proficiency in the L1, both of which are arguably shaped by the expected decrease of L1 use. Dominance reversal (i.e., back to the L1) is expected to induce the opposite constellation, i.e., loss of proficiency in the L2 and a re-emergence of L1 proficiency to the previous proficiency level. Importantly, regardless of the type of developmental process – positive or negative development, first-time acquisition, or reversal – changes in the system are assumed to strive towards a state of stability in which variables that favor negative development and variables that favor positive development are in balance. In their DMM, Herdina and Jessner heavily stress the effect of external variables such as the frequency of language use which they see as the driving forces not only in L1 attrition but in all areas and types of linguistic development including positive growth, negative growth and the stable state. However, their heavy focus on social and individual variables leaves the contribution of language-internal variables largely unaddressed and indirectly suggests that grammar-internal characteristics like linguistic markedness play a subordinate role in language development and change.

Finally, the acquisition of additional languages is assumed to bring about a change of quality of a speaker's linguistic system: Bilingual linguistic systems qualitatively differ from monolingual linguistic systems by way of accommodating more than one language. While this argument has been previously made in relation to linguistic patterns observed in bilinguals (Grosjean, 1998), Herdina and Jessner (2002) claim that the acquisition of an L2 qualitatively differs from L1 acquisition, but they remain silent with regard to the causes of this ‘change of quality’ and the differences induced by such change.

In its sum, the DMM attempts to integrate a number of observations on the nature of bilingualism and bilingual mental grammars. In this way, it can be said to unify insights from a vast range of research in SLA and bilingualism within a single, holistic framework. Nevertheless, the DMM suffers from several shortcomings. Most notably, it relies heavily on the explanatory power of external variables for language acquisition and development, but often lacks empirical evidence for such effects. Particularly in relation to L1 attrition, this raises several issues. To address these shortcomings, the following section intends to provide a brief overview of the causes and progression of L1 attrition according to the DMM, which will be followed by a discussion of the problems associated with various assumptions within the DMM.

8.2.2 L1 attrition and language development across the life span in DST

Although Herdina and Jessner (2002) make a strong case for the importance of taking language attrition into account in their DMM, they argue L1 attrition to be largely guided by external variables. In contrast, Herdina and Jessner (2002) so far remained silent about the contribution of structural properties of each of the languages in a bilingual’s mental grammar. L1 attrition, they argue, is “a function of language acquisition” (Herdina & Jessner, 2002 p. 106) and affects the L1 grammar whenever a speaker acquires new knowledge in another language. The links bilinguals establish between their languages opens the systems of both languages to mutual influence which results in continuous interaction leading up to change and attrition. The magnitude of attrition (i.e., the degree or severity of change in individual structures and the entire system) is controlled exclusively by external variables. Herdina & Jessner extensively discuss the impact of language use, but also mention variables such as the speaker’s motivation regarding acquisition and maintenance, the prestige of the languages, metalinguistic awareness, to name a few. Beyond language use they also see the language maintenance effort, a compound variable that unites the time and the effort a speaker invests in maintaining their L1, as a powerful determinant of L1 development in attrition (Herdina & Jessner, 2002). In this way, external variables occupy a privileged position within the

DMM, introducing a bias which overemphasizes the effect of external variables in language attrition despite lacking sound empirical support as previous research on L1 attrition largely failed to provide evidence for a relationship between the degree of attrition and any external variable. As mentioned briefly above, Herdina and Jessner (2002) view language use as one of the primary variables which affect all development in a bilingual's languages, however, the effect of language use has not been shown to reliably affect the strength of L1 attrition in a number of studies, including the study in this dissertation. Indeed, the idea that attrition can be attributed to changes in language use is a pervasive one in linguistic implementations of the DST. For example, de Leeuw et al. (2013) claim that within dynamic approaches, "the development of the L1 is seen as emergent from ongoing human social interactions across the lifespan" (p. 670), and thereby express the claim that attrition is modulated largely by the impact of external variables. Similarly, Jessner (2008, p. 274) argues that attrition is "an adaptive process in which the level of language proficiency is adjusted to the perceived communicative needs" and that "the system will erode if not enough energy and time is invested in maintaining the system.“ The effort necessary to maintain a linguistic system decreases disproportionally to the proficiency level in that language, where attrition involving a minor decrease in proficiency leads to a comparatively large decrease of maintenance effort (Herdina & Jessner, 2002). In relation to language attrition in particular, Herdina and Jessner (2002) claim that

> "[…] [l]anguage attrition is a gradual and much less spectacular process than abrupt complete language loss.... Language attrition is not observable because, at least at an early stage, it expresses itself in the form of an increased scatter of performance. As long as there is no explicit performance measure, this increased scatter will go unnoticed." (Herdina & Jessner, 2002, p. 96)

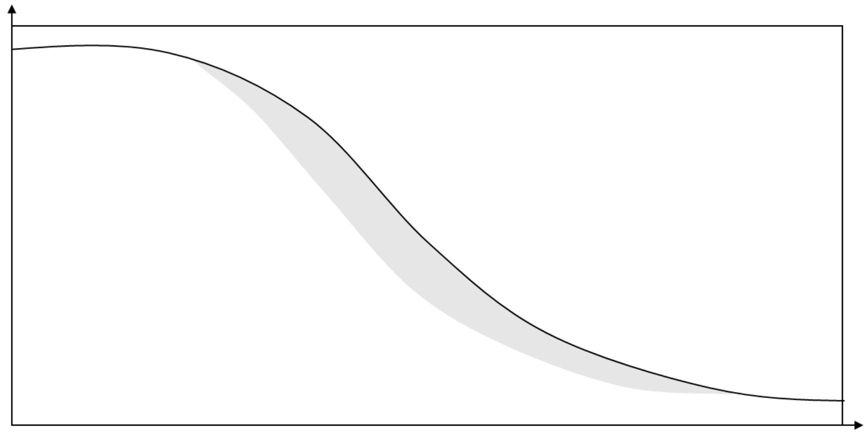

Figure 8.1: Chronological progression of L1 attrition, shown as scatter (from Herdina & Jessner, 2002, p. 96).

The initial phase of attrition which is characterized by *scatter* is followed by a phase Herdina and Jessner (2002) describe as "easily perceived forms of language loss" (p. 97); this is shown in Figure 8.1. Even here, however, loss is constrained by external variables which decrease or stop a further progression of L1 attrition. To illustrate, persistent language disuse is argued to fuel attrition. In particular, language disuse and loss will progress until a stable state is reached, i.e., a state where disuse is balanced by variables that disfavor attrition, such as maintenance efforts.

Here, a few words on what Herdina and Jessner (2002) call *scatter* are in order. They argue that

> "[…] research on second language variability has identified two forms of variability: systematic variability […] and non-systematic variability […]. Interlanguages can be shown to vary in a systematic way depending on the strategies employed by the speaker and the situation in which the language is used, that is, language production will systematically conform with a rule/principle and then systematically fail to conform with a rule/principle depending on the language use situation and the stage of language development. This systematic variation is complemented by non-systematic variation, a phenomenon we later refer to as scatter."
>
> (Herdina & Jessner, 2002, p. 50)

By using the term *scatter*, Herdina & Jessner suggest that changes under L1 attrition represent random variability, thus variability which is unconstrained by the laws known to shape language change. However, systematicity in L1 attrition has not been investigated previously, and few studies have addressed the question whether L1 attrition is random and unconstrained, or whether it progresses systematically. de Leeuw et al. (2013) indirectly address this issue as they argue that

> "[w]ithin DST the development of the L1 is seen as emergent from ongoing human social interactions across the lifespan. However, L1 development as a dynamic system is nonetheless thought to be highly, or sensitively […], dependent on its initial state (i.e., the L1, as a dynamic system, is dependent on its initial state, but may nonetheless undergo L1 attrition)." (p. 670-671).

Their remark that the initial state bears immediate consequences for L1 development resonates with the model I will present below in that the variability that emerges in L1 attrition proceeds systematically, but it can only emerge if the initial state of the L1 grammar allows for that type of variability to emerge in the first place.

The gaps and weaknesses in the DMM raise some questions in relation to modeling lifespan change in bilinguals, in particular questions like which variable(s) exactly trigger(s) L1 change in adult bilinguals, how an increase of variability manifests itself in late bilinguals, and whether variability is systematic or unconstrained. Similar questions are also raised by de Leeuw et al. (2012), who ask "if – as our evidence suggests – maturational constraints are insufficient in predicting L1 attrition, what variables must also be considered within a full dynamic systems theory and how can they be operationalised?" (p. 698).

To summarize, language attrition is assumed to be modulated (i.e., boosted or restrained) through external variables such as use and proficiency level. Importantly, these assumptions lack empirical evidence (see also Chapter 3). Furthermore, the DMM stays largely silent on the effect and contribution of internal variables such as structural properties of the L1 and L2 in language attrition. Instead, the DMM relies on sociolinguistic and individual (e.g., affective and attitudinal) variables to explain language development and language attrition and does not offer the means to incorporate the contribution of internal variables which are known to influence the progression of language change.[75]

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[75] Although frequently referred to as a *model*, de Bot et al. (2007) argue that the DMM "sounds like (and basically is) an ultimately mechanistic metaphor for language and language use, it is able to make clear the link between the social and the psychological aspects of the individual and language through the interconnectedness of systems" (p. 117).

8.2.3 Attractor and repeller states

In contrast to Herdina and Jessner (2002), de Bot et al. (2007) address possible contributions of internal variables. In their view, the contributions of internal variables are guided by *attractor states* and *repeller states*. The system gravitates towards preferred configurations (the attractor states) whereas dispreferred configurations (the repeller states) are avoided or, if a system reaches a dispreferred state, induce reorganization. de Bot et al. (2007) metaphorically describe the attractor and repeller states as “somewhat analogous to a ball rolling over a surface with holes and bumps, with the ball’s trajectory as development, the holes as attractor states and the bumps as repeller states” (p. 8).

It should be noted that Herdina and Jessner (2002) strongly argue against the necessity of a Universal Grammar (UG) in the DMM and suggest that language development can be accounted for within the DMM without assuming innate properties in language. In particular, they argue that UG fails “to explain why the level of L2 competence is not equivalent to that of L1 competence” (p. 43). In contrast, de Bot et al. (2007) do not see dynamic systems in conflict with generative approaches to language, and indeed with several other approaches to language development.

8.2.4 Variability in the DMM

Linguistic systems are in constant flux, giving rise to continuous development. Crucially, development can be positive (i.e., acquisition) or negative (i.e., attrition and loss). According to de Bot et al. (2007), linguistic development of individual speakers is closely intertwined with the degree of variability in individual language production, where increased variability – as observed in L1 attrition research as well as in the study presented in this dissertation – indicates a transitional stage characteristic of on-going language development. de Bot et al. (2007) further claim that “variability permits flexible and adaptive behavior and is a prerequisite to development” (p. 2).

In contrast, de Bot et al. (2007) see variability as an inherent feature of all (linguistic) systems, and governed by the laws of the languages involved, as well as a multitude of cognitive, physical and general features and limitations, e.g., memory and memory capacity, the time available to practice, use or maintain each language, physical limitations, and so on. Arguably, although not directly stated in de Bot et al. (2007), limitations to variability may also be imposed by universal linguistic laws, reflecting for example laws of phonetics and grammatical constraints.

It is conceivable, for example, that parts of the system are more resistant to changes, whereas others are more susceptible. How, then, can a part of a system be identified as potentially susceptible to changes? van Dijk (2004) argues that “variability bears important information about the nature of the developmental process” (p. 133), and that it functions “as the source of new forms” (p. 133). This idea can be extended to monolingual systems, which are also known to be subject to variation depending on context, i.e., grammar-internal contexts such as phonetic environment, or grammar-external contexts such as situational adjustments. Furthermore, van Dijk (2004) argues that

> “[v]ariability is considered to be the result of the systems’ flexibility and adaptability to the environment. From a dynamic systems angle, variability has been viewed as the source of development and the indicator of a specific moment in the developmental process, namely in the presence of a developmental transition.” (2004, p. 133)

Again, extending this to linguistic systems, those structures that show a high degree of variability are the structures that are inherently more flexible and adaptable.

This now allows us to draw important conclusions about potential fields targeted in dynamic approaches with respect to language attrition. The structures which have been shown to be highly variable even in monolingual speakers may indeed be the structures which are subject to change under the pressure of a second language.

8.3 Bilingual grammars in a dynamic perspective

As demonstrated above, the DMM provides insightful, albeit overly holistic and metaphorical, contributions to bilingualism as a dynamic development that is open to changes and modifications throughout the lifespan. In their version of the DMM, however, Herdina and Jessner (2002) strongly argue in favor of dynamic behavior across all linguistic sub-domains and neglect ample empirical evidence in support of developmental stages, and structures that are favored and disfavored in language acquisition and change. The DMM furthermore remains silent on a number of relevant questions, for example whether some L1-L2 constellations are more likely to trigger L1 attrition in a structure than others. The latter closely relates to the behavioral patterns observed in this dissertation which require an explanation beyond the influence of external variables (e.g., L1 attrition as result of diminished L1 use during L2 acquisition) to trigger attrition as well as beyond the structures in the L2 to account for changes in the L1. It should be added that previous research on L2 acquisition shows not only that CLI-effects are guided by their L1 and L2, but also that interlanguages exhibit features which seem to be rooted in universal laws as observed in cross-linguistic, synchronic, and diachronic research on language variability and change. These two observations also crucially underlie the phonological and phonetic attrition findings the present study yielded.

Since I have argued that language attrition in the domain of phonetics and phonology is reminiscent of variation and change at large, turning to phonological theory, which offers a variety of theories which can account for variability and change in phonetics and phonology, is a viable option. Recently, for example, constraint-based approaches to phonological grammars (e.g., classical Optimality Theory) have been adapted to model variability in monolinguals. Despite the popularity of constraint-based grammars and the advantages they provide, their application in bilingualism research is very limited although previous work suggests that they offer a fruitful avenue to model bilingual behavior (see Lombardi, 2003).

In the following section, I will show that systematic L1 attrition in phonology observed in the empirical studies presented here can be successfully modeled in a modified version of NHG. More precisely, I will show that the bilingual data can be accounted for, as NHG provides theoretical and empirical insights to the structural characteristics of languages as dynamic systems which are ignored in the DMM. In contrast to the DMM, NHG allows well-attested systematic behaviors to be expressed in structural constraints, and therefore it can be used as a tool to approach phonetic and phonological patterns observed in SLA and L1 attrition.

8.3.1 Variability in phonological constraint grammars

In constraint-based grammars, phonological processes are expressed as violable, conflicting constraints that are assumed to be universal. Thus, all languages operate with the same full set of constraints but differ from each other with respect to the hierarchical order of the constraints, giving rise to differences between individual languages.[76] The constraint set is divided into the primary two constraint families, the MARKEDNESS constraints, and the FAITHFULNESS constraints. MARKEDNESS constraints impose restrictions on the output form by penalizing marked structures in the output whereas FAITHFULNESS constraints regulate input-output correspondence by requiring output forms to correspond faithfully to the input form. While the constraints are ranked hierarchically with respect to each other in OT, NHG uses weighted constraints where higher weights correspond to higher ranks in OT. Here, constraints receive numerical weights which determine their rank relative to other constraints in the constraint set.

In classical HG, like in all constraint-based grammars, the grammar selects the winning output form from a set of possible output forms – the candidate set – by evaluating their Harmony – that is, how well-formed each candidate is – with regard to the constraint set. A candidate receives a violation mark for each constraint they violate; the sum of the constraint weights of each constraint multiplied by the number of the violation marks a candidate has received for that constraint yields a candidate's *Harmonic Score* (henceforth 'H-score'). The candidate with the H-score closest to 0 is the most harmonic candidate and selected as winner.

Like classical OT, classical HG gives rise to invariant grammars because the static constraint weights remain constant in every evaluation and fail to model variability in language. Noisy Harmonic Grammar is a modified version of classical HG which resolves the problem of modelling variability by introducing a noise component in the evaluation process which adds the potential for variability to the grammar, hence rendering the evaluation process a 'noisy' one. More precisely, in NHG, a candidate's H-score is the factored sum of the sum of any given constraint weight (w_i) and evaluation noise sampled randomly from a Gaussian distribution (nz_i), multiplied by the number of the candidate's violation marks of

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[76] Naturally, stating new constraints bears the risk of ungrounded or unmotivated constraints which reflect the dataset rather than phonetic and phonological laws; such constraints may fail when transferred to other contexts. Arbitrariness of constraints can be avoided in a number of ways; most importantly phonological constraints must be phonetically grounded. That is, phonological processes are motivated by phonetic properties which give rise to the process regulated by a constraint (Hayes, 2004). As pointed out before, constraint-based grammars like OT assume a universal and invariant underlying grammar. This strong version of phonetic grounding has been weakened by findings that language-specific constraints as well as 'unnatural' or 'unmotivated' constraints (Hayes, Siptár, Zuraw, & Londe, 2009).

that constraint (C_i(cand)).[77] The evaluation of a candidate's H-score can be expressed in the mathematical formula shown in (29).

(29) H-score in Noisy Harmonic Grammar (from Coetzee, 2016).

$$H(cand) = \sum_{i=1}^{n} (w_i + nz_i) \times C_i(cand)$$

Where C_i is the $_i$th constraint, w_i is the weight of this constraint, nzi the noise associated with C_i at a given evaluation, and C_i(cand) the number of C_i-violations of candidate *cand*, expressed as a negative integer.

Because evaluation noise is sampled from a Gaussian distribution, the constraint weights fluctuate slightly in each evaluation such that a candidate can emerge as the most harmonic candidate if the evaluation noise adjusts the constraint weights to result in that candidate receiving the lowest H-score. To illustrate, if the H-score of candidate A (CA) is closer to zero than the H-score of candidate B (CB), CA will win in most evaluations. However, if the H-scores of CA and CB do not differ by much, it is possible for CB to outscore CA at a small percentage if the H-score of CB falls closer to zero than that of CA through the addition of evaluation noise.

Yet, the subtle effect of evaluation noise cannot give rise to more substantial variability emerging under the influence of external variables (e.g., different degrees of formality). Recently, however, Coetzee (2016) demonstrated that scaling the constraint weights can help account for the effects of external variables known to introduce variability.

[77] Various implementations of evaluation noise have been suggested, either sampled per individual constraint (constraint noise), or per candidate, where evaluation noise is added to the sum of weights at the end of the evaluation process (candidate noise). However, Hayes (2017) argues that both implementations can be expected to yield similar results: In both cases, evaluation noise is sampled from a Gaussian distribution. The sum of noise added to individual constraints would thus follow a Gaussian distribution itself and is not expected to lead to far-reaching differences in the evaluation outcome. Constraint noise is often rejected in favor of candidate noise, but this rejection is based on the higher theoretical complexity of constraint noise leading to the same result as candidate noise (Hayes, 2017). In this dissertation, I will use constraint noise; however, this is not a theoretical decision or assumption, instead constraint noise falls out naturally from my Dynamic Constraints Model, where grammar-internal and grammar-external factors modify the behavior of noise in the grammar in a constraint-specific way.

Coetzee uses scaling factors[78], i.e., a numerical expression of the effects of social or individual variables which add to or subtract from the weights of FAITHFULNESS constraints. In this way, the weight difference between any two constraints can increase or decrease, decreasing or increasing the likelihood of variability, respectively. Coetzee's (2016) modified H-score formula is shown in (30).

(30) NHG with weight scaling of FAITHFULNESS constraints (from Coetzee, 2016).

$$H(cand) = \sum_{i=1}^{n} (w_i + nz_i + sf_{external\ variable})\, F_i(cand) + \sum_{j=1}^{m} (w_j + nz_j) M_i(cand)$$

Where F_i is the $_i$th FAITHFULNESS constraint, w_i is the weight of this constraint, nz_i the noise associated with the constraint at this particular evaluation occasion, $sf_{external\ variable}$ is the scaling factor, and $F_i(cand)$ the number of times that candidate cand violates F_i, expressed as a negative integer. And where M_j is the $_j$th MARKEDNESS constraint, w_j is the weight of this constraint, nz_j the noise associated with the constraint at this particular evaluation occasion, and $M_j(cand)$ the number of times that candidate cand violates M_j, expressed as a negative integer.

A comparison of the formulas in (29) and (30) reveals that Coetzee (2016) modifications give rise to a grammar which formally distinguishes MARKEDNESS and FAITHFULNESS constraints: In Coetzee's grammar, scaling factors adjust the weights of FAITHFULNESS constraints, but never affect MARKEDNESS constraints. Moreover, Coetzee argues that the scaling factors affect FAITHFULNESS constraints in a uniform manner, i.e., the scaling factor remains constant across FAITHFULNESS constraints. This results in a highly restrictive grammar which imposes limitations on the typologically possible set of variability and predicts some types of variability patterns to be impossible, namely those which require scaling of MARKEDNESS constraints. The motivation to restrict scaling to FAITHFULNESS constraints remains unclear; indeed, earlier proposals of such constraint scaling did not address the necessity of such restrictions (Boersma and Hayes, 2001).

[78] I use the term *variable* to refer to the property, process, or condition (e.g., the variable 'pre-rhotic vowel') that impacts speech, and the term *factor* to refer to a mathematical expression, i.e., the quantification the effect of a variable. A factor is therefore a quantified expression of the effect of a variable (or sum of variables).

In addition, Coetzee's weight scaling does not easily account for variability patterns, which suggests differential scaling of individual constraint weights within a constraint family. More precisely, because Coetzee does not allow FAITHFULNESS constraints to be scaled with respect to each other, no variability can emerge from one FAITHFULNESS constraint surpassing another one. It is worth noting here that the question whether the impact of external variables is indeed uniform across constraints has not been investigated in detail. Considering the wide range of variability in language, there are good reasons to believe that external factors do not necessarily affect FAITHFULNESS constraints in the same way, and that the same external factors may very well be able to influence MARKEDNESS constraints as well. English (non-) rhoticity, for example, tentatively supports differential weight scaling: Here, Coetzee's (2016) modifications fail to produce a grammar that mimics the changes to rhoticity whereas scaling both FAITHFULNESS and MARKEDNESS constraints can do so (see Himmel & Kabak, in preparation).

The change of English (non-)rhoticity therefore makes a case in favor of differential constraint scaling, and if the differences in scaling are motivated by some (phonetic or typological) property of the affected constraint, there is no good argument to prohibit the individual scaling of constraints. This can be achieved by considering whether the adjustment leads to changes that are typologically more frequent or to typologically more infrequent phonological patterns, and also applies to diachronic language change and change across the life span, which I will discuss below. In the next section, I will provide a brief outline of some of the central assumptions on language acquisition, development and change in constraint grammars, and finally suggest and demonstrate a modified version of NHG based on Coetzee's (2016) model to account for variability and change in language attrition, namely my Dynamic Constraint Model.

8.4 A Dynamic Constraint Model to L1 attrition

Coetzee's version of NHG outlined above accommodates phonological variability by allowing adjustments to FAITHFULNESS constraints via scaling factors controlled by external variables. Variability does not genuinely change inherent constraint weights but instead adds flexible adjustments which affect adult grammars by introducing optional temporary changes to previously learned default constraint weights. This model resonates well with the patterning of the L1 attrition data presented in this dissertation but needs some crucial adjustments. Below, I will argue that the effect of late L2 acquisition on the L1 does not induce grammatical change in the grammar of late bilinguals but is highly reminiscent of synchronic variability leading up to language change. In particular, attrition in a late bilinguals' L1 grammar is not characterized by changes to the learned constraint weights, but by adjustments to individual constraint weights of both types (i.e., FAITHFULNESS and MARKEDNESS constraints) induced by the acquisition of an L2. I will show that the structural consequences of L1 attrition can be captured in scaled constraints in an NHG-based implementation and develop a version of the model that will incorporate mechanisms to handle variability due to the differential weight of the MARKEDNESS constraints. I will call this the *Dynamic Constraints Model of L1 attrition*.

8.4.1 Accounting for increased variability in language attrition: 'bilingual noise'

First, we need to account for the emergence of L1 attrition of /r/ and /l/ in adult grammars. The study presented above revealed that the late bilinguals' L1 grammar exhibited a monolingual-like hierarchy with regard to the order of /r/-loss, characterized by a sharp increase of variability in postvocalic /r/. In particular, I argue that the results of the study presented here show that L1 attrition is not merely a result of CLI and transfer from the L2, but results from an increase in variability; crucially, the domains which are subject to increased variability are those already known to be prone to variability and change in the bilingual's L1. That is to say; I argue that L1 attrition reflects language change in that it mirrors an accelerated progression of changes to a language on a small scale – across an individual's lifespan.

As variability in language emerges through fluctuations of individual constraint weights introduced by evaluation noise, it is possible to account for L1 attrition data in a similar way, i.e., by introducing increased noise into the grammar. In this way, the noise pattern in NHG can be changed by carefully evaluating the variability that also emerges in bilinguals by adding a scaling factor which I will refer to as 'Bilingual noise' (henceforth nz_b) to account for emergent variability in the L1 of late bilinguals. In the case of bilinguals, the value of nz_b is larger than 1, i.e., $nz_b \geq 1$.

During the evaluation process, the effect of nz_b emerges as it adjusts the evaluation noise in each individual evaluation. To increase the evaluation noise in each evaluation, nz_b is a multiplier of nz_i. Importantly, nz_b is a compound factor consisting of multiple external properties which increase or decrease, the combination of which leads to a qualitative change in all grammars a speaker acquired across the life span. That is, the value of nz_b is subject to modification by external and individual variables, which is only natural given the diverse set of individual differences in SLA as well as L1 attrition in late bilinguals. This derives the formula shown in (31).

(31) NHG with scaling factor for increased variability in bilinguals.

$$H(cand) = \sum_{i=1}^{n} (w_i\,(nz_i \times\ nz_b) C_i(cand)$$

Where C_i is the $_i$th constraint, w_i is the weight of this constraint, nz_i the noise associated with C_i at a given evaluation, nz_b the noise multiplicator [Bilingualism adjustment], and C_i(cand) the number of C_i-violations of candidate *cand*, expressed as a negative integer.

Although this accounts for increased variability in bilinguals, the data presented in this dissertation indicated something beyond just a consolidated increase of that variability. While bilingual productions were monolingual-like in some contexts, they were less monolingual-like in others. This pattern was especially evident in the /r/ data, where SCHWA showed considerable variability as opposed to, say, NURSE. This difference is likely a result of the acoustic differences which (among other phonetic variables) also play a role in diachronic sound change. Thus, L1 attrition in phonology does not reflect direct influence from a similar L2 feature or constellation. Instead, the L2 seems to accelerate the inertia of the constraints that are underlyingly present in the L1 grammar and in that way speeds up the rise of language change to come.

The lateral data presented in this dissertation show similar patterns. First, phonetic change to L1 laterals seems to progress more quickly in word-initial position than in word-final position, which implies that the bilinguals' L2 is not the only driving force in the change observed. Second, in contrast to rhotics, bilinguals fully maintain the allophonic distribution of the English lateral. This raises questions as to how the discrepancies between the two phonological phenomena can be accounted for.

Recall from Chapter 2 of this dissertation that liquids may be unified in a single natural class but behave differently under language change as /r/ is known to undergo change more readily and more rapidly than /l/. On the other hand, the constellation of allophony in the L1-L2 combination investigated in this dissertation yields differences between /r/ and /l/ in relation to the cross-linguistically preferred pattern of change. More precisely, vocalization of consonants (i.e., lenition) is considerably more frequent than the opposite direction where vocalic segments become increasingly consonantal (i.e., fortition). The L1-L2 constellation reported in this dissertation represents both such cases of change with the L2 calling for vocalization of /r/, and for a more consonantal realization of /l/. If L1 attrition was exclusively controlled by direct influence and transfer of the L2, the result reported here cannot be readily accounted for. Admittedly, the data presented here does not reveal the cause of the difference between /r/ and /l/ regarding the successful acquisition of L2-allophony for /r/ and the failure to suppress allophony for /l/ by the late bilinguals. The asymmetry may be due to the higher stability of laterals in comparison to rhotics under language change, to differences between the acquisition and attrition of allophony in comparison to the suppression of allophony, to differences with regard to the type of change, i.e., vocalization (as in the case of postvocalic /r/) or consonantization (as arguably in the case of coda laterals), or something else entirely. Regardless, the results demonstrate that L2 influence alone is insufficient to account for phonetic and distributional L1 attrition, and instead calls for a broadened perspective of phonetic and phonological L1 attrition asymmetries.

Phonological constraints are argued to be phonetically grounded (Hayes, 2004), that is, MARKEDNESS constraints aim to shift phonetic characteristics of the structure they regulate towards a less complex alternative and optimize phonetic structure. Language change, on the other hand, has been shown to be subject to recurrent patterns time and again. To fully model L1 attrition, it is necessary to take (i) the expected direction of change (for example as implied by universal hierarchies of phonological processes such as lenition), and (ii) susceptibility to change into account. To account for these, I argue that all phonetically grounded phonological constraints are characterized by a fixed and constraint-specific compound factor which I will refer to as *speed and direction of change* (henceforth 'sdc). In particular, I argue that this factor is a part of the inherent constraint weight (i.e., the modifiable portion of the total weight), and that its value expresses the likelihood and preferred direction range a constraint may be subject to. This part of the inherent constraint weight interacts with scaling factors to constrain the effect such scaling factors may have on the affected constraint. In this sense, sdc can be said to play a role in guiding the evaluation process by adding information on both directionality and susceptibility to change. Due to the limited scope of the data presented here, the full extent of sdc remains speculative. However, the likelihood and preferred direction for change in language attrition seems to be reflected in the likelihood and direction of the same (or a very similar) change across languages and in its phonetic properties and therefore it should be possible to account for it via sdc. As its properties may either accelerate or inhibit change, sdc must be able to take on a positive or negative numerical value in which the likelihood of any change is expressed by the absolute numerical value of its sdc, and the direction of change is controlled by the sign, which may be positive or negative. Finally, it also interacts with the speaker's characteristics captured by nz_b, which will be indicated by multiplying sdc and nz_b for each constraint. This derives the final formula shown in (32).

(32) Constraint weight adjustment via Dynamic Constraint Model implemented in Noisy Harmonic Grammar.

$$H(cand) = \sum_{i=1}^{n} (w_i + (nz_b \times sdc_i) + (nz_i \times nz_b))C_i(cand)$$

Where C_i is the $_i$th constraint, w_i is the weight of this constraint, nz_i the noise associated with C_i at a given evaluation, nz_b the noise multiplicator [Bilingualism adjustment], sdc_i the change factor associated with the constraint, and C_i(cand) the number of C_i-violations of candidate *cand*, expressed as a negative integer.

The interaction between nz_b and sdc in the evaluation of the most harmonic candidate can be used to model the direction and magnitude of L1 change while accounting for the contribution of the L2 and general cross-linguistic observations at the same time. Here, a low sdc (say, +0.05) of a constraint will only marginally change the default constraint weight, even if nz_b is high. For example, if nz_b= 1.1 and sdc = 0.5, this yields via $1.1 \times 0.5 = 0.55$, i.e., an increase of 0.55 to the default constraint weight. Similarly, a high sdc will lead to more extensive changes only if nz_b is sufficiently large to yield variability beyond the monolingual norm.

8.4.2 Implementing the model: Liquids in L1 attrition

8.4.2.1 The loss of rhoticity

Let us now turn to an implementation of the model described above to account for the data presented above. In particular, the following subchapter aims to demonstrate that the modifications to NHG in my Dynamic Constraint Model can account for L1 attrition as observed in the study presented above. The weight adjustments through scaling factors will be tested based on learning simulations run in Praat's (Boersma & Weenink, 2018) positive

NHG algorithm. This algorithm simulates the process of L1 acquisition through its imitation of weight adjustments in weighted grammars as assumed for a learning child's grammar.

In the initial state of L1 acquisition, the constraint set is assumed to universally rank MARKEDNESS constraints above FAITHFULNESS constraints (M >> F), within each constraint family, however, constraints are unranked with respect to each other.[79] The linguistic input children repeatedly receive in L1 acquisition triggers the constraint reranking process (or the modification of constraint weights in weighted grammars respectively) by demoting (or lowering the weight of) constraints that favor a losing candidate.[80] The reranking/reweighting process in L1 acquisition yields developmental stages the learner progresses through before they reach an adult-like constraint setting, opening the grammar to variability and change. The plasticity of the grammar decreases continuously as the learner matures, decreasing the speed and the likelihood of grammatical change with age. Once the learner reaches adulthood, plasticity is assumed to reach minimum which stabilizes the grammar throughout the lifespan. Praat's learning simulations also imitate the decrease of plasticity by lowering a plasticity factor in the algorithm throughout the iterations. As shown in the review of Coetzee's (2016) suggestion, however, variability emerges through modifications to constraint weights by external variables which he expresses as mathematical scaling factors in the weighted grammar. These scaling factors quantify the effect of external factors in real numbers to temporarily adjust default constraint weights of FAITHFULNESS constraints, giving rise to variability in the grammar despite a lack of plasticity in the adult grammar. Scaling factors, however, are not integrated into Praat's learning algorithm and must be implemented manually (as also demonstrated in Coetzee, 2016).

Learning simulations were run using the data on the pre-rhotic vowel as it was shown to give rise to significant variability with regard to the degree of rhoticity in English, to test whether the Dynamic Constraints Model and the constraint set I postulated for English rhoticity give rise to a grammar that is learnable with regard to the input and yields an output

[79] For some constraints, fixed ranking orders are assumed, i.e., the constraints are ranked in a universally fixed ranking which cannot be reordered. Fixed ranking orders are therefore part of the grammar even in the initial state and exceptional as they are ranked with respect to each other.

[80] Whether the acquisition process involves constraint promotion or constraint demotion primarily depends on the learning algorithm and, by extension, the initial state of the grammar, i.e., the initial constraint ranking. Usually, MARKEDNESS constraints are assumed to universally outrank FAITHFULNESS constraints. Within many OT-based frameworks, learning is believed to be error-driven. Therefore, constraints which favor a losing candidate are penalized by demotion, whereas constraints which favor a winning candidate remain unaltered.

distribution that approximates the production pattern observed in the bilingual group. If both are true, this can be taken to confirm that both the grammar and the modifications via Dynamic Constraint Model are theoretically viable.

The simulations are based on a grammar regulating English rhoticity presented in (33), which contains two general constraints: MAX, a general FAITHFULNESS constraint shown in (33a) which requires output forms to be faithful to the input forms, and *RHOTIC, a general MARKEDNESS constraint in (33b) which requires surface forms to avoid rhotics. In addition, the grammar contains positional MARKEDNESS constraints which require output forms to avoid postvocalic /r/.[81] These constraints take into account the fine-grained differentiation across structural contexts which have been shown to strongly contribute to variable rhoticity in previous studies (see Chapter 2) and the present study. The constraints shown in (33c) to (33h) reflect the individual /r/-preceding vowels.

(33) Pre-rhotic vowel constraint set: Structural constraints for [Vr]-sequences in English rhoticity.

(33a) MAX	“Do not delete R”
(33b) *RHOTIC	“Do not have R”
(33c) *SCHWA	“Do not have R after unstressed central vowels”
(33d) *NEAR	“Do not have R after high front vowels”
(33e) *NORTH	“Do not have R after mid-low back vowels”
(33f) *NURSE	“Do not have R after stressed central vowels”
(33g) *START	“Do not have R after low back vowels”
(33h) *SQUARE	“Do not have R after mid front vowels”

[81] In contrast to Coetzee (2016), positional MARKEDNESS constraints rather than positional FAITHFULNESS constraints will be used in the account presented here. Unlike in Classical and Stochastic OT, where positional FAITHFULNESS is necessary to account for a variety of widespread phonological processes, weighted grammars including HG arguably suffer from positional FAITHFULNESS with regard to their predictive power; For instance, weighted grammars have been argued to overgenerate unattested grammars (e.g., Jesney, 2016). Jesney (2016) suggests a reduction of positional constraints in HG to include only positional MARKEDNESS constraints. Jesney argues that positional MARKEDNESS sufficiently accounts for phonological processes which are difficult to model in OT and require positional FAITHFULNESS constraints (see Jesney, 2016, for an extensive discussion).

First, it is necessary to determine the weights in an adult grammar without signs of L1 attrition – this stage of the grammar is represented by the monolingual American English speakers in the study above. The first learning simulation was based on an empty default grammar, i.e., an unranked grammar containing the necessary constraints in which constraint weights are set to the same arbitrary value; in the simulations here, the initial constraint weight was set to 100, Praat's default constraint weight. Praat's 'Positive HG' algorithm was used in all simulations and, except for Number of chews, the default settings were left unchanged.[82] Number of chews (i.e., the number of repetitions of each input-output-pair fed into the grammar; default value = 1) was raised to 5, which increases the amount of input fed into the grammar by five. Arguably, this reflects the maturing and repeated input expected in an adult grammar more closely and furthermore yields a higher accuracy of the constraint weights across the board. The grammar was trained using the distribution of presence and absence of postvocalic /r/ across preceding vowel contexts in the monolingual American English dataset; this training set is shown in (34).

(34) Distribution of /r/ after vowels in the monolingual American English training set.

Pre-rhotic vowel	Rhotic [%]	Non-rhotic [%]
*NURSE	100	0
*NEAR	99.4	0.6
*START	100	0
*SQUARE	96.8	3.2
*NORTH	98.8	1.2
*SCHWA	84.5	15.5

The learning simulation for the monolingual English grammar was run five times in total. After each trial, the resulting weights were recorded, and grammar was reset to its initial state (all constraint weights to 100) before the next trial. The weights from each trial were averaged, yielding the final constraint weights shown in (35).

[82] Noise = 2.0; Initial plasticity = 1.0; Replications per plasticity = 100000; Plasticity decrement = 0.1; Number of plasticities = 4; Relative plasticity spreading = 0.1; Honour local rankings = on.

(35) Final constraint weights of the monolingual grammar for pre-rhotic vowel constraint set.

Constraint	Ranking value[83]	Disharmony[84]
MAX	155.084	154.457
*SQUARE	103.632	102.255
*NORTH	102.234	102.826
*NEAR	101.445	101.665
*START	90.543	89.511
*SCHWA	59.020	58.158
*RHOTIC	44.916	45.025
*NURSE	47.063	46.417

The monolingual grammar in (35) shows that, as expected, the general FAITHFULNESS constraint MAX which requires the output to preserve postvocalic /r/s from the input received a high weight far above the remaining constraints. The comparatively low weight of *NURSE which prohibits postvocalic /r/ after the NURSE vowel in the output reflects the lack of /r/-dropping after NURSE by the monolinguals, and also reflects the low probability of /r/-dropping after NURSE in general as for example observed in the bilingual data above and across varieties of English. Likewise, the weights of the remaining pre-rhotic vowel contexts are expected given the data observed in this study.

With these weights, an output distribution was generated which shows that overall, the learning simulation mirrors the observed frequencies in the data set well. The expected (i.e., the simulated) distribution of the grammar's output matches the observed monolingual data very closely as visible in the comparison in (36).

[83] Ranking value refers to the constraint weight before noise is added.
[84] Disharmony refers to the constraint weight after noise is added.

(36) Observed and expected distribution of frequency of /r/-dropping in L1 English monolinguals. Expected distributions are based on the grammar in (35).

Pre-rhotic vowel context	Observed [%]	Expected [%]
*NURSE	100	100
*NEAR	99.4	99.4
*START	100	100
*SQUARE	96.8	97.0
*NORTH	98.8	98.9
*SCHWA	84.5	84.7

With the monolingual L1 grammar, i.e., the grammar before the onset of L1 attrition, in place, the explanatory power of the adjustments via the Dynamic Constraint Model developed for L1 attrition can be put to the test. As the formula requires values for both nz_b and sdc, it is necessary to estimate these two scaling factors first. Here, a word of caution regarding the constraint weights from the learning simulations and especially regarding the monolingual grammar above are in order.

To estimate the magnitude of the adjustments necessary to produce the data observed in the bilingual group, nz_b was inductively derived by using the dataset for the pre-rhotic vowel condition and was estimated using the difference between the monolingual's average constraint weight and the bilinguals' average constraint weight. In particular, I argued that the presence of an L2 leads to an increase of nz_b, but also that nz_b is subject to individual variability, leading to inter-speaker variability. For the sake of simplifying the scaling procedure, however, I will limit the implementation to the pooled group data to demonstrate the central steps.

Considering that bilingual grammars show increased variability and that NHG uses noise in the grammar to give rise to variability, $nz_b > 1$ follows. In lieu of a convention, the magnitude of nz_b was estimated as follows. To approximate the change from a grammar with 'monolingual constraint weights' in the direction of the 'bilingual constraint weights', another learning simulation was run: Using the monolingual constraint weights shown in (35) above as initial weights, the grammar was retrained with the bilingual data. The settings were adjusted by reducing the plasticity to 0.1 and plasticity increments to 1, so plasticity stayed level throughout the simulations to approximate the stability in mature grammars more closely, imitating an adult speaker rather than a child learner. To determine an estimate of the overall difference in constraint weights, the weights were averaged across the constraint set for each group, and the average weight of bilingual constraints (average weight = 86.77575) was subtracted from the average weight of monolingual constraints (average weight = 87.992125), resulting in a difference of 1.216375. In light of the considerations on the nature of nz_b above, it seems reasonable to adopt nz_b= 1.2 for the data presented above. As a preliminary test to see whether the adjustment by nz_b induces a change in the monolingual grammar and whether the changes induced by nz_b pattern as expected via the results of the study presented here, the formula in (31) – which still lacks sdc but is otherwise identical to the final formula in (32) – was implemented. The monolingual constraint weights in their initial state shown before in (35) were used to imitate L1 attrition, i.e.., change starting from a monolingual adult grammar, and an evaluation was run with 100 000 trials to compute the output distributions; nz_b was added by changing the evaluation noise from Praat's default value 2.0 to 2.4.[85] The output distributions of the nz_b-adjusted monolingual grammar, the output of the unscaled monolingual grammar for comparison and the difference between expected output distributions (in %) are shown in (37).

(37) Output distributions for the unscaled monolingual grammar and the partially scaled monolingual grammar.

		Output distributions [% rhoticity]		
Constraint (Vowel)	Observed distribution [%]-rhoticity (bilingual data)	Unscaled monolingual grammar	Partially scaled monolingual grammar	Difference % rhoticity (unscaled vs. scaled grammar)
*NURSE	98.8	100.00	100.00	0.00
*NEAR	89	99.42	98.22	1.20
*START	92.8	100.00	100.00	0.00
*SQUARE	87.5	97.04	94.11	2.93
*NORTH	82.6	98.91	97.21	1.70
*SCHWA	57.7	84.68	80.27	4.41

Comparing the output distributions in (37) reveals that the effect of nz_b patterns correctly in that it predicts *less* rhoticity in a scaled grammar as compared to an unscaled one.

[85] Changing the noise from a sample from a Gaussian distribution with *sd* = 2.0 to a Gaussian distribution with *sd* = 2.4 reflects $(nz_i \times nz_b)$ in (31).

Furthermore, the differences in the output distributions between the unscaled and the scaled grammar differ across vowel contexts. Moreover, the differential change to expected rhoticity between the two simulation trials, i.e., a stronger decrease of rhoticity in SCHWA as compared to other pre-rhotic vowels, closely reflects the differential change across pre-rhotic vowels also observed in the bilingual data. This shows that using nz_b to scale the grammar helps approximate the observed attrition data. However, the grammar still does not accurately reflect the magnitude of change to rhoticity in bilinguals observed in the study above which shows that further adjustments are necessary.

With nz_b in place, we can now turn to the estimation of sdc. Recall that nz_b is a *speaker*-specific and constant factor which quantifies the effect of bilingualism on the grammar, whereas sdc is *constraint*-specific as it regulates the direction and the magnitude of any weight adjustment by other factors (such as nz_b). Due to its constraint-specific nature, I argue that sdc is an expression of universal laws of phonetics which can be observed cross-linguistically in language variation and change past and present, and which must be taken into account to estimate the value of sdc.

In Chapter 2 of this dissertation, I reviewed the phonetic and phonological behavior of liquids. In particular, I highlighted several generalizations that emerge from cross-language observations: For instance, rhotic sounds in postvocalic position were shown to be subject to considerable phonetic and phonological variability, and also interact with their phonetic environment. These interactions modulate the changes to rhoticity diachronically and synchronically in that they can help preserve postvocalic /r/, but also contribute to its loss. Despite the preserving effects of some phonetic environments, synchronic research has shown that a change from non-rhoticity to rhoticity can progress within less than a century (e.g., Nagy & Irwin, 2010). Finally, the phonetic variability of /r/ is considerable and provides additional support to its inherent susceptibility to change, but also demonstrates that changes to phonetic quality do not seem to interfere with its phonotactic qualities. Despite their excessive phonetic spectrum, rhotic sounds remain genuinely ‘rhotic’ even under vocalization. This behavior implies that the sdc of English /r/ favors change and it can be tentatively assumed to differ in magnitude between the position-specific constraints regulating the presence and absence of /r/.

The exact value of sdc for each constraint was estimated inductively, relying on the data from the study presented above. While the differences between the corresponding monolingual and bilingual constraint weights were taken as a primary indicator to estimate

sdc in the data modeled here, it is important to note that sdc values require previous research in phonetic and phonology as well as historical and synchronic insights to be taken into account. That is to say, sdc values should be phonetically and phonologically grounded – analogue to the phonetic grounding of grammatical constraints – to ensure that sdc is indeed a powerful predictor for variability and change rather than an arbitrary means to mend inconsistencies in the grammar.

To that end, sdc values were distributed across the constraints following the general assumption in OT that language acquisition is error-driven and proceeds by demoting constraints which do not select the most harmonic (or optimal, in OT terms) candidate as the winner. This yielded two possible grammars, A and B, shown in (38), both of which produced an acceptable approximation to the bilingual data; the real bilingual data and the simulated distributions from both grammars are shown in (39).

(38) Adjusted weights and sdc values for Grammar A and Grammar B.

	Grammar A		**Grammar B**	
Constraint	**sdc weight**	**Adjusted weight**	**sdc weight**	**Adjusted weight**
*RHOTIC	0.5	45.516	0.5	45.216
MAX	0.7	153.284	0.75	152.984
*NURSE	0.25	47.363	0.25	47.363
*NEAR	0.5	102.045	0.25	102.045
*START	0.7	91.023	0.75	91.143
*SQUARE	0.2	103.872	0.5	104.232
*NORTH	0.4	103.074	0.5	103.134
*SCHWA	-1.5	59.86	-1.75	59.92

(39) Observed and expected distributions of [%]-rhoticity in Grammar A and Grammar B.

Pre-rhotic vowel	**Observed distribution [%]-rhoticity (bilingual data)**	**Expected distribution [%]-rhoticity (Grammar A)**	**Expected distribution [%]-rhoticity (Grammar B)**
*NURSE	98.8	100	100
*NEAR	89	91.4	93.33
*START	92.8	99.99	99.99
*SQUARE	87.5	80.1	84.75
*NORTH	82.6	86.62	88.15
*SCHWA	57.7	53.78	56.5

(38) and (39) show that the adjustments match the actual distributions in the bilingual data fairly well, although neither of the two possible *sdc* types do so very neatly. Two deviations are worth highlighting: The overproduction of /r/ in START and the underproduction of /r/ in SQUARE. These two deviations can be explained by looking at the monolingual data, where rhoticity in START-contexts is produced categorically, whereas SQUARE-contexts show a minor decrease in rhoticity. Here, Praat adjusts the default weights to match the distribution, leading to an excessively high weight of the START constraint, while the minor decrease of rhoticity in SQUARE leads to a relatively low weight of the SQUARE constraint, especially in relation to the other contextual constraints. The adjustments above, which were matched to more general observations in phonetics and phonology rather than to match the data of the present study closely, fail to adjust the constraints as neatly as would be desirable as the constraints reflect a relatively limited set of data with categorical results for the data belonging to some of the constraints. Nevertheless, the constraint weights yield a distribution which matches well in most contexts, and approaches the real data in the remaining contexts, indicating that the Dynamic Constraint Model can account for L1 attrition of rhotics and liquids by taking diachronic, synchronic, phonetic, phonological, and typological observations into account within a single mechanism.

8.4.2.2 The survival of lateral allophony

Finally, let us account for the lateral results. Recall that phonetic change but no allophonic change occurred in laterals: The late bilinguals maintained their L1 allophonic pattern in their L1 productions, and the effects of L1 attrition were limited to phonetic changes which affected the onset more severely than the coda. This asymmetry can be accounted for in a straightforward fashion in the Dynamic Constraint Model.

As already stated above, I assume that nz_b, which is responsible for the introduction of variability in bilingual grammars, is a constant scaling factor which applies uniformly and permeates the entire grammar. This means that the constraints responsible for lateral allophony are subject to the effect of nz_b just like the constraints that regulate rhoticity. Considering that rhoticity (i.e., /r/-allophony) was shown to change in the L1 (English) of the late bilingual group, which raises the question why lateral allophony seems unaffected by the L2.

First, let us cover the implications from typological, diachronic, and synchronic studies. In Chapter 2, I showed that laterals differ from rhotics in several ways. Most importantly, the review demonstrated that laterals readily participate in variation and change synchronically and diachronically but do so less extensively and more slowly as compared to rhotics. The higher resistance of laterals to change also emerges in their behavior across their positional distributions, where /l/ is treated as more consonantal than /r/, and in phonological processes which aim to avoid liquid consonants such as dissimilation, where sequences with multiple /r/ are strictly avoided whereas /l/ may stand in for /r/ even if both liquids are illicit. These facts can be taken as evidence of the less variable nature of laterals as compared to rhotics. With regard to their phonetic properties, a wealth of studies investigating the phonetic characteristics of clear and dark laterals suggests that the likelihood of change is lower for velarized laterals, which were shown to be highly resistant not only to change but also to coarticulatory variability. In contrast, non-velarized laterals allow for more variability which becomes evident in the larger acoustical continuum available to the speakers.

These insights suggest that the constraints that regulate American English laterals are less likely to be subject to variability and change than rhotics which the model can compensate with lower sdc values for constraints that typically give rise to variability in laterals. Furthermore, as shown in Chapter 2, historical changes to laterals and the progression of such change, which gave rise to vocalization and deletion of /l/ in postvocalic position, and synchronic variability, which yields vocalized variants in varieties of English, reflect a preference towards a weakening of the consonantal quality of /l/.

The observations above provide sufficient ground to propose relatively low sdc values in the constraints regulating laterals and lateral allophony (recall that a high sdc value leads to a more severe loss of constraint weight for those constraints which favor a losing candidate, i.e., one that disfavors /l/-vocalization). In addition, the strong preference for /l/-vocalization (especially in coda position) can be accounted for by assigning positive sdc values to increase the weight of constraints which punish non-vocalizing candidates, and negative sdc values to decrease the weight of constraints which punish vocalizing candidates.

Turning back to the question why lateral allophony did not change in the bilinguals' L1 despite the presence of the same category which can occur in the same positions in their L2, then, can be accounted for by suggesting that the constraints which lead to velarization (e.g., /l/ IS DARK) have a positive sdc value, which allows the weight of the constraint to increase. In this way, violations by non-velarization yield more severe penalties. In contrast, the weight cannot easily be decreased to weaken the penalty on violations as German would require. Thus, the influence of German is blocked because a movement towards German means that the direction of change inherited from universal laws of phonetics would need to be reversed.

The Dynamic Constraint Model therefore predicts that whether change will emerge to begin with depends on the universal properties of the structures involved, but also on the constellation of structures in the L1 and the L2. The specific L1-L2 constellation which determines the direction of change (i.e., the L1 has lateral allophony with an alternation of clear and dark laterals while the L2 has exclusively clear laterals) as well as the type of process (lenition vs. fortition, just to name one) is therefore an integral part of the model in that it affects change if that change runs opposite to the preferred direction. While much of this has been captured by approaches in the past, the Dynamic Constraint Model adds a unique facet: Even if the L2 induces a change in the L1, that change need not be structurally related to the L2 but may emerge as a genuinely L1-based pattern on which the L2 has no further effect. To that end, the model I propose, albeit in need of further testing and possibly substantial revision, shows that a vast variety of patterns that emerge in any kind of linguistic system can be holistically accounted for.

8.4.3 Implications for phonetics, phonology, and language change

Beyond L1 attrition in phonetics and phonology, the study presented in this dissertation bears implications for more general issues in the phonetics and phonology of liquids. Most notably, the changes of liquids in the bilingual group support and confirm previous observations from various linguistic approaches.

First, rhoticity emerges hierarchically across contextual environments, following structural constraints reminiscent of those which seem to operate in synchronic and diachronic variation of English /r/. This suggests that the L1 mental grammar included these constraints which is further supported by the presence of similar structural hierarchies in the English monolingual control group, and that the constraints were previously hidden by the higher-order FAITHFULNESS restriction which causes /r/ to surface in all positions (see also Zuraw, 2010). This also bears implications for the phonetic properties of the structural constraints; as constraints are required to be phonetically grounded, such phonetic grounding is expected to also exist for the sub-constraints. Here, it is conceivable that the constraints mirror a developmental progression which may potentially be observable during first language acquisition and rooted in perceptual or articulatory variables as suggested by Ohala (1981). This notion also finds support in cross-linguistic evidence: Storme (2018), for example, showed that the perceptibility of French postvocalic /r/ is lower in some structural contexts, which is likely to have induced a loss of postvocalic /r/ in the development of Haitian French.

The phonetic analysis of rhotics, on the other hand, informs models of phonetic learning such as the SLM. Here, it could be shown that the vowel contexts for /r/, albeit equivalent to the vowels tested in their L2, German, did not approximate the L2 phonetic target to the same degree. Crucially, such differential approximation has been addressed by Flege (2007), who argued that the degree of phonetic approximation of L1 and L2 categories is not merely influenced by phonetic similarity of an L1 and L2 category, but that "features may enjoy an advantage over others because of the nature of their acoustic (or gestural) specification, or their reliability of occurrence" (Flege, 1995, p. 268). Here the difference of the magnitude of change between /r/ after front vowels and /r/ after back vowels is conspicuous, where acoustic properties of /r/ after back vowels seemed to provide favorable conditions for changes to rhoticity as compared to /r/ after front vowels.

Similarly, the bilingual data on laterals confirms suggestions that initial clear /l/ is subject to larger phonetic variation and by extension more susceptible to change than final dark /l/ as evidenced by the larger increase of F2 in initial clear /l/s as compared to their syllable-final dark counterparts.

Finally, a comparison of the relative degree of change in English rhotics and laterals produced by the bilingual group reveals that rhoticity seems to undergo change more readily than laterals. For example, while the categorical absence and presence of rhoticity were affected, lateral allophony was unaffected by the L2. However, this result is in line with an abundance of cross-linguistic evidence that rhotics are more vulnerable to variation and change and accept changes more quickly than laterals do.

The auditory analysis of rhoticity in the speech of the German monolingual controls showed that the East Franconian dialect of Modern German is categorically non-rhotic; although it has been suggested that most German dialects went through a change from full or variable rhotic to categorical non-rhoticity (e.g., Wiese, 2001, 2003), this has not been demonstrated in empirical research. The result also implies that this development has been underway for several decades (or even centuries) as none of the German monolingual controls produced rhotic instances.[86] This suggests that categorical non-rhoticity does not seem to be limited to young speakers and implies that the change from rhoticity to non-rhoticity is not a recent change in the dialect. Nevertheless, rhoticity in Modern German remains understudied and lacks empirical research beyond small-scale studies on individual dialects. Here, more general cross-dialectal investigations can inform both accounts of German phonology and of the phonetics and phonology of liquids.

In a similar way, the analysis of the English controls' productions yields implications for both English rhotics and laterals. The auditory analysis of rhotics showed that monolingual speakers produce low frequencies of non-rhoticity in informal tasks. Although this can be argued to fall out from acoustic and auditory properties of rhotics, little research has been dedicated to structural constraints potentially at work here. Importantly, the monolingual's structural restrictions bear considerable similarity to the distributional hierarchies observed elsewhere, for example, the large body of sociolinguistic research on postvocalic /r/ in English as shown above. This suggests that variation in rhoticity and the pathways of change to English rhoticity are subject to universal constraints.

The lateral data, on the other hand, showed that American English monolinguals produced dark laterals across the board (see Recasens 2004, who argues that laterals can be categorized cross-linguistically as clear or dark by way of their acoustic profile). Crucially, however, this lack of an acoustic clear-dark distinction (i.e., the lack of clear acoustic counterparts) does not inhibit positional allophony in American English. Instead, a significant difference between initial and final laterals emerged in the monolingual English controls, who

[86] But recall that in the introduction of this dissertation, I mention evidence that that even monolingual grammars are not as stable across the life span as often assumed. A lack of rhoticity in the German monolinguals may be a result of an adaption to a general loss of rhoticity across the speech community.

produced a type of positional lateral allophony in which the two extremes of the allophonic spectrum usually represented by a clear and a dark counterpart fall into the acoustic range typically assigned to dark laterals. Therefore, the suggestion that (unlike British English laterals) because American English laterals are ‘dark’ across the board leads to a weakening (or even lack) of lateral allophony in American English is too simplistic and in need of revision.

Chapter 9

Conclusions

In this dissertation, I investigated liquids in L1 attrition and L2 acquisition by late bilinguals. I focused on the attrition process and asked questions regarding the contribution of structural transfer from the L2, the role of the L1 grammar and typological, diachronic and synchronic variability in liquids. I offered a unification of various strands of linguistic research to shed light on variables beyond the influence of the L2 that contribute and shape L1 attrition to arrive at a better understanding of L1 attrition in general and to address gaps in theoretical approaches to L1 attrition.

First, I presented theoretical backgrounds on English liquids and reviewed the justifications to unify them into a natural class of segments. I highlighted that their unification is not based on phonetic specifications, which varies within and across languages, but on their phonological behavior which, despite its considerable variability, remains constant from diachronic, synchronic, and cross-linguistic perspectives. I argued that it is precisely this quality which demonstrates their ‘unity in variability’ that offers fruitful grounds for L1 attrition research and research on language development more generally: In particular, liquids are open to various phonetic and phonological processes which affect them in a fine-grained structural progression of hierarchical changes. These subsequent stages can help tease apart the differential influence of the L2, other grammar-internal and universal properties of the segments and grammar-external variables relevant to language development.

Secondly, I showed that L1 attrition, which can be seen as a subtype of language development, does not seem to straightforwardly progress along the lines of structural transfer from the L2. Here, I reviewed several studies on attrition in phonetics and phonology and showed that while there is indeed some evidence that the L2 determines the number of phonetic changes, it is not sufficient to account for all of them. Previous studies often resorted to explanations from sociolinguistic studies and argued that variability in the input might cause a lack of attrition (e.g., Bergmann et al., 2016), yet these suggestions were not supported by empirical evidence. Here, I suggested that more general universal laws may also take part in guiding L1 attrition in phonetics as also expected via the SLM. Concerning changes to L1 phonology, I reviewed previous research and showed that only a handful of studies investigated phonological L1 attrition directly, and often did so by resorting to case studies. Thus, whether an L1 phonological system can change, for example as a result of phonetic L1 attrition, and how change progresses throughout a phonological structure is unknown.

In this dissertation, I addressed these gaps by investigating L1 attrition in the distributional and phonetic characteristics of liquids to shed light on the contribution of the L2 and the role of general phonetic and phonological variables to the processes that drive change in an L1. I investigated changes to phonetic properties and distributional patterns of rhoticity and /l/-allophony in the L1 of American-German late bilinguals, a language constellation which offers an instructive test case to investigate the causes of L1 attrition as well as the source from which change due to L1 attrition emerges. Furthermore, changes to liquids can also shed light on the processes which drive sound change, gradience and variability due to various positional and phonetic factors (e.g., preceding vowel quality, syllable structure) in liquids across many native varieties of English. In particular, I explored the variable realization and distributional patterns of two sounds known to be subject to a considerable degree of gradience and variability, namely English /r/ and /l/, in American English-German late bilinguals.

The results of the auditory and acoustic analyses from my production study of American English-German late bilinguals showed that both liquids were subject to L1 attrition in the bilinguals' speech, but also that /r/ and /l/ were not affected in the same way. Furthermore, none of the extralinguistic variables (i.e., L1/L2 proficiency, language use, etc.) explained the variation observed here.

The results of the auditory analyses of postvocalic /r/ revealed that the late bilinguals showed non-convergence with monolingual (non-)rhoticity in both of their languages. In their L1, English, they used vocalized variants of postvocalic /r/ more frequently than the monolingual controls did. Conversely, the late bilinguals failed to entirely suppress transfer of L1 rhoticity into their L2, German, leading up to a higher degree of rhoticity in their L2. While the loss of rhoticity in the bilingual’s English was distributed along a spectrum of contextual constraints (e.g., type of pre-rhotic vowel and morpho-phonological environment) known to affect rhoticity in other English varieties, the non-targetlike productions of non-rhoticity (i.e., non-vocalized postvocalic /r/) in their L2, German, were not sensitive to the same contextual constraints. The acoustic analyses of the bilinguals' rhotic productions in English and German differed from the respective monolinguals in the acoustic correlates of rhoticity, for example in pre-rhotic vowels in English, where they showed reduced anticipatory F3-lowering (i.e., less /r/-colored vowels).

I take my results to indicate that the bilinguals operate in two separate phonological grammars which approximate the respective L1 norm but show an increase of variability along constraints already present in each grammar. The bilinguals' phonetic system, in turn, seems to be shared between the two grammars, leading to persistent L1-L2 interaction in phonetics. Their non-nativelikeness (or non-conformity with the monolingual norm) in both languages can be seen as a result of two grammars operating within the same phonetic space. Thus, the changes in L1 attrition are induced but not governed by the L2: Change to the L1 reflects constraints underlying the L1 as well as more general laws of phonetics and universal trajectories of language change.

The lateral results revealed that just like in postvocalic /r/, the bilinguals showed non-convergence with the monolingual norm regarding the velarization of coda /l/ in both of their languages. The changes to English laterals were sensitive to their positional context and more substantial for word-initial laterals than word-final laterals. Similarly, their German laterals were non-convergent with the monolinguals in two ways. Firstly, the bilinguals differed with regard to the acoustic specifications of their laterals, and secondly, the bilinguals failed to suppress the lateral allophony from their L1, leading to a non-targetlike allophonic pattern in their L2 laterals.

I interpreted the lateral results to lack evidence that the L1 allophonic rule was affected by the presence of an L2; nevertheless, L1 change emerged in the phonetic specifications of laterals. Furthermore, the bilinguals did not establish a nativelike allophonic pattern in their L2, leading to non-convergence in the allophonic distribution as well as the phonetic realization of German laterals.

The results are in line with the predictions of models of phonetic learning (i.e., SLM), and furthermore provide evidence that language attrition follows paths also found in cross-linguistic and general phonetic variability as observed in monolingual populations.

Returning to the overall implications, this dissertation offers several insights into the nature of L1 attrition. For instance, I provide evidence that L1 phonetic attrition neither progresses like L2 acquisition nor is L1 attrition a mirror image of L2 acquisition, as is often assumed. The comparison of the attrition data with the late bilinguals' L2 acquisition data revealed that universal factors (e.g., articulatory constraints, typologically frequent patterns of variability) may enhance learning to the extent that undesirable patterns are eradicated more quickly: Rhoticity is more variable, and rhotics are more vocalic – acquisition was also more successful in the sense that the pattern acquired is more target-like as compared to the laterals.

Language attrition can therefore be said to be *induced* by the L2, but it is not governed by the L2, but by language-specific and universal trajectories of sound change also active in the L1. In this way, language attrition is closely related to processes we see in language change as it affects those domains more strongly which are by default open to variability and change.

Finally, I suggested that L1 attrition – and language development more generally – can be accounted for using a combination of theoretical tools from research in SLA, the Dynamic Model of Multilingualism, and a model from phonetic and phonological theory, Noisy Harmonic Grammar. Here, I suggested and, using artificial learning simulations, also demonstrated that the phonological constraints which govern variability in the L1 are adjusted by an increase of noise in a speaker's system: The L2 increases noise as it enlarges the system and adds linguistic material, causing the evaluation to become fuzzier. I furthermore argued that noise increases are constrained by universal properties inherent to each constraint. Thus, the weight of any constraint can only be adjusted by the noise increase if the constraint is open to such modifications. Coincidentally, the model is in line with various, more general assumptions about the nature of L1 attrition. For instance, the model does not require genuine restructuring of the bilingual's mature mental grammar, which is in line with several studies implying that no such restructuring takes place in the bilingual's grammar (see, for example, Chamorro, Sturt & Sorace, 2015). Furthermore, my model is in line with observations that the effects of L1 attrition impact different variables in diverse ways: For example, L1 attrition is subject to considerable individual variability, affecting some speakers extensively and noticeably, whereas other speakers do not seem to be affected at all. This can be explained by the values of the constraint scaling factors, which may be shaped by individual language biographies. Likewise, the effect of the level of formality on attrition demonstrated by Major (1992) and which has also been evident in the data presented in this dissertation could be straightforwardly accounted for using the sociolinguistic implementation of scaling factors a la Coetzee (2016).

In my dissertation, I showed that future studies in L1 attrition should focus on features which allow for a variety of contextual factors to be explored. In particular, my study showed that L1 attrition is subject to fine-grained contextual variation which also offers important insights into the nature of language development. It is furthermore recommendable to take a wider variety of possible sources for changes in L1 attrition into account as the lack of doing so in previous studies raised a number of gaps; these gaps, however, can supply important information on the progression of L1 attrition in an individual and across the board.

Future research is necessary to further test the Dynamic Constraints Model with regard to its explanatory power and its components. For instance, more research into the nature of scaling factors in general is necessary to investigate whether social factors interact by being conjoined into a single factor which accounts for the whole array of changes, or whether it is necessary to let scaling factors adjust the grammar individually. Future research is also necessary to test whether the noise I argued to result from the acquisition of a second language indeed results in a single noise factor, or whether bilingualism causes a multitude of different changes to other domains in the grammar (e.g., morphology and syntax), the noise levels of which may need to be computed individually.

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Appendix

Appendix A: Materials

A1: English Text

Sue and her friend Chad had planned a hiking trip in the mountains. This was going to be the trip of her life. Sue was nervous for weeks. When she found a tent on sale, she immediately bought it. She didn't know if she would ever use it for future trips. However, since the price was so much lower than that of any hotel, Sue couldn't resist. Although a tent didn't provide the same comfort a hotel room would, she wanted to experience the outdoors for a change.

One week before she left, she wanted to start preparing home-made beef jerky. However, her local supermarket had run out of beef. This came as a surprise and she was forced to buy pork instead. However, she couldn't tell if this would make an authentic 'beef' jerky. She had never seen this sort of jerky at a store, but she figured it would do for her trip.

Though Sue enjoyed the urban life in the city, her work as a Marketing Agent, which she had started right after she graduated college had been very stressful recently. The day before leaving she had yet to file a report on an urgent project. She was worried that this might interfere with her plans. She went to her boss's office to inform him of her shortcoming. Her boss was not pleased about this but he couldn't argue with her. After all, she spent her time finishing other, more important projects.

Relieved, Sue went home to do the packing. Only a few hours later, she embarked on her journey to meet up with Chad. It was late in the evening when she arrived at the small farm her friend Chad owned. This was the place she chose as her home base. She took a deep breath of fresh mountain air. When she looked up, she saw a single star twinkling in the night sky. She felt the excitement over things to come rise in her chest. Chad welcomed her and unloaded her bags from the car to give Sue some time to rest. Sue went inside and was immediately delighted by the small hut. The floorboards creaked slightly as she made her way to the living room. She picked up some logs from a stack in the corner and quickly made a fire to heat up the cold room. The old, wooden building soon was flooded by the flickering light. Sue liked the old but classy furniture that Chad inherited from his aunt. It didn't take long for Chad to carry her bags upstairs and join Sue. They spent the evening sitting in the warm living room and going over their plans for the next day.

They got up early the next morning to go on their first hike. A cold breeze blew the fresh snow over the tops of the pine trees. Sue was sure that the beautiful nature would clear her mind from the worries of daily life. Sue couldn't wait for the adventure to begin.

After an hour they arrived at the foot of a mountain, but the weather started to change. The small clouds had built up and darkened. It wouldn't take long for the rain to pour down and ruin their hike. Suddenly, Chad noticed the sound of rattling leaves in the woods they had just left. Sue looked at Chad in shock. She went through a mental list of wild animals that had the potential to harm them. Chad laughed off her concern. He wasn't the person to freak out easily. After all, he had never come across any wild animals on former hikes, except for an encounter with a beaver.

Sue turned around quietly and stared at the trees. She was certain that something was hiding in the bushes. Suddenly, she could feel Chad stiffen up next to her. He whispered something that Sue couldn't understand through her wool hat. Chad leaned closer, but before he could open his mouth, Sue noticed a huge bear trotting through the trees.

When Sue saw the bear, she started screaming and ran off. In panic, she ran across the meadow towards the forest opposite of them, hoping to find a shelter to hide in. A twig caught her arm and she could feel her sleeve rip. Finally, she came to a clearing in the forest. She checked her wound and cursed under her breath. A scar would certainly remain from the gash the branch had ripped into her arm. Her heart was pounding wildly. After taking a few deep breaths, she looked around. Standing in the middle of the clearing was a deer grazing peacefully. Sue's presence didn't seem to scare the animal. Sue knelt down into the soft grass. She had completely forgotten the threat of the bear – it just did not seem important to run any further. Instead, she watched the creature silently. Before too long, Chad arrived at the clearing, completely out of breath. His shock and fear disappeared when he noticed the serene scene. Carefully, Chad knelt down beside Sue. She was relieved that she hadn't run too far for Chad to find her. As Chad took Sue's hand, a bird in the tree behind them started singing its tune.

A2: German Text

Sina hatte sich vorgenommen, ihr Leben in diesem Jahr völlig zu ändern. Spontan hatte sie ihre Stelle als Pflegerin in einer großen Hundeklinik gekündigt. Sina wollte gerne ihre Zeit in der Natur verbringen, doch das konnte sie in der Klinik nicht. Sie hatte zwar Zweifel daran, ob es richtig war, ihre feste Anstellung aufzugeben, aber dennoch freute sie sich auf ihren neuen Job. In der Klinik war die Arbeit frustrierend und bürokratisch geworden. Oft füllte sie stundenlang Formulare aus und besonders viel Geld verdiente sie auch nicht. Deshalb entschloss sie sich, für eine Organisation zu arbeiten, die auf Naturschutz spezialisiert war. Diese war besonders dafür bekannt, einheimische Arten zu schützen. Anfangs würde sie noch in einer Praxis für verletztes Wild arbeiten, später jedoch würde man sie auch auf Außeneinsätze mitnehmen. Natürlich würde ihre neue Stelle mehr von ihr fordern, doch Sina freute sich auf neue Herausforderungen und Erfahrungen.

Als Sina an ihrem ersten Tag aufwachte und auf die Uhr sah, packte sie der Schrecken. Hastig sprang sie aus dem Bett. Sie hatte direkt am ersten Morgen verschlafen.

Nun blieben ihr nur noch Minuten, um sich fertig zu machen. Sie duschte, frisierte ihr Haar so schnell wie sie konnte und zog sich an. Für das Frühstück blieb ihr keine Zeit.

Sina blickte in den Himmel als sie das Haus verließ. Sie seufzte laut, denn sie war sich sicher, dass das schöne Wetter nicht halten würde. Und sie sollte Recht behalten. Auf der Fahrt zur Praxis begann es zu Regnen. Zu allem Übel musste sie feststellen, dass sie ihren Schirm zuhause vergessen hatte. Missmutig trottete sie über den Parkplatz und fluchte leise, da ihre Frisur nun ruiniert war. Als sie die Praxis betrat, wurde sie von Sandra, ihrer neuen Kollegin, freundlich begrüßt. Dies ließ sie ihren Ärger über ihre Frisur sofort vergessen.

Wenig später betrat ein hysterischer, älterer Herr die Praxis. Er hatte einen Korb bei sich, aus dem seltsame Geräusche kamen. Sina führte den Mann schnell in eines der Behandlungszimmer. Sie hob die Decke über dem Korb leicht an. Zum Vorschein kam ein Adler, der sich augenscheinlich verletzt hatte. Das aufgeregte Tier krächzte schrecklich. Immer wieder versuchte er, seinen Schnabel an seinem rechten Flügel zu reiben. Er schien große Schmerzen zu haben. Sina war klar, dass das Tier Hilfe brauchte. Sie nahm ihn vorsichtig auf den Arm und streichelte ihn sanft. Der Vogel jedoch beruhigte sich nicht. Sina konnte fühlen, wie das Herz aufgeregt pochte.

Der Mann erzählte in der Zwischenzeit, dass er gerade im Wald spazieren ging, als er ein seltsames Geräusch hörte. Er sah sich um und stellte fest, dass das Geräusch von einem Stapel Holz einige Meter entfernt kam. Als er nachsah, was das Geräusch verursachte, entdeckte er den Adler. Daraufhin holte er eine Decke aus dem Auto und wickelte den Adler ein. Er wollte ihn warm halten, da das Tier vom Regen völlig durchnässt war. Danach fuhr er schnell in die Praxis.

Sandra rief einen jungen Arzt hinzu, der den Adler untersuchte. Vorsichtig setzte Sina ihn auf den Untersuchungstisch. Der Adler jedoch setzte sich zur Wehr und versuchte, zu entkommen. Der Arzt packte ihn, bevor er vom Untersuchungstisch entkommen konnte, und bat Sina, das Tier fest zu halten. Mit ernstem Blick untersuchte der Doktor den wütenden Vogel von oben bis unten. Schließlich lächelte der Arzt und holte eine Zange aus seinem Kittel hervor. Mit einem Ruck zog er einen rostigen Nagel aus dem Flügel des Adlers. Der Arzt erklärte allen, dass die kleine Wunde harmlos war. Zur Sicherheit gab er dem Adler aber dennoch eine Spritze, um eine Entzündung zu verhindern. Der Mann war erleichtert, dass seine Sorge völlig unbegründet war.

Nachdem die Wunde versorgt war, setzte Sina die majestätische Kreatur zurück in den Korb. Sandra hatte ihr den Vorschlag gemacht, loszufahren und den Adler frei zu lassen. Sina hatte sofort glücklich zugestimmt.

Als Sina die Praxis verließ, hatte der Himmel wieder eine strahlend blaue Farbe angenommen. Die Sonne hatte bereits jede Wolke vom Himmel verdrängt. Sie fuhr in einen Park in der Nähe der Praxis. Dort angekommen stieg sie aus dem Auto und sah sich um. Sie fand, dass dies der richtige Ort für den Adler war. Sina öffnete den Korb. Der Adler blinzelte kurz in der Sonne, streckte dann seine Flügel aus und flog davon. Erleichtert, dass nun alles wieder in Ordnung war, sah sie ihm nach. Sie blieb noch eine Weile stehen und lauschte einem Vogel, der in den Ästen eines Baumes saß. Sina lächelte und genoss das sichere Gefühl, dass dieser Job perfekt für sie war.

A3: Background questionnaire

1) What is your date of birth? ……………………………………………19………………….
2) Are you: ❑ male ❑ female
3) Where were you born: Village/Town:…………………………………………………… County:…………………………………..Country:……………………………………
4) What nationality do you have? ❑ US ❑ US & GER ❑ GER
5) Would you say that you spoke a variety or a dialect of American English while you lived in the US?
   ❑ Standard American English ❑ a dialect, namely:
6) What is the highest level of education you have completed?
   ❑ primary school ❑ secondary school, level ❑ higher education ❑ university
7) When did you come to Germany (year)? ……………………………..19…………………
8) Why did you emigrate and why to Germany in particular?
   ❑ job ❑ partner's job ❑ partner ❑ other, namely: ……………………………………
9) Apart from Germany, have you ever lived in a country other than the USA for a longer period of time (that is, more than 6 months)?
   ❑ no
   ❑ less than 1 year, in: town)…………………………..(country)……………………...❑ 1 year or more, in: town)…………………………..(country)………………………
10) What language(s) did you acquire before starting school?
   ❑ English ❑ English & other ❑ other
11) Did you attend any German classes before coming to Germany? (this has to be in an educational environment, like a school or some similar institution):
❑ no
❑ yes, less than 1 month
❑ yes, less than 3 months
❑ yes, less than 6 months
❑ yes, less than 1 year
❑ yes, more than 1 year
12) Have you pursued further education while living in Germany (this does not have to be language-related)?
❑ yes, for (number of years):…………………………… ❑ no
13) What language or languages did you learn professionally or at school?
……………………………………………………………………………………………
14) What language or languages did you learn outside of an educational environment (so outside of school or work)?…………………………………………………………………
15) What is your current profession? If you are retired, could you please indicate your last profession before retirement? ………………………………………………………….
16) If you have had several professions, could you indicate each one of them in chronological order?
…………………………………………….from……………..until………………………
…………………………………………….from……………..until………………………
…………………………………………….from……………..until………………………
17) Have you ever attended American heritage classes while living in German?
   ❑ yes, in (year): 19………for the period of: ……….months,……………hours a week
   ❑ no
18) Have you ever been back to the US since leaving for Germany?
❑ never
❑ seldom
❑ regularly, 1-2 times a year
❑ regularly, 3-5 times a year
❑ regularly, over 5 times a year

19) If you have indicated that you have been back to the USA, could you please indicate what the reason or reasons for such a visit were (you may tick more than one box here)?
❑ because of urgent family matters (such as a wedding or a funeral)
❑ to visit without a particular reason
❑ for another reason
20) Do you ever go to church in Germany?
❑ no, never
❑ yes, sometimes
❑ yes, regularly
21) If you have indicated you go to church, could you please indicate in which language the services are held? ❑ EN ❑ GER ❑ EN & GER ❑ other
22) In general, how would you rate your German language proficiency before you moved to Germany? ❑ none ❑ very bad ❑ bad ❑ sufficient ❑ good ❑ very good
23) In general, how would you rate your German language proficiency at present?
❑ none ❑ very bad ❑ bad ❑ sufficient ❑ good ❑ very good
24) In general, how would you rate your English language proficiency before you moved to Germany? ❑ none ❑ very bad ❑ bad ❑ sufficient ❑ good ❑ very good
25) In general, how would you rate your English language proficiency at present?
❑ none ❑ very bad ❑ bad ❑ sufficient ❑ good ❑ very good
26) How often do you speak English? ❑ rarely ❑ few times a year ❑ monthly ❑ weekly ❑ daily
27) Do you consider it important to maintain your English?
❑ unimportant
❑ relatively unimportant
❑ not very important
❑ important
❑ very important
28) Do you consider it important that your children can speak and understand English?
❑ unimportant
❑ relatively unimportant
❑ not very important
❑ important
❑ very important
29) In general, do you have more German- or English-speaking friends in Germany?
❑ only English-speaking friends
❑ both, but more English-speaking friends
❑ as many German- as English-speaking friends
❑ both, but more German-speaking friends
❑ only German-speaking friends
30) Do you feel more at home with American or with German culture?
❑ with American culture
❑ with both, but more with American culture
❑ with both cultures, equally
❑ with both, but more with German culture
❑ with German culture
31) Do you feel more comfortable speaking German or English?
❑ English ❑ German ❑ no preference
32) Could you elaborate on your answer: why do you feel more comfortable speaking either German or English or why don't you have any preference? ………………………………….
33) What is your current marital status?
❑ married ❑ separated/divorced ❑ widow/widower ❑ with partner ❑ single

34) With what language(s) was your (ex)partner brought up?
❑ German ❑ English ❑ other, namely: ……………………………………………….
35) If your (ex)partner was not born in Germany, what were the reasons that he or she came to Germany?
❑ job ❑ partner’s job ❑ partner ❑ other, namely: ………………………….
36) When did your (ex)partner come to Germany (year)? 19…………………………………..
37) Where did you meet?
❑ GER ❑ USA ❑ other, namely: …………………………………………………
38) What language or languages do you mostly use when talking to your (ex)partner?
❑ only English
❑ both German and English, but mostly English
❑ both German and English, without preference
❑ both German and English, but mostly German
❑ only German
❑ other or no answer
39) What language or languages does your (ex)partner mostly use when talking to you?
❑ only English
❑ both German and English, but mostly English
❑ both German and English, without preference
❑ both German and English, but mostly German
❑ only German
❑ other or no answer
40) What is the current profession of your (ex)partner? If your (ex)partner is retired, could you please indicate what his or her last profession before retirement was? ………………
41) Do you have children?
❑ no ❑ yes, number: ………and they are…………………………………years old
42) What language or languages do you mostly use when talking to your children?
❑ only English
❑ both German and English, but mostly English
❑ both German and English, without preference
❑ both German and English, but mostly German
❑ only German
❑ other or no answer
43) What language or languages do your children mostly use when talking to you?
❑ only English
❑ both German and English, but mostly English
❑ both German and English, without preference
❑ both German and English, but mostly German
❑ only German
❑ other or no answer
44) Do you have grandchildren?
❑ no ❑ yes, number: ……………and they are……………………………years old
45) What language or languages do you mostly use when talking to your grandchildren?
❑ only English
❑ both German and English, but mostly English
❑ both German and English, without preference
❑ both German and English, but mostly German
❑ only German
❑ other or no answer
46) What language or languages do your grandchildren mostly use when talking to you?
❑ only English
❑ both German and English, but mostly English

❑ both German and English, without preference
❑ both German and English, but mostly German
❑ only German
❑ other or no answer

47) Do you encourage your children to speak German?
❑ no, never ❑ yes, occasionally ❑ yes, often

48) Did your children ever follow American heritage classes (Saturday classes for example)?
❑ yes ❑ no

49) Did /do you ever correct your children's English?
❑ never ❑ very rarely ❑ sometimes ❑ regularly ❑ very often

50) If your children do not speak or understand English, do you regret that?
❑ not at all ❑ not much ❑ no opinion ❑ a bit ❑ very much ❑ no answer

51) Are you in frequent contact with relatives and friends in the USA?
❑ very rarely ❑ rarely ❑ sometimes ❑ frequently ❑ all the time

52) How do you keep in touch with those relatives and friends in the USA?
❑ telephone ❑ letters ❑ e-mail ❑ another way, namely: …………………………...

53) What language or languages do you mostly use to keep in touch with relatives and friends in the USA?
❑ only English
❑ both German and English, but mostly English
❑ both German and English, without preference
❑ both German and English, but mostly German
❑ only German
❑ other or no answer

54) Do you think English plays an important role in the relationship between your direct family members?
❑ not at all ❑ not much ❑ probably ❑ a bit ❑ very much ❑ no answer

55) Have you made many new friends in Germany?
❑ yes ❑ no

56) What is the mother tongue of the majority of these people?
❑ English ❑ German ❑ equal ❑ another language

57) How did you meet most of these people?
❑ through a English club or organisation
❑ through mutual friends
❑ through work or the children's school
❑ through another way, namely: ……………………………………………………

58) Could you please fill in those people that you are most frequently in touch with in the following table? These people can live in the USA or in Germany. I wish to see through this table which language you most frequently use in your daily life: German or English. You don't have to fill in the name of the person if you do not wish to. I would like to ask you, however, to provide the rest of the information asked for.

Name (optional)	Does this person live in the US or German?	What language(s) do you use when communicating with each other?	How did you meet this person?	How long have you known this person?	What is your relationship with this person?

Could you, in the following tables, please indicate to what extent you use English (table 1) and German (table 2) in the domains provided? You may simply tick the box. If a certain domain is not applicable to you (for example, if you don't have any pets), you may leave the box empty.

I speak English					
	all the time	frequently	sometimes	rarely	very rarely
With relatives					
With friends					
To pets					
At work					
In church					
In shops					
At clubs or organisations					

I speak German					
	all the time	frequently	sometimes	rarely	very rarely
With relatives					
With friends					
To pets					
At work					
In church					
In shops					
At clubs or organisations					

59) Have you ever been a member of an American/English club or organisation in Germany?
❑ yes, namely (name of the organisation and period of membership): ………………..
❑ no
60) Are you now a member of an American/English club or organisation in Germany?
❑ yes, namely (name of the organisation):…………………………………....❑ no
61) Do you ever get homesick in the sense of missing the USA?
❑ yes, what I then miss most is/are: ………………………………………………
❑ no
62) Do you ever listen to English songs?
❑ yes ❑ no
63) Do you ever watch English television programmes?
❑ yes ❑ no ❑ I would love to, but I can't get them

64) Do you ever listen to English radio programmes?
❑ yes ❑ no ❑ I would love to, but I can't get them
65) Do you ever read English newspapers, books or magazines?
❑ yes ❑ no
66b) If you have indicated that you never listen to English songs or radio programmes, nor read English newspapers, books or magazines and that you don't watch English television programmes, could you indicate why you think that is? ……………………………………
66) Do you think your English language proficiency has changed since you moved to Germany?
❑ yes, I think it has become worse
❑ no
❑ yes, I think it has become better

67) Do you think you use more or less English since you moved to Germany?
❑ I think I use less English
❑ I don't think I use more or less English now
❑ I think I use more English
68) Do you ever feel uncomfortable when speaking English with an American person who has never spent a considerable amount of time in an German-speaking country?
❑ yes, sometimes ❑ no, never
69) If you ever do feel uncomfortable in such a situation, could you indicate whether this is also the case when you speak English with someone who, like you, has lived in Germany for a long time? ❑ yes ❑ no
70) Do you see yourself as bilingual? In other words, do you think you are as proficient in German as in English?
❑ no, I'm more proficient in English
❑ yes
❑ no, I'm more proficient in German
❑ I don't know, because:……………………………………………………………..
71) Are you better at guessing a person's social position/status when they speak German or English?
❑ English
❑ equal
❑ German
❑ I don't know, because: …………………………………………………………….
72) How do you feel about English people (tourists for example) who speak German with a heavy English accent? ❑ that annoys me ❑ I don't have any problems with that
73) Do you ever intend to move back to the USA?
❑ yes, I would eventually like to move back to the USA
❑ no, I don't intend to ever return to the USA
❑ I don't know
74) If you have indicated that you do not intend to ever move back to the USA, can you explain why you feel that way? ………………………………………………………...
75) Looking back, do you think you have made the right decision in moving to Germany?
❑ yes ❑ no, I wouldn't do it again if I had to make the choice again, because: ………………❑ I don't know, because: ……………………………………………………..

A4: English C-test

Text 1:

We all live with other people's expectations of us. These are a refl____________________ of th____________________ trying to under____________________ us; the____________________ are predic____________________ of wh____________________ they th____________________ we will think, d____________________ and feel. Gene____________________, we acc____________________ the sta____________________ quo, but these expec____________________ can be ha____________________ to han____________________ when they co____________________ from our fami____________________ and can be diff____________________ to ign____________________, especially wh____________________ they come from our par____________________.

Text 2:

Founded in 1878 by Bishop Isaac Hellmuth and the Anglican Diocese of Huron as "The Western University of London Ontario", Western is one of Canada's oldest and best universities. The fi____________________ students grad____________________ in ar____________________ and medi____________________ in 1883. To____________________, The University of Western Ontario is a vib____________________ centre of lear____________________ with 1,164 fac____________________ members and alm____________________ 29,000 underg____________________ and graduate stud____________________. Through i____________________ 12 Facu____________________ and Sch____________________, and three affi____________________ Colleges, the University off____________________ more th____________________ 60 diffe____________________ degree and dip____________________ programs to London's comm____________________.

Text 3:

The BBC's core purpose is broadcasting. Since the lau____________________of Radio Times in 1923 it h____________________ also eng____________________ in comme____________________ activities. If pur____________________ properly, su____________________ commercial activities he____________________ to rea____________________ the va____________________ of lic____________________ payers' ass____________________ and gene____________________ income to be plou____________________ back in____________________ the public ser____________________ programming. The____________________ commercial Policy Guidelines s____________________ out the fram____________________ which ens____________________ that the BBC's commercial activities supp____________________ its public purpose.

Text 4:

The decision to remove soft drinks from elementary and junior high school vending machines is a step in the right direction to help children make better choices when it comes to what they eat and drink. Childhood obe____________________ has bec____________________ a ser____________________ problem in th____________________ country a____________________ children cons____________________ more sugar-based fo____________________ and sp____________________ less ti____________________ getting the nece____________________ exercise. Many par____________________ have quest____________________ schools' deci____________________ to al____________________ vending machines which disp____________________ candy and so____________________ drinks.

Many schools, th____________________, have co____________________ to re____________________ on the mo____________________ these machines generate through agreements with the companies which makes soft drinks and junk food.

Text 5:

In the last federal election, 61% of eligible voters cast a ballot. That's a fright____________________ lack of inte____________________ by the elect____________________, but is not____________________ compared to the turn____________________ in provi____________________ and munic____________________ elections, which sh____________________ even lo____________________ turnouts. It's diff____________________ to bel____________________ there's so lit____________________ interest in elections.

In Canada, we're fort____________________ to have pol____________________ stations wi____________________ a short wa____________________ or dr____________________. There are volun____________________ more th____________________ willing to pro____________________ rides to someone unable to walk or who doesn't have a car.

A5: German C-test

Text 1:

Die Geschichte der Kernspaltung reicht zurück in das frühe 19. Jahrhundert. In
d____________________ Folgejahren leg____________________ Chemiker
d____________________ Grundstein f____________________ den
mode____________________ Atombegriff. S____________________ erkannten,
da____________________ die chemi____________________ Elemente
a____________________ Teilchen aufg____________________ sind,

d____________________ untereinander völ____________________ gleichartig
reag____________________ sich jed____________________ von

and____________________ Elementen unters____________________. 1871

erschien d____________________ erste tabell____________________ Aufstellung
d____________________ Eigenschaften al____________________ bekannten
Elem____________________ , das Periode____________________ .

Text 2:

Den zweiten von mir verwendeten Text kann ich aus urheberrechtlichen Gründen leider nicht aufnehmen.

Text 3:

Eine Wünschelrute ist ein gegabelter Zweig, ursprünglich meist vom Haselnussstrauch, später
verwe____________________ man au____________________ ähnliche
Instr____________________ aus untersch____________________ Materialien.
S____________________ dient d____________________ so gena____________________
Rutengänger, ei____________________ Person, d____________________ für
si____________________ eine beso____________________ Begabung
bean____________________, als Hilfs____________________ zum
Auff____________________ von unterir____________________ »Reizzonen«,
z____________________ Beispiel Wasse____________________ , Erdölvorkommen
od____________________ Erzlagerstätten.

Text 4:

Sicherheitshinweise

Bedienungsanleitung bitte vollständig vor Inbetriebnahme des Bügeleisens durchlesen und aufbewahren.

Reparaturen an Elektro____________________ dürfen n____________________ von
Fachk____________________ durchgeführt wer____________________. Durch
unsach____________________ Reparaturen kön____________________ erhebliche
Gefa____________________ für d____________________ Benutzer

entst____________________. Wird d____________________ Gerät zwecken____________________ oder fal____________________ bedient, ka____________________ keine Haf____________________ für dad____________________ verursachte Sch____________________ übernommen wer____________________.

Das Ge____________________ wurde v____________________ uns sicherheitstechnisch geprüft.

Text 5:

Schon in ältester Zeit haben die Menschen den Himmel beobachtet. Je stä____________________ frühe Kult____________________ von d____________________ Natur abhä____________________ waren, de____________________ näher l____________________ es f____________________ sie, a____________________ den o____________________ periodischen Ersche____________________ der Na____________________ und d____________________ Sternenhimmels besti____________________ Faktoren abzul____________________ , die i____________________ tägliches Le____________________ beeinflussten. I____________________ Verlauf d____________________ Entwicklung d____________________ mensch____________________ Zivilisation verl____________________ diese natür____________________ Zyklen im____________________ mehr a____________________ Bedeutung.

A6: Bilingual speaker characteristics

Speaker	Gender	Area of origin[87]	AoA (in years)	Age	LoR	Education	C-Test (Englishscore, z-transf.)	C-Test (German score, z-transf.)	L1 Fluency (z-transf.)	L2 Fluency (z-transf.)	Language use (z-transf.)	Affiliation (z-transf.)
TGEL1-1	m	Illinois	19	51	33	High School	0.847099	-0.5505446	1.02832905	-1.0872063	-0.13729635	0.94810757
TGEL1-2	m	Illinois	23	34	15	High School	0.3797341	-0.8121895	-0.7178901	-0.1553152	1.70996365	-0.304898
TGEL1-3	m	Texas	19	49	30	College	0.1460516	0.03815655	0.91191444	1.0872063	-0.78633365	-2.6104283
TGEL1-4	m	Alabama	26	58	32	High School	0.2044722	0.43062396	-0.7178901	-0.6212607	1.31055608	0.597266

[87] In some cases, place of birth differed from place of socialization as a number of participants was born into active military families. In these cases, place of socialization (estimated by the number of years spent in an area below the age of 12) was used as area of origin.

TGEL1-5	m	Maryland	20	49	27	High School	0.9055197	0.49603519	-0.9507193	0	-0.13729635	0.29654466
TGEL1-6	m	Georgia	24	50	26	College	-0.8334003	-1.8587692	-0.4850609	-0.7765759	-1.83477852	-0.9564609
TGEL1-7	f	Texas	26	50	12	College	0.4381547	-0.943012	2.19247515	1.708467	0.86122257	-0.1044171
TGEL1-8	m	New York State[88]	20	43	12	College	0.1460516	0.23439026	-0.0194024	-0.9318911	0.26211122	0.29654466
TGEL1-9	m	California	22	40	22	High School	0.6134165	2.19672728	-0.4850609	-0.1553152	-0.13729635	1.24882891
TGEL1-10	m	New York State	23	48	30	High School	-0.6718372	0.43062396	-1.2999631	-1.0872063	0.66151879	-0.0041767

[88] The New York State participants were carefully checked to avoid non-rhotic New York City speech affecting the results. Both New York State participants come from military families. None of them have spent any time in New York City except occasional visits, and none of them had family originating from or residing in New York City. Both participants originate from the Northwestern area of New York State and were born only a few miles apart.

TGEL1-11	m	Missouri	19	57	38	High School	-0.3797341	-0.0926659	0.446256	1.5531519	-0.38692608	0.29654466
TGEL1-12	m	Arizona	30	44	15	College	0.2044722	0.43062396	0.09701217	0.4659456	-0.385445	0.29654466