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Dynamic Systems, Maturational Constraints, and L1 Phonetic Attrition

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Abstract

The present study comprises a phonetic analysis of the lateral phoneme /l/ in the first (L1) and second language (L2) of ten late German-English bilinguals. The primary objective of the study was to compare the predictive power of dynamic systems theory (de Bot, Lowie, & Verspoor, 2007; Herdina & Jessner, 2002; Thelen & Smith, 1996; van Geert, 2009) with that of maturational constraints (Bylund, 2009; Hyltenstam & Abrahamsson, 2003; Long, 1990) through a phonetic investigation of L1 attrition in the lateral phoneme /l/ of the late bilinguals.

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1. Dynamic systems and maturational constraints

It has recently been proposed that language development shows some of the core characteristics of dynamic systems, such as "sensitive dependence on initial conditions, complete interconnectedness of subsystems, the emergence of attractor states in development over time and variation both in and among individuals" (de Bot et al., 2007, p. 7). In line with dynamic systems theory, language development is seen as a system primarily because variables mutually interact; each variable affects all the other variables contained in the system, and thus also affecting itself over time (van Geert, 2009). This holistic view of language development contrasts with another model of language development, that of maturational constraints. According to Hyltenstam and Abrahamsson (2009), maturational constraints prevent L2 learners (those who began learning their L2 after the brain's maturation) from actually ever attaining the level of competence which is achieved by true native speakers, who learn their L1 within the timeframe of the brain's maturation. Such claims are nested in a linguistic tradition whose exponents range from Scovel (1969), who has stated that it is impossible for adults (i.e. post-puberty) to achieve perfect pronunciation in a foreign accent; to the work of Flege who has stated that "[...] all else being equal, early bilinguals will be more likely to establish new phonetic categories for L2 speech sounds than late bilinguals will be" (Flege, Schirru, & MacKay, 2003, p. 469). Although most research embedded within a maturational constraints framework has examined L2 acquisition, recent work has questioned whether attrition of an L1 to which contact ceases late in life is really ever possible. To a certain extent, such research postulates that, just as a late learned L2 can never really reflect the same level of (complete) competence as an L1 acquired from birth onwards, the reverse is also true, and an L1 acquired from birth onwards and then left in cognitive suspension, can never really achieve the same level of (incomplete) competence as a late learned L2. For example, it has been noted that "there is a small gradual decline in attrition susceptibility during the maturation period followed by a major decline at its end (posited at around age 12)" (Bylund, 2009, p. 706). Arguably, such research examining whether maturational constraints impact L1 attrition predicts more L1 attrition in individuals who lose contact with their early acquired L1 in childhood than in those individuals who lose

contact with their L1 in adulthood. Here, the prediction is based on the understanding that an L1 which does not fully develop within the timeframe in which maturational constraints are active does not in fact achieve the status of an actual L1, hence such an "early lost" L1 is less stable and more likely to undergo L1 attrition than a "late lost" L1.

The present research examines L1 attrition within the domain of phonetics and discusses the results in relation to the predictive power of maturational constraints and dynamic systems theory. It is not the aim to reduce the complexity of the selected theoretical frameworks, nor is it the intention to disregard other models of speech acquisition such as Flege's Speech Learning Model (SLM) or Best's Perceptual Assimilation Model (PAM). Ideally, a study might be able to incorporate the testing of all of these theories; however, for want of focus and clarity, it is maturational constraints and dynamic systems theory which are juxtaposed with one another here.

For maturational constraints to be considered the most powerful predictor factor in determining L1 attrition in late bilinguals (as frameworks founded on maturational constraints assume), L1 attrition in the domain of phonetics should not be evidenced, or only weakly evidenced, in the L1 speech of the late bilinguals (because the L1 was able to develop in full up to puberty, after which contact with the L1 decreased due to immigration). Furthermore, if L1 attrition *is* observed, it should be similarly (weakly) observed across *all* late bilinguals, given that they *all* learned their L2 in late adolescence to adulthood, when contact with the L1 was reduced. Alternatively, if a high degree of inter- and intrapersonal variability is evidenced, along with clear cases of L1 attrition in *some* of the late bilinguals, but not in all, the predictive power of maturational constraints is lessened. In this case, the dynamic systems theory more adequately explains L1 attrition in late bilinguals because variation within and across the bilinguals is interpreted as evidence for the efficacy of additional predictor variables not specified within a theory founded on maturational constraints.

More specifically, the current paper examines these contrasting theoretical models through investigating the phonetic realisation of the lateral phoneme /l/ from ten German native speakers who grew up in a monolingual environment in Germany and moved to Anglophone Canada in either late adolescence or adulthood, in other words, after L1 acquisition is posited to be complete. The speech of these late bilinguals, who ceased contact with their German L1 in late adolescence to adulthood, was instrumentally investigated in phonetic detail in order see whether the bilinguals evidenced L1 attrition in their German.

However, before turning to the actual experiment, the degree of permanency of L1 attrition is discussed in relation to methodological considerations. This ensuing discussion is relevant because it addresses the question of whether the subject of the discussion is, in fact, L1 attrition, and hence whether it is possible to juxtapose the two theoretical frameworks through consideration of the experiment's findings. The discussion examines the question of how, if L1 attrition *is* found, it is possible to know whether this truly represents "loss". If one cannot be sure of this, the juxtaposition is weakened; if one can be sure of this (or at least as sure as possible) the juxtaposition is strengthened.

2. Permanency of L1 attrition and methodological considerations

The question here is, essentially, if L1 attrition is evidenced in the bilinguals examined, how does one determine whether this is actually indicative of "loss"? Alternatively, it may be the case that the German claimed to exhibit L1 attrition in the present investigation has actually only undergone superficial mutations, or the late bilinguals exhibit some sort of access inability, rather than what could be considered truly "lost". Essentially, the argument presented here is that due to methodological constraints, it is impossible to determine whether the language claimed to exhibit L1 attrition exhibits actual *permanent* loss, or whether it only superficially undergoes some sort of change. We call this the 'Constraints in Determining Permanency of L1 Attrition Argument' and commence its discussion with reference to Chomsky's original differentiation between competence and performance (1965).

In the past, demonstrating L1 attrition at any linguistic level has almost exclusively been accomplished by comparing the language performance of a group of immigrants in their L1 with the language performance of monolinguals from the immigrants' country of origin in the same language (see Hutz, 2004 for a review). This is, in fact, the same methodology as applied in the present study. In such cross-sectional studies, if the performance of the bilinguals is different from that of the monolingual control group, the assumption made is that L1 attrition has occurred. However, (amongst other considerations as will be discussed shortly) it stands to reason that the question *not* addressed in such studies is whether or not the loss is permanent. Essentially, it can be counter-argued that the language performance of a bilingual cannot be equated to his or her actual competence. The elements of the L1 which deviate from the norm, or the performance of the monolingual group in the country of origin, may in fact be stored - and in the proper environment retrieved. However, as will be

explained, the argument presented here is that due to methodological constraints it is simply *not* possible to know whether research into L1 attrition using cross-sectional methodology accesses competence or performance, i.e. it is not possible to know whether the "loss" is permanent (and hence indicative of competence).

Very few studies have aimed to specifically investigate the permanence of L1 attrition, or an underlying competence. An objective of those which have done so is to examine the impact of *training* on the performance of bilinguals in their L1. The theoretical question is whether individuals who demonstrate the loss of a particular aspect of their L1 at the level of performance (for example after migration to a country in which there is reduced contact to the L1) are able to "relearn" that which was "lost". Crucially, such participants must "relearn" that which was lost faster than another group of participants who had never learned the feature under investigation. Only if the "relearners" (i.e. those who were initially assessed to exhibit L1 attrition) do so faster than the "first-time-learners" (i.e. those who are learning the features for the first time), is it possible to ascertain that an underlying *competence* in the relearners was an advantage. Although the relearners might suffer at the level of performance, which would be (falsely) interpreted as L1 attrition, they might maintain an underlying competence, which was simply not evident before training. The resulting conclusion could be that the immigrants had in fact *not* undergone L1 attrition (if it is defined in terms of loss of competence, or permanency), although they superficially appeared to do so. In theory, this is a valid consideration. In practice, however, this (arguably sceptical interpretation of research suggesting L1 attrition) is next to impossible to investigate. This is because the probability of finding *two* groups, on the one hand composed of relearners, and on the other hand composed of first-time-learners, who are at *exactly* the same (performance) level (in order to see which one (re)learns faster), is next to none and it is for this reason that methodological constraints impede determining permanency of L1 attrition.

In fact, adopted children potentially represent the only group in which such an investigation can be *practically* conducted. For these individuals, if adopted in early childhood, exposure to the initial language is limited. The idea behind such studies (e.g. Au, Knightly, Jun, & Oh, 2002; Oh, Jun, Knightly, & Au, 2003; Pallier et al., 2003; Park, 2007; Tees & Werker, 1984; Ventureyra, Pallier, & Yoo, 2004) is that when the individuals are investigated later on, after they have acquired the language of their new environment, a language test (in the initial language) can verify that the performance level of the adoptive

group is the same as that of a control group which had *never* undergone early exposure. In this way, the equivalence of the performance level in the control and experimental group is more likely to occur (i.e. both groups, at least superficially, display no knowledge of the language under investigation), so that the presence of an underlying competence in the experimental adoptive group can be investigated. Simply put, it is because the performance of the adoptive group is the same as the performance of the experimental group which makes the former attractive in these studies. However, research addressing the competence versus performance issue in individuals who have undergone early language exposure, such as in the case of adoption, presents conflicting results.

For example, Ventureyra et al. (2004) examined L1 attrition at the level of phonetics when a language is "acquired" in early childhood, before adoption, but exposure to it is discontinued at a young age. They investigated whether adopted Koreans, who were raised in France, were better at discriminating Korean voiceless consonants, which are difficult to perceive by native French speakers, than native French speakers who had never been exposed to Korean in early childhood. The results from their study indicated that the adopted Koreans did not perceive the differences between Korean phonemes better than native French speakers who were previously unexposed to Korean. It was therefore claimed that the adopted Koreans who had been raised in France had undergone L1 attrition, as there was no longer any presence of that which was assumed to have once been acquired (Ventureyra et al., 2004). In further studies, their results were confirmed by Pallier et al. (2003) whose functional magnetic resonance imaging (fMRI) study indicated that adopted Koreans, who had been raised in France, displayed similar activation patterns while listening to Polish, an unfamiliar language, and Korean. This suggests that the brain was activated equally by these two languages. Together, the studies suggest that a language overheard in early childhood can in fact be completely forgotten. Relating this to the competence performance dichotomy, it appears that the adopted children did not have an underlying competence, concealed at the level of performance.

To a certain extent, such results contradict other, similar investigations. Au et al. (2002) found that native English participants taking Spanish lessons in adulthood spoke Spanish with a more native-like accent if they had overheard Spanish regularly in early childhood than if they had not. Oh et al. (2003) came to a similar conclusion based on both speech perception and production tasks regarding English speakers exposed to Korean before the age of five and English speakers hearing Korean for the first time in a language class for

adult learners. Those who had heard Korean in early childhood "outperformed" novice Korean learners in the perception but not production of Korean phonemes. Similarly, those who had spoken Korean in early childhood "outperformed" those who had heard Korean in early childhood and novice Korean learners in phoneme production. Ventureyra et al. (2004) however argue that the bilinguals in Au et al. (2002) and Oh et al.'s (2003) studies "either came from immigrant communities or grew up in communities where the attrited language was used" (2004 : p. 82). Accordingly, they argue that when they were later tested as adults, their capabilities were not indicative of L1 attrition because the language under investigation had not ceased to be activated. This suggests that the results from the above studies may contradict one another because the participants differed from one another.

As suggested in a study by Bowers, Mattys and Gage (2009), the relevant question to ask is whether preserved knowledge is visible when contact with the initial language is completely cut *after* training. Their study investigated the fate of early-acquired phonological knowledge when the language in question is subsequently unused, revealing that participants who were exposed to either Zulu or Hindi in early childhood, and subsequently immersed in an English language environment, had an advantage over control subjects, who were only ever exposed to English. Training was offered to both groups, and some experimental subjects acquired phonological distinctions characteristic of their early childhood language (but not of English) noticeably faster than both the control subjects and the alternative language. These results suggest that when it comes to language loss in children, the effects of training may re-activate an underlying competence which is in fact present, although before training the language superficially appears to have been completely forgotten (i.e. at the level of performance).

However, generally, research into L1 attrition (which adheres to the present definition) examines individuals who move abroad at the age of 16 or after, therefore ensuring *complete* L1 acquisition. It is this older group which is of particular interest to studies in L1 attrition because the core of the research paradigm is to determine whether a fully acquired L1 can ever undergo "loss"; obviously, in the case of the children, as discussed above, the language was not "fully" acquired, which doesn't make the research less interesting, but the focus is elsewhere, and L1 attrition research takes the child research findings to the extreme. Again, the question is whether any loss exhibited in such late bilinguals who learned their L2 post-pubescently is indicative of performance or competence attrition.

Much of the research on recovering aspects of an L1, when contact ceases in adulthood, is based on anecdotal reports, or observational. Yağmur, De Bot and Korzilius (1999) investigated Turkish native speakers who had moved to Australia in adulthood. The researchers pointed out that participants in their study displayed a marked decrease of L1 lexical skills in Australia, but when they returned to Turkey every four to six years, they "do not experience much difficulty in understanding or speaking Turkish" (1999 : p. 59). In Major's study (1992) it is reported that one of the English L1 speakers who had moved to Brazil recovered her native accent shortly after returning to the United States. Sancier and Fowler (1997) similarly found that native Brazilian Portuguese speakers reported a stronger foreign accent in the pronunciation of a native Brazilian Portuguese speaker after her extended sojourn in the United States in comparison to after a return to Brazil. These findings indicate that what appears to be lost in a certain environment is in fact an access problem due to the lack of appropriate contexts and retrieval cues. Temporarily inaccessible structures may be recovered if the right cues become available, such as those which are available in an individual's home country (Ecke, 2004). In other words, performance may not be a reflection of competence. However, as already explained, it is in fact not known in these studies whether the participants had "relearned" the aspects of the L1 under investigation (which means that in the L2 environment the structures were inaccessible, but not permanently lost), or whether they had acquired them as a "first-time-learner" would have, meaning that they were in fact completely forgotten (as was able to be controlled for in the case in the adoption studies). In theory, a study investigating this would need to involve an adult "first-time-learner" with *exactly* the same knowledge as the adult "relearner", in order to determine whether they (re) learned at different rates. In practice, as already mentioned, finding such equally matched adult participants is with all likelihood impossible. This means that the question - of whether or not L1 loss in late bilingual migrants is permanent, and hence a reflection of competence rather than performance - is similarly with all likelihood unanswerable.

Another argument used to disqualify results indicating L1 attrition is cross-sectional methodology (Jaspaert & Kroon, 1989; Yağmur, 2004); we call this the 'Cross-Sectional Methodology Criticism in Determining L1 Attrition Argument'. This argument does not focus on the differentiation between competence and performance but rather on diachronic language change. The argument claims that the L1 of bilingual migrants may differ from the language of the monolingual control group (assuming this is the same language), not because

the bilingual migrants have undergone L1 attrition, but because the language of the monolingual control group has changed since departure from the country of origin (see for example Harrington's longitudinal study of the Queen's Christmas speeches, 2006). It has therefore been suggested that longitudinal studies be incorporated into L1 attrition research, although here the methodological problem is that the repeated testing of variables may disturb the "natural course of the process it [the test] hoped to track down" (Jaspaert and Kroon, 1989: p. 81). For now, it is important to state that *if* there is interpersonal variation across the experimental group (some immigrants performing similar to the control group and others not), it can be counter-argued that, at least with regard to the phonetic elements investigated, the speech of the control group resident in Germany had not changed since the experimental group emigrated (because some of the late bilinguals do in fact perform like the monolingual controls).

Both the Constraints in Determining Permanency of L1 Attrition Argument and the Cross-Sectional Methodology Criticism in Determining L1 Attrition Argument embody scepticism towards findings which are interpreted as L1 attrition. The intention of the above discussion, however, has been to illuminate the challenges associated with these arguments, and to show that *when* in the present study differences between monolingual control group and the German of the late bilinguals are revealed, this can indeed be interpreted as L1 attrition although the degree of permanency is not known (and this is fact cannot be known, see Constraints in Determining Permanency of L1 Attrition Argument) and that *if* some of the late bilinguals perform similarly to the monolingual control group, whilst others do not (see Cross-Sectional Methodology Criticism in Determining L1 Attrition Argument) this supports the claim that L1 attrition has occurred in the experimental group. Again, the permanency of the loss remains open for debate, although proving or disproving either way seems unlikely; however, by including loss of control, or performance, into a definition of L1 attrition, one logically, in effect, by-passes the argument that attrition is only just this when loss occurs within competence. Perhaps more importantly, the risk of overlooking the sociolinguistic impact of L1 loss, or change, in bilingual migrant communities is not overlooked.

3. The lateral phonemes of German and English

In German and English there is a lateral phoneme which is symbolised as /l/ in both cases because it is characterised by lingual contact on the alveolar ridge in the mid-sagittal plane. During articulation of this phoneme, the breath stream flows laterally, freely without friction, over the lowered sides of the tongue. As a result, the lateral phoneme /l/ has been classified as an approximant (see amongst others Hayward, 2000; Ladefoged, 2000; Neppert, 1999; Scobbie & Wrench, 2003; Stevens, 2000). In addition to the alveolar closure, the tongue dorsum or root may form a secondary constriction of open approximation, and the complex resonance characteristics of the resulting vocal tract shape give lateral alveolar approximants their acoustic properties. Of interest here is the articulatory production of /l/ in terms of these secondary articulations, and hence its acoustic correlates, which typically vary between German and English.

In Standard German, the back of the tongue is usually not constricted during the realisation of /l/ (Kufner, 1970; Moulton, 1970; Wells, 1982). This position of the dorsum is reflected in a higher second formant (F2) frequency and a 'clear' (Gimson, 1989, p. 202) or 'light' /l/ (Olive, Greenwood, & Coleman, 1993, pp. 204–216) is the result. The phonetic symbol used to represent the realisation of the German lateral is [l]. However, the high F2 frequency of [l] in German can be influenced by either regressive or progressive coarticulation (Neppert, 1999, pp. 229, 242). If the preceding vowel of /l/ is high and back, for example in the case of German /u/, a lower F2 frequency in the German phoneme /l/ is often the result due to progressive assimilation.

Contrastingly, in Canadian English, the back of the tongue is generally retracted during the realisation of word final laterals.[i] This constriction creates what can be termed a "velarised", or even "pharyngealised", lateral which is most clearly reflected in the acoustic signal as a decrease in the frequency of the F2 (Hayward, 2000, p. 201; Kent & Read, 1996, p. 140; Olive et al., 1993, p. 207). When F2 frequency is low, the literature refers to a 'dark' /l/ (Gimson, 1989; Olive et al., 1993), expressed by the IPA symbol [ɫ]. Specifically, Wells summarises that "Canadian /l/ is dark in all positions" (1982, p. 495). Ladefoged and Maddieson elaborate that in American English word final /l/ may be more velarised than word initial /l/, but that both are characterised by a low F2 frequency (1996, p. 361). As such, there may be less allophonic variation in the realisation of Canadian English /l/ than in the /l/ of Standard British English. Moreover, Recasens contrasts the German and North American English /l/ phoneme: "[...] the mean F2 for [l] is found at 1680 Hz in the case of male speakers of German... On the other hand the finding that dark [l] in the same string [ili] has a

mean F2 across male speakers of American English (about 1000 Hz) indicates that [l] could be darker in the latter dialect versus the former" (2004, pp. 594–595). Additionally, he observes that "[d]ark [l] has been set in contrast with clear [l] based on well defined articulatory and acoustic properties, namely, the formation of a post-dorsal velar or pharyngeal constriction and active pre-dorsum lowering causing F2 to lower and F1 to raise" (2004, p. 594).

4. Methodology

4.1 Participants

In total, 30 participants were examined: 10 German L1, English L2 bilingual migrants; 10 monolingual German controls; and 10 monolingual English controls.[ii] The bilinguals' age of arrival (AOA) ranged from 16 to 32 years of age and their length of residence in Canada (LOR) from 18 to 55 years. As all bilingual migrants reported that their English was rudimentary upon arrival to Canada, we consider that their AOA also represents the onset of English acquisition. Accordingly, the possibility of the L2 influencing the L1 began at the earliest in late adolescence, and L1 acquisition was, at least in terms of a narrow interpretation of the critical period hypothesis (Lenneberg, 1967; Scovel, 1969), complete upon the onset of L2 acquisition. Therefore, the participants are appropriate for testing the predictive power of maturational constraints versus dynamic systems theory.

Table 1: AOA, LOR and sex of bilingual migrants. "EX" stands for experimental participant.

Participant	1ExBG	2ExCL	3ExDZ	4ExFS	5ExGB	6ExIKH	7ExID	8ExMZ	9ExMB	10ExRMW
AOA	16	19	24	21	32	29	20	32	23	23
LOR	48	22	55	53	29	18	49	48	38	40
Sex	M	F	M	M	F	F	F	F	F	F

We matched the Canadian and German control groups for age at recording (AAR), education, sex, as well as regional accent. Each group consisted of three males and seven females giving a total of nine males and 21 females.

4.2 Procedure

The experimental procedure was divided into two sessions: English or German, with counter-balanced presentation across participants. A native speaker of each language (who was familiar with the other language but hid this until after the interview had ended) conducted the interview in English or German respectively to ensure (to the greatest extent possible) that the speakers were in a monolingual mode for each language session (Grosjean, 2001).

Participants were presented with monosyllabic words which appeared on a monitor every 2.3 seconds and asked to say each word as it appeared, as naturally as possible. If the participant mispronounced his or her first attempt, the decision to repeat a sentence was left up to the participant. In the case that a word was elicited more than once, the most fluently produced token (as judged auditorily by the first author) was chosen for the analysis; mispronunciations and repetitions were very rare. Each interview contained a number of other tasks not relevant here (for more information, see de Leeuw, 2009; de Leeuw, Schmid, & Mennen, 2010; de Leeuw, Mennen, & Scobbie, 2012) .

The lateral task was divided into three parts, separated by short breaks. In the German and English session respectively 28 and 52 words containing the lateral were presented, and repeated three times, generating a total of 84 words in the German and 156 in the English session. The fact that each word was elicited three times was considered appropriate given that especially in German relatively few words fulfil the specified phonemic criteria, as will be discussed in the following section (see tables 2 and 3). Lateral words were interspersed with distracters, including language-specific names and cultural words to help reinforce the appropriate language mode. Although using real words meant that fewer tokens were available, the fact that real words are more representative of normal language use, as well as that they were more likely to enhance the monolingual mode in each language (Grosjean, 2001), made using them more advantageous than nonsense words. All words were partly randomised in their respective languages using a pseudo random number generator that generated an evenly distributed set of (pseudo) random numbers and ensuring that distracters were generally evenly dispersed. The total duration of the English section was just under 18 minutes, whereas that of the German section was just over 14 minutes.

4.3 Materials

The materials were designed to provide a common environment in both languages which would enable English darkness to be detected, i.e. a lower F2 and a higher F1 frequency. Word final /l/ was preceded by a high or mid-high front unrounded vowel; here only those results from /i/ are reported (n=16 in English and 8 in German, see tables 2 and 3). These rhymes were preceded by one or more consonants, dependent upon the word. As already mentioned, the preference for the high front unrounded vowel to precede the final lateral was based on the finding that the German lateral is readily influenced by coarticulation (Neppert, 1999, pp. 229, 242), so low and back preceding vowels were avoided. Moreover, as discussed in greater detail in de Leeuw (2009), the results from both phonetic environments were very similar and hence an analysis of /l/ preceded by the mid-high front unrounded vowel does not add content to the present discussion.

German words with /l/	English translation
viel	a lot, many
Stiel	stem
Kiel	city in northern Germany
Nil	Nile
Ziel	goal
Siel	sluice
Spiel	game
Priel	tidal creek

Table 2: German word list

English words with /l/
heal
eel
spiel
veal
real
heel
steal
teal
peal
meal
feel
zeal
deal
seal
kneel
wheel

Table 3: English word list

4.4 Annotation

The frequencies of F1 and F2 were measured in relation to the end of the lateral, as no single time point in the acoustic signal could be found to characterise the beginning of the lateral in all tokens. Firstly, the end of the voicing in the word final lateral was manually marked using Praat (Boersma & Weenink, 2008) and labelled END (see Figure 1). The preference was to place the marker END according to two specified criteria evidenced in the spectrogram: drop of intensity and ceasing of regular periodic phonation. In some tokens a slight F1 frequency fall occurred just before the onset of ceasing of regular periodic phonation. In these tokens the preference was to place the marker END at the onset of the steep F1 frequency fall, as displayed in Figure 2, so as to minimise the chance of spurious measures. It was the aim to place the marker END where no voicing followed, but no exhalation preceded the marker.

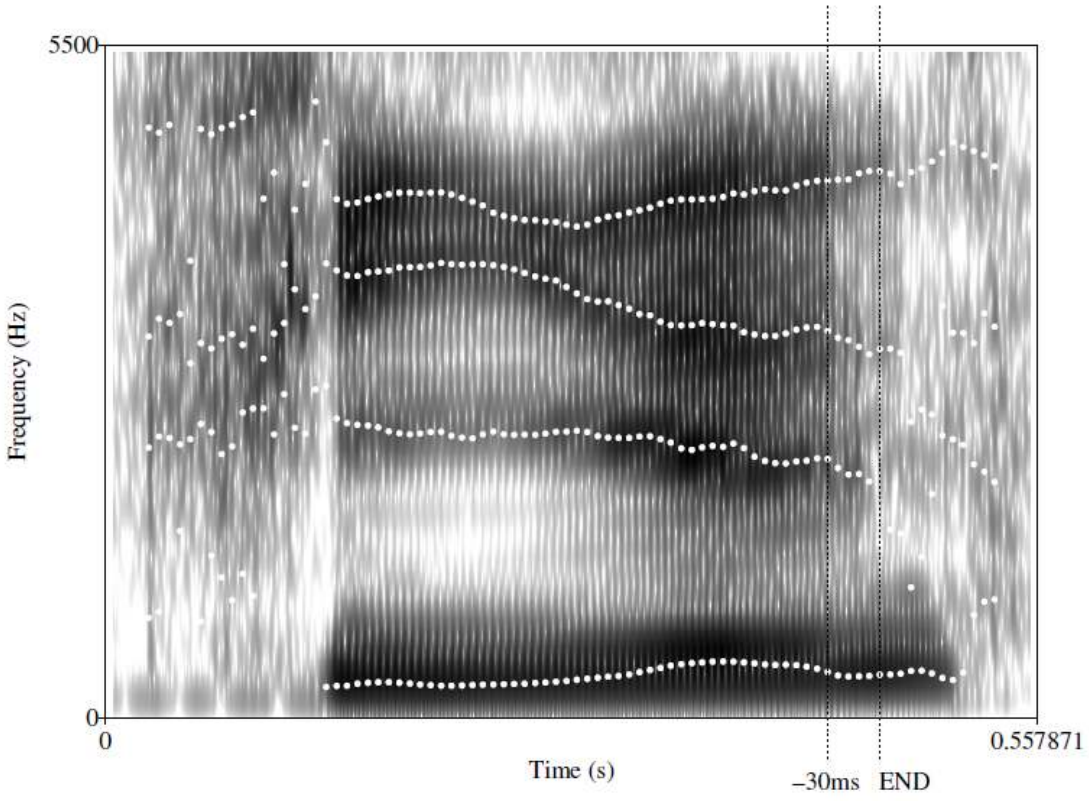

Figure 1: A typical token of the word '*viel*' (many) as spoken by a female German control participant. The relatively flat F1 and F2 contours are characteristic of a 'light' German lateral throughout. The END annotation has been inserted at the last point where F1, F2 and F3 can be reliably measured.

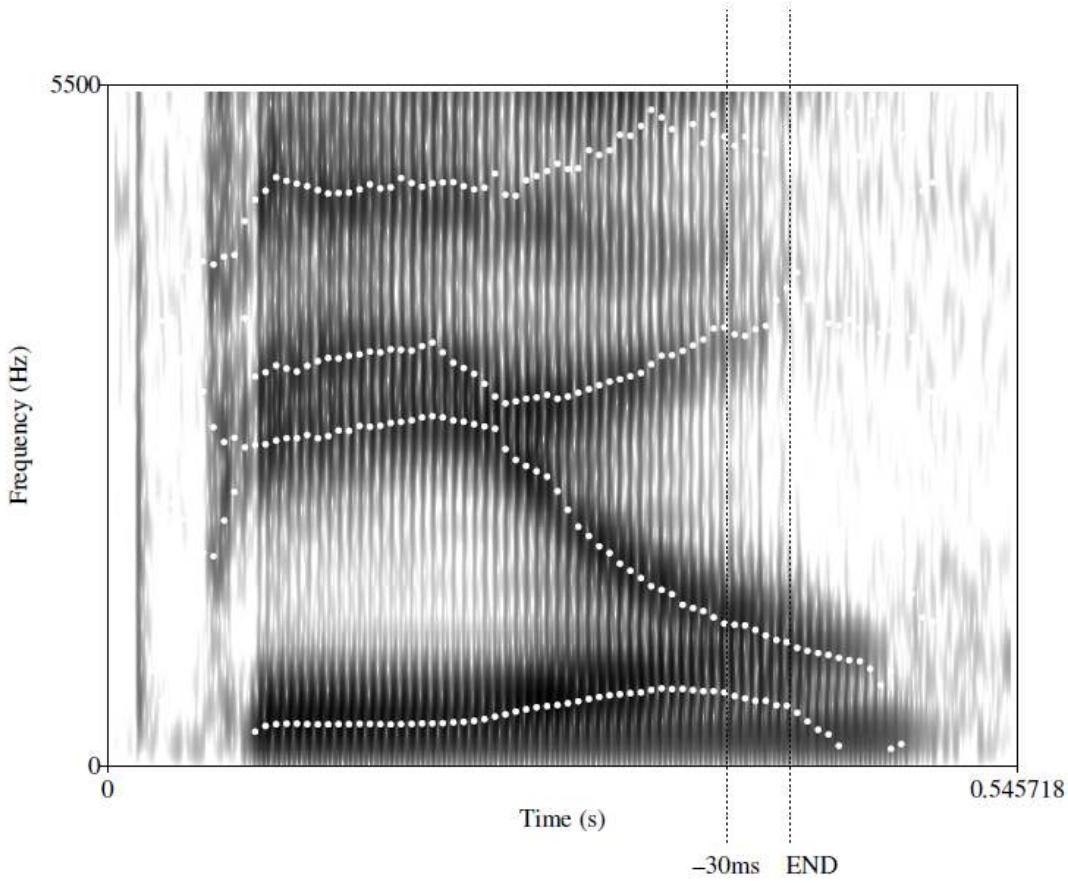

Figure 2: The word '*feel*' as spoken by a typical female English control participant. The relatively high F1 and very low F2, developing towards the end of this dark lateral, are evident and quite clearly distinct from the values during /i/.

Thereafter, a Praat script automated the insertion of another marker 30 ms prior to the END marker (see figures 1 and 2). It was at this point where the frequencies of F1 and F2 were measured.

Through auditory inspection, it was ensured that in all cases the annotation at -30ms was in fact within the lateral. Global perceptual criteria were used to ensure that only laterals which were longer than 30 ms were included in the analysis. In doing so, approximately 10-30 ms prior to the lateral plus all material up to the END marker was listened to. Speakers had ample time to produce each word, which had been prompted individually, and speech was in general quite clear and not rushed. Segments were therefore relatively long in duration. Tokens preceded by short /ɪ/ or /ɛ/, which were also elicited in the original experiment did not always satisfy these criteria but are not discussed here as they were not included in the present analysis (de Leeuw, 2009). This observational data corresponded to

the durational study by Lavoie (2001) who found that in American English speech, /l/ in stressed position had an average duration of 70ms with a range of 36ms to 159ms.

The F1 and F2 frequencies were measured semi-automatically which allowed for visual cross-validation, ensuring that the automatically extracted F1 and F2 were in fact accurate. Particularly in the case of dark /l/, in which F1 and F2 are close together, the automatic formant extraction process often finds only one formant, resulting in F3 being reported as F2. In such cases, the individual token was remeasured so that the visual analysis of the acoustic signal corresponded with Praat's automatic extraction.

Hypotheses

Verification of the first hypothesis ensured that 'clear' /l/ was indeed realised by the German control group, as was 'dark' /l/ by the English Canadian controls:

- Hypothesis 1: a significantly lower F1 and a significant higher F2 will occur in the lateral phoneme /l/ of the German control group than in the English control group.

The second hypothesis was tested in order to determine whether L1 attrition was evidenced in the German of the late consecutive bilinguals:

- Hypothesis 2: a significantly higher F1 and a significantly lower F2 will occur in the lateral phoneme /l/ in the native German speech of the bilingual migrants than in the German monolingual control group's speech).

The third hypothesis was examined in order to determine whether variation was more prevalent in the German speech of the bilinguals than in the monolingual German speech.

- Hypothesis 3: More interpersonal and intrapersonal variation with regard to the F1 and F2 frequencies in the lateral phoneme /l/ will occur in the German speech of the bilinguals than in the German monolingual speech.

L1 attrition (i.e. a high F1 and a low F2 in the German lateral phoneme of the bilinguals) was interpreted as support for dynamic systems theory whilst stability in the L1 (i.e. a low F1 and a high F2 in the German lateral phoneme /l/ of the bilinguals) was interpreted as support for

maturational constraints. Individual analyses were also undertaken to determine the extent of interpersonal and intrapersonal variation across the bilinguals' realisation of the lateral phoneme /l/. Variability was interpreted as support for the dynamic systems theory whilst homogeneity amongst the bilinguals was regarded as support for maturational constraints. However, variability could only be seen as support for dynamic systems theory when the individual variation amongst the monolingual groups was less than that within the bilingual group. In addition, the extent to which the bilingual speakers merged or differentiated the lateral phoneme in German and English was examined.

5. Results

The F1 and F2 frequency measurements were entered separately into two one-way ANOVAs with Group as the independent variable with four levels: German controls (G), English controls (E), bilingual subjects in German (BG) and bilingual subjects in English (BE). The ANOVA was run twice (once for the female speakers and once for the male speakers) and followed by planned contrasts. All tokens were entered into the ANOVAs to allow for an adequate representation of possible variability in the tokens of the bilingual speakers. As our hypotheses were directional one-tailed significances are reported in all cases. We refer to table 4 for the group means and standard deviations for F1 and F2 values.

For the female speakers, results yielded a significant effect of Group for both F1 [$F(2,467) = 444.68$, $p < .0001$] and F2 frequency values [$F(2,433) = 1208.74$, $p < .0001$]. Planned contrasts for the F1 frequency values showed significant differences between the two control groups ($t(443) = 34.31$, $p < .0001$), with, as hypothesised, lower F1 values for the German than the English control group (with an average of 348 Hz for G versus 549 Hz for E). The F1 values for the bilingual speakers were found to be intermediate between those obtained for the two control groups: in their German they had significantly higher F1 values than those obtained for the German control group ($t(95) = -17.92$, $p < .0001$, with an average of 429 Hz for BG versus 349 Hz for G. Furthermore, F1 values were significantly higher in the bilinguals' English than in their German ($t(95) = -17.92$, $p < .0001$), with an average of 429 Hz in BG versus 506 Hz in BE.

Planned contrasts for the F2 frequency also showed significant differences between the two control groups in the expected direction, i.e. a significantly higher F2 for the German than for the English female controls ($t(273) = -45.70$, $p < .0001$), with averages of 1864 Hz

and 1061 Hz respectively. This time, however, there was no significant difference between the values for BG and those obtained for G ($t(325) = -1.70$, $p = .09$). Nevertheless, F2 values were significantly lower in the bilinguals' English than in their German ($t(95) = 15.46$, $p < .0001$), evidencing that as a group distinct phonemes were maintained in the L1 and L2.

For the male speakers, results yielded a significant effect of Group for both F1 [$F(2,218) = 421.77$, $p < .0001$] and F2 frequency values [$F(2,80) = 154.43$, $p < .0001$]. Planned contrasts for the F1 frequency values showed significant differences between the two control groups ($t(157) = 27.90$, $p < .0001$), with, again as expected, lower F1 values for the German than the English control group (with an average of 244 Hz for G versus 470 Hz for E). The F1 values for the bilingual speakers were likewise revealed to be intermediate between those obtained for the two control groups: in their German the males had significantly higher F1 values than those obtained for the German control group ($t(130) = 23.07$, $p < .0001$), with an average of 390 Hz for BG versus 224 Hz for G). Furthermore, F1 values were significantly higher in the bilinguals' English than in their German ($t(38) = -11.95$, $p < .0001$), with an average of 390 Hz in BG versus 443 Hz in BE.

Planned contrasts for the F2 frequency again showed significant differences between the two control groups in the expected direction. The German males had a significantly higher F2 frequency than the English males, $t(166) = -56.81$, $p < .0001$ (respectively 1551 Hz versus 891 Hz). Moreover, the bilingual males had a significantly lower F2 in German than did the German males, $t(75) = -4.12$, $p < .0001$ with averages of 1344 Hz and 1551 Hz respectively. F2 values were also significantly lower in the bilinguals' English (988 Hz) than in their German ($t(38) = 8.16$, $p < .0001$).

		German Control	Bilinguals in German	Bilinguals in English	English Control
Females (n=7)	F1 (Hz)	349 (42)	429 (84)	506 (113)	549 (82)
	F2 (Hz)	1864 (198)	1824 (228)	1396 (276)	1061 (146)
Males (n=3)	F1 (Hz)	244 (32)	390 (43)	443 (51)	470 (75)
	F2 (Hz)	1551 (72)	1344 (421)	988 (185)	891 (83)

Table 4: Mean F1 and F2 (Hz) of the lateral phoneme /l/ preceded by the high front vowel /i/.The standard deviation is reported in brackets.

Individual analyses confirmed the above inferential analysis that bilinguals evidenced L1 attrition in the lateral phoneme. However, as displayed in figures 3 and 4, they did so in different ways. Participant 4ExFS evidenced an /l/ phoneme in German which was completely within the English monolingual norm (see Figure 4). Likewise, participant 10ExRMW (see Figure 3) had a higher F1 frequency and lower F2 frequency than the German monolingual norm. Similarly, participants 2ExCL, 5ExGB, 6ExIKH, 9ExMB (see Figure 3) and participants 1ExBG, 3ExDZ (see Figure 4) appeared to undergo L1 attrition in their German /l/. In their cases, this was reflected in a higher F1 frequency than that evidenced by the German monolingual norm whilst the frequency of F2 remained rather high in their German. Only participants 7ExID and 8ExMZ did not evidence L1 attrition in the /l/ phoneme of their German L1. This individual analysis reflects a high interpersonal variation (i.e. across participants with regard to both F1 and F2 values) and a high intrapersonal variation (i.e. more L1 attrition evidenced in the F1 frequency than in the F2 frequency).

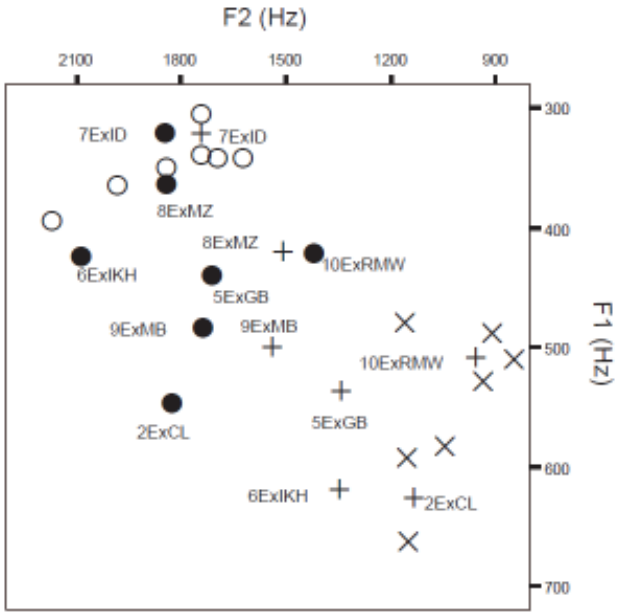

Figure 3: Scatterplot of F1 and F2 of females in /l/ after /i/. The symbols are as follows: German Controls: ○; Bilinguals in German: ●; Bilinguals in English: +; English Controls: ×.

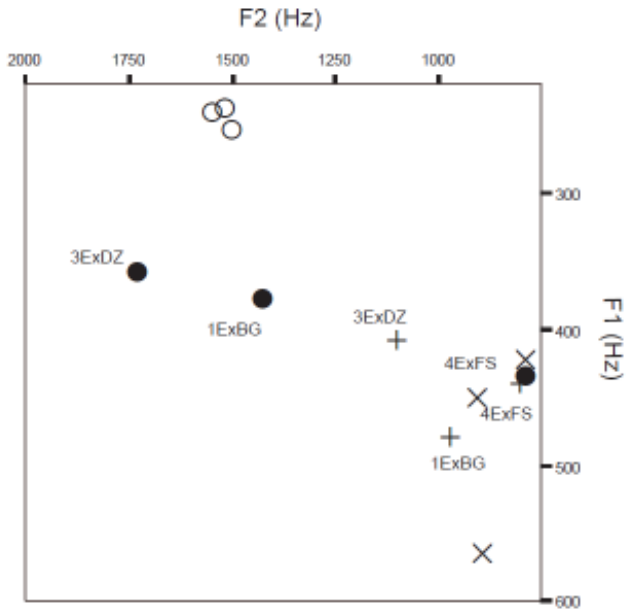

Figure 4: Scatterplot of F1 and F2 of females in /l/ after /i/. The symbols are as follows: German Controls: ○; Bilinguals in German: ●; Bilinguals in English: +; English Controls: ×.

5.1 Summary of results

The results of the group analyses verified Hypothesis 1 on all accounts: for both males and females, a significantly lower F1 frequency and a significantly higher F2 frequency occurred in the German monolingual control group than in the English monolingual control group. Hypothesis 2 was for the most part confirmed. The frequency of F1 in the lateral phoneme was significantly higher in the German of both the female and male bilinguals than in the respective German control group, indicating L1 attrition. For the males, F2 frequency was significantly lower in the German of the bilinguals than in the German monolinguals, revealing L1 attrition. On the other hand, there was no significant difference between the F2 frequency of the lateral phoneme of the German monolingual females and the German of the bilinguals, which contra-indicated L1 attrition. Hypothesis 3 (more interpersonal and intrapersonal variation with regard to the frequency of F1 and F2 in the lateral phoneme /l/ will occur in the German speech of the bilinguals than in the German monolingual speech) was confirmed in the group and individual analyses. This was confirmed by intrapersonal differences: F1 frequency was susceptible to L1 attrition than F2. The individual analyses showed interpersonal differences in that some participants realised their German lateral phoneme within the English norm, whilst others evidence no L1 attrition in this phoneme.

6. Discussion

As stated in the results section, there is clear evidence of L1 attrition in both group and individual analyses. In particular, it is the high degree of variability we observed in our data both within and between bilinguals which supports the dynamic systems theory. Although group analyses revealed L1 attrition on the whole, it appeared that L1 attrition was more likely to be displayed in the frequency of F1 rather than F2, and that some bilinguals were more likely to exhibit L1 attrition than others. For example, participant 7ExID displayed a German /l/ phoneme within the German monolingual norm whilst participant 4ExFS did so within the English monolingual norm. Such late bilinguals who are similar in age of L2 acquisition, and yet behave very differently in terms of their degree of L1 attrition lead one to question the power of other factors beyond maturational constraints. For maturational constraints to be considered the most powerful predictor factor, L1 attrition should not have been evidenced across the board, and if it was, it should have been similarly (weakly) evident across all bilinguals, given that they all learned their L2 in late adolescence to adulthood, when contact with the L1 was reduced. This was, however, not the case. Although our findings clearly support L1 attrition, the degree of permanency of such attrition remains, of course, unknown (see Constraints in Determining Permanency of L1 Attrition Argument, above, for a discussion). Moreover, the finding that some of the late bilinguals performed similarly to the monolingual control group, whilst others did not (see Cross-Sectional Methodology Criticism in Determining L1 Attrition Argument, above, for a discussion) points to the fact that it is more likely that L1 attrition has occurred in the experimental group, rather than that a change has occurred in the monolingual control group.

We therefore interpret the results from this study as support for dynamic systems theory, which moves away from viewing language development (i.e. acquisition and loss) as semi-static (with terminology like ‘final state’ and ‘fossilization’) towards interpreting language development as a complex process which continues throughout life and presumably at different rates for different parts of the phonetic and phonological system. Specifically, “[l]inguistic decline may have its basis in biological changes, but the interaction between psychological and social changes will affect the rate of decline” (de Bot, 2007: p. 56). Moreover, according to dynamic systems theory, unpredictable changes in language development are expected which cannot be explained by either the influence of the L2 on the

L1 or language internal processes. However, if – as our evidence suggests – maturational constraints are insufficient in predicting L1 attrition, what factors must also be considered within a full dynamic systems theory and how can they be operationalised? Before one even begins to examine the multitude of potential predictor variables, there must be a move away from a one-dimensional interpretation of language development in bilinguals which focuses predominantly on age constraints, and broaden the analyses to include a more realistic set of factors which might explain the variability evidenced in L1 attrition (and in bilingual acquisition for that matter).

References

Abrahamsson, N., & Hyltenstam, K. (2009). Age of Onset and Nativelikeness in a Second Language: Listener Perception Versus Linguistic Scrutiny. *Language Learning*, *59*(2), 249–306.

Au, T. K., Knightly, L. M., Jun, S.-A., & Oh, J. S. (2002). Overhearing a language during childhood. *Psychological Science*, *13*, 238 – 243.

Boersma, P., & Weenink, D. (2008). *Praat: doing phonetics by computer (Version 4.6.14) [Computer program]*.

Bowers, J. S., Mattys, S. L., & Gage, S. H. (2009). Preserved Implicit Knowledge of a Forgotten Childhood Language. *Psychological Science*, *20*(9), 1064–1069. doi:10.1111/j.1467-9280.2009.02407.x

Bylund, E. (2009). Maturational Constraints and First Language Attrition. *Language Learning*, *59*(3), 687–715. doi:10.1111/j.1467-9922.2009.00521.x

Chomsky, N. (1965). *Aspects of the theory of syntax*. MIT Press, Cambridge MA.

de Bot, K., Lowie, W., & Verspoor, M. (2007). A Dynamic Systems Theory Approach to Second Language Acquisition. *Bilingualism: Language and Cognition*, *10*(01), 7–21. doi:10.1017/S1366728906002732

de Leeuw, E. (2009). When your native language sounds foreign: A phonetic investigation into first language attrition. Unpublished Ph.D. thesis. Queen Margaret University, Edinburgh.

de Leeuw, E., Mennen, I., & Scobbie, J. M. (forthcoming). Dynamic Systems, Maturational Constraints, and Phonetic Attrition. *International Journal of Bilingualism*.

de Leeuw, E., Schmid, M. S., & Mennen, I. (2010). The Effects of Contact on Native Language Pronunciation in an L2 Migrant Setting. *Bilingualism: Language and Cognition*, *13*(Special Issue 01), 33–40. doi:10.1017/S1366728909990289

Ecke, P. (2004). Language attrition and theories of forgetting: A cross-disciplinary review. *International Journal of Bilingualism*, *8*(3), 321 – 354.

Flege, J. E., Schirru, C., & MacKay, I. R. (2003). Interaction between the native and second language phonetic subsystems. *Speech Communication*, *40*, 467 – 491.

Gimson, A. C. (1989). *An Introduction to the Pronunciation of English*. London: Edward Arnold.

Grosjean, F. (2001). *Life with Two Languages: An Introduction to Bilingualism*. Harvard University Press, Cambridge, MA.

Harrington, J. (2006). An acoustic analysis of 'happy-tensing' in the Queen's Christmas broadcasts. *Journal of Phonetics*, *34*(4), 439–457. doi:10.1016/j.wocn.2005.08.001

Hayward, K. (2000). *Experimental Phonetics*. Essex: Pearson Education.

Herdina, P., & Jessner, U. (2002). *A dynamic model of multilingualism*. Multilingual Matters.

Hutz, M. (2004). Is there a natural process of decay? A longitudinal study of language attrition. In M. S. Schmid, B. Köpke, M. Keijzer, & L. Weilemar (Eds.), *First Language Attrition: Interdisciplinary perspectives on methodological issues* (pp. 189 – 206). John Benjamins Publishing Company, Amsterdam.

Hyltenstam, K., & Abrahamsson, N. (2003). Maturational constraints in SLA. In C. J. Doughty & M. H. Long (Eds.), *The Handbook of Second Language Acquisition* (pp. 539 – 599). Blackwell, Oxford.

Jaspaert, K., & Kroon, S. (1989). Social determinants of language loss. *Review of Applied Linguistics (I.T.L.)*, *83-84*, 75 – 98.

Kent, R. D., & Read, C. (1996). *The Acoustic Analysis of Speech*. San Diego: Singular.

Kufner, H. L. (1970). *Kontrastive Phonologie. Deutsch-Englisch*. Stuttgart: Klett Verlag.

Ladefoged, P. (2000). *A course in phonetics*. Fort Worth, Texas: Harcourt College Press.

Ladefoged, P., & Maddieson, I. (1996). *The Sounds of the World's Languages*. Oxford: Blackwell.

Lavoie, L. M. (2001). *Consonant Strength Phonological Patterns and Phonetic Manifestations*. New York and London: Garland.

Lenneberg, E. H. (1967). *Biological Foundations of Language*. New York: Wiley.

Long, M. (1990). Maturational constraints on language development. *Studies in second language acquisition*, *12*, 251 – 285.

Major, R. C. (1992). Losing English as a first language. *The Modern Language Journal*, *76*, 190 – 208.

Moulton, W. G. (1970). *The sounds of English and German*. Chicago: University of Chicago Press.

Neppert, J. M. H. (1999). *Elemente einer Akustischen Phonetik*. Hamburg: Buske Verlag.

Oh, J. S., Jun, S.-A., Knightly, L. M., & Au, T. K. (2003). Holding on to childhood language memory. *Cognition*, *86*, B53 – B64.

Olive, J. P., Greenwood, A., & Coleman, J. (1993). *Acoustics of American English Speech: A Dynamic Approach*. New York: Springer.

Pallier, C., Dehaene, S., Poline, J.-B., LeBihan, D., Argenti, A.-M., Dupoux, E., & Mehler, J. (2003). Brain imaging of language plasticity in adopted adults: can a second language replace the first? *Cerebral Cortex*, *13*, 155 – 161.

Park, H.-S. (2007). Have Korean adoptees completely lost their first language Korean. *6th International Symposium on Bilingualism*. Hamburg, Germany.

Recasens, D. (2004). Darkness in [l] as a scalar phonetic property: implications for phonology and articulatory control. *Clinical Linguistics and Phonetics*, *18*(6), 593–603.

Sancier, M. L., & Fowler, C. A. (1997). Gestural drift in a bilingual speaker of Brazilian Portuguese and English. *Journal of Phonetics*, *25*, 421 – 436.

Scobbie, J. M., & Wrench, A. (2003). An articulatory investigation of word-final /l/ and /l/-sandhi in three dialects of English. *Proceedings of the XVth International Congress on Phonetic Sciences* (pp. 1871–1874). Barcelona, Spain.

Scovel, T. (1969). Foreign Accents, Language Acquisition, and Cerebral Dominance. Retrieved from http://www.eric.ed.gov/ERICWebPortal/detail?accno=EJ016089

Stevens, K. (2000). *Acoustic Phonetics*. Cambridge, Massachusetts: MIT Press.

Tees, R. C., & Werker, J. F. (1984). Perceptual flexibility: maintenance or recovery of the ability to discriminate non-native speech sounds. *Canadian Journal of Psychology*, *38*, 579 – 590.

Thelen, E., & Smith, L. B. (1996). *A dynamic systems approach to the development of cognition and action*. MIT Press.

van Geert, P. (2009). A Comprehensive Dynamic Systems Theory of Language Development. *Language Development Over the Lifespan* (pp. 60–104). Oxon: Routledge.

Ventureyra, V. A. G., Pallier, C., & Yoo, H.-Y. (2004). The loss of first language phonetic perception in adopted Koreans. *Journal of Neurolinguistics*, *17*, 79 – 91.

Wells, J. C. (1982). *Accents of English*. Cambridge: Cambridge University Press.

Yagmur, K. (2004). Issues in finding the appropriate methodology in language attrition research. In B. K. Monika S. Schmid & L. Weilemar (Eds.), *First Language Attrition: Interdisciplinary perspectives on methological issues* (pp. 133 – 164). John Benjamins Publishing Company, Amsterdam.

Yagmur, K., Bot, K. de, & Korzilius, H. (1999). Language attrition, language shift and ethnolinguistic vitality of Turkish in Australia. *Journal of Multilinguals and Multicultural Development*, *20*(1), 51–69.

[i] "English" refers to Canadian English. Studies which refer to the lateral phoneme in American English are assumed to hold true for Canadian English as well. This assumption is based on other studies, which indicate that the consonantal systems of Canadian and American English are very similar (Wells, 1982 : pp. 491 and 495).

[ii] We use the term "monolingual" to describe individuals with limited knowledge of additional languages.