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Plasticity of Native Intonation in the L1 of English Migrants to Austria

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Abstract: This study examines the plasticity of native language intonation in English-Austrian German sequential bilinguals who have migrated to Austria in adulthood by comparing it to that of monolingual English and monolingual Austrian control speakers. Intonation was analysed along four intonation dimensions proposed by the L2 Intonation Learning theory (LILt): the inventory of categorical phonological elements ('systemic' dimension), their phonetic implementation ('realizational'), the meaning associated with phonological elements ('semantic'), and their frequency of use ('frequency'). This allowed us to test whether each intonation dimension is equally permeable to L2-on-L1 influences. The results revealed L2-on-L1 effects on each dimension. These consistently took the form of assimilation. The extent of assimilation appeared to depend on whether the cross-language differences were gradient or categorical, with the former predominantly resulting in intermediate merging and the latter in a complete transfer. The results suggest that native intonation remains plastic in all its dimensions, resulting in pervasive modifications towards the L2. Finally, in this first application of the LILt to the context of L1 attrition, the study confirms the model's suitability not only to acquisition of L2 intonation but also for predicting where modifications of L1 intonation are likely to occur.

Keywords: speech plasticity; malleability of speech; phonetic attrition; intonation; L2 Intonation Learning theory (LILt); cross-language influences; transfer; late bilingualism; English; Austrian German

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1. Introduction

Bilinguals are in the unique situation of regularly having to use two languages, a situation which is known to lead to cross-language interaction (e.g., Green 1998; Van Hell and Dijkstra 2002). At the phonetic level, it is well established that such instances of interaction will often lead to transfer from the native (L1) to the second language (L2), such that traces of the L1 are almost inevitably present in the pronunciation of the L2, particularly when the L2 was acquired after the age of puberty[1]. Far less research attention has been given to the effect the L2 can have on speech patterns in the L1, even though this influence is equally plausible. Indeed, studies show that the extent of L2 influences on L1 pronunciation can lead to individuals being perceived as non-native in their mother tongue (Bergmann et al. 2016; de Leeuw et al. 2010; Hopp and Schmid 2013). The latter type of influence, and the one we focus on in this paper, is usually referred to as *phonetic attrition* or *L1 attrition of speech*, the non-pathological and non-age-related pronunciation changes that late sequential bilinguals who are being immersed in an L2 environment may experience in their L1 (de Leeuw et al. 2013; de Leeuw 2019a; Major 2010).

While an increasing number of studies has evidenced changes to the L1 of late sequential bilinguals in segmental areas of speech production (see de Leeuw 2019a for an overview), only a handful of studies (de Leeuw et al. 2012; de Leeuw 2019b; Gargiulo and Tronnier 2020; Mennen 2004; Mennen and Chousi 2018) have examined the effect the

L2 may have on prosodic areas of the L1. These suggest that prosodic effects also occur and that listeners base their judgements of non-nativeness in part on perceived prosodic changes, in particular intonational ones (Mayr et al. 2020)[2]. Given the above-described lack of studies on phonetic attrition of prosodic areas of the L1, the present study will focus on one such aspect, namely intonation. It will do so by examining the extent of L1 intonational changes of English-Austrian German late sequential bilinguals who grew up in the UK as L1 speakers of English and emigrated to Austria in adulthood where they acquired (Austrian) German as their L2. In particular, the present study will be the first to apply a model that was originally developed to account for the difficulties L2 learners may experience when acquiring L2 intonation—L2 Intonation Learning theory (LILt, Mennen 2015)—to the context of L1 attrition. As we will see later in this paper, this allows for a more comprehensive investigation of potential changes to L1 intonation as hitherto seen.

1.1. Plasticity of Speech in Bilingual Contexts

Early investigations of cross-linguistic influences between the two sound systems of late sequential bilinguals started from the assumption that an L1 sound system that has reached biological maturity, is unlikely to be susceptible to influences from the L2 (Lado 1957; Lenneberg 1967). This view of non-plasticity of an individual's native language sound system resulted from the prevailing influence of the critical period hypothesis (Lenneberg 1967; Penfield and Roberts 1959), which holds that while children will have no problem acquiring their L1 within the time period of brain maturation occurring during adolescence, these maturational processes constrain the ability to acquire an L2. While L1-to-L2 transfer was therefore expected to occur, the L1 was thought to be protected against any L2 influences once it had reached neural maturity. As a consequence, the focus of research was on unidirectional L1-to-L2 influences, and L2-to-L1 influences were largely ignored. More recent studies, however, show that an individual's native sound system is not as impermeable to L2 influences as previously assumed (see Flege 1995 for an overview, and below) and it is now widely acknowledged that bidirectional influences are not unusual but a logical consequence of the constant interaction or co-activation of a bilingual's two languages (Flege 1987; Odlin 1989, 2006; Sharwood Smith and Kellerman 1986). This view of the plasticity of both the L2 and the L1 is reflected in one of the most influential models on L2 acquisition of speech, the Speech Learning Model (SLM) (Flege 1995) and its recently revised version, SLM-r (Flege and Bohn 2021), which posit that bidirectional influences are expected to occur because the L1 and L2 share a common phonetic space[3].

There is now an abundance of evidence for the plasticity of L1 speech in late sequential bilinguals. Such changes to the L1 have been observed in situations where a bilingual's two languages are active for a restricted period of time, leading to temporary drifts in L1 speech. Such short-term L2-induced influences on the L1 are typically referred to as instances of *gestural or phonetic drift*, rather than phonetic attrition (Chang 2012, 2013; Sancier and Fowler 1997). Examples are situations where (novice) foreign language learners receive, sometimes intensive, language instruction (Chang 2012, 2013, 2019; Dmitrieva et al. 2020; Kartushina et al. 2016; Osborne and Simonet 2021), where bilinguals regularly change their linguistic environment by moving between an L1 and L2-speaking country (Sancier and Fowler 1997; Tobin et al. 2017), or where intensive code-switching is observed (Reubold et al. 2021). These studies show a relatively subtle restructuring in segmental areas of L1 pronunciation, which is thought to be fully (Kartushina and Martin 2019) or partially (Chang 2019) reversible, and "may be a precursor to more persistent changes that may become apparent over time" (Reubold et al. 2021, p. 20).

Changes in L1 pronunciation have also been observed in situations where a bilingual's two languages are more permanently activated, i.e., in experienced L2 learners who have migrated to another country and have been long-term (or even permanently) immersed in an L2 environment. Phonetic attrition of this kind appears to be common in most (but not all) late sequential bilinguals, with documented changes in L1 pronunciation affecting a wide range of segmental areas of L1 production, at least in the L1-L2 combinations

investigated so far ((Alharbi et al. forthcoming) for L1 Arabic-L2 English and L1 English-L2 Arabic; (Bergmann et al. 2016) for L1 German-L2 North-American English; (de Leeuw et al. 2013) for L1 German-L2 North-American English; (de Leeuw et al. 2018a) for L1 Albanian-L2 British English; (de Leeuw 2019b) for L1 German-L2 American English; (Guion 2003) for L1 Quichua-L2 Spanish; (Flege 1987) for L1 French-L2 American English and L1 American English-L2 French; (Kornder and Mennen 2021) for L1 Austrian German-L2 American English; (Major 1992) for L1 American English-L2 Brazilian Portuguese; (Mayr et al. 2012) for L1 Dutch-L2 English; (Mayr et al. 2020) for L1 Spanish-L2 British English; (Stoehr et al. 2017) for L1 Dutch-L2 German and L1 German-L2 Dutch; (Ulbrich and Ordin 2014) for L1 German-L2 Belfast English). Modifications to prosody and intonation have also been observed, although they have received far less research attention. With the exception of Gargiulo and Tronnier (2020), who investigated the use of prosodic cues to pronominal anaphora resolution, all studies focused on L2-induced changes to L1 intonation ((de Leeuw et al. 2012) for L1 German-L2 English; (de Leeuw 2019b) for L1 German-L2 English; (Mennen 2004) for L1 Dutch-L2 Greek; and (Mennen and Chousi 2018) for L1 Greek-L2 Austrian German). These studies all investigated just one particular aspect of intonation, i.e., tonal alignment (i.e., how the start or end of pitch rises are coordinated in time with segments), and showed a change in tonal alignment patterns in the L1 under the influence of the L2. However, L2-induced changes in L1 intonation are unlikely to be restricted to just aspects of its phonetic realization. The current study will therefore investigate L2-induced modifications in L1 intonation along the four intonation dimensions proposed by Mennen's (2015) L2 Intonation Learning theory (LILt), as explained later in this paper. This approach will ensure that L1 attrition in intonation is investigated in a more comprehensive and theoretically motivated way.

1.2. Approaches to Intonational Description

1.2.1. The Autosegmental-Metrical Model of Intonation

Intonation is said to be particularly susceptible to cross-language influences (Mackey 2000), yet the focus of most research studies on L1 attrition of speech has been on segments rather than intonation. A likely reason for this lack of research may be that intonation poses a particular challenge for researchers given the fact that it interacts with other prosodic aspects, like for instance tempo, rhythm, and loudness (e.g., Nolan 2006) and it is difficult—more so than in segments—to separate influences that are categorical from those that are gradient (Ladd 1996). It has been argued (Mennen 2004, 2007, 2015), however, that this is an important distinction to make, as cross-language influences may differ depending on whether they concern categorical (phonological) aspects of intonation or whether the aspects are gradient (phonetic). The few studies on cross-language influences in intonation suggest that gradient aspects may be more vulnerable to cross-language influences than categorial elements (Graham and Post 2018; Jun and Oh 2000; Mennen et al. 2010; Sanchez 2020). Thanks to the advent of the Autosegmental Metrical (AM) framework it has become more feasible to consider both types of influences in intonation, as it provides the tools to separate categorical phonological elements of intonation from the phonetic nature of their implementation. While the AM theory originates from Pierrehumbert's (1980) intonational description of American English, a series of language-specific annotation systems for many other languages has been derived from it (see Jun 2005, 2014, for overviews), and it has now become the most dominant approach to intonational description (Ladd 2000).

In the AM approach, the intonation of an utterance is presented phonologically as a sequence of high (H) and low (L) tones which are internally structured into pitch accents (when they associate with metrically prominent syllables) or boundary tones (when they associate with the edges of phrases). Pitch accents, often referred to as 'starred' tones because of their notation with an asterisk (*), can be monotonal (L* or H*) or bitonal (e.g., LH*, L*H, or H*L, where the asterisk indicates the most prominent tone within the accented syllable). Boundary tones describe the L or H tones at the beginning or end of an intonational phrase (e.g., H%) or an intermediate phrase (e.g., H-). Phonetically,

intonation is represented by the phonetic shape of the phonological categories, i.e., how phonological categories are phonetically realized in terms of, for instance, their height or timing. That is, the same phonological category (e.g., L*H or H*L) may be realized differently in different languages and dialects. Similarly, languages and dialects also differ in the inventory, complexity, and distribution of categorical phonological elements (see Jun 2005, 2014, for an overview). A more detailed description of the AM notations used in our study is given in Section 2.3.

1.2.2. The L2 Intonation Learning theory (LILt)

It has long been established that late sequential bilinguals who are long-term immersed in an L2 environment experience difficulties with the acquisition of L2 intonation, and often transfer elements of L1 intonation to the L2. Mennen (2015) proposed a model—the L2 Intonation Learning theory (LILt)—with roots in the AM approach, in order to account for and predict the difficulties learners may have in producing L2 intonation. The model is based on the premise that cross-language influences in intonation may occur along four dimensions (modified from Ladd 1996)[4]. These are:

1. The *systemic* dimension (the inventory and distribution of categorical phonological elements of intonation, such as boundary tones and pitch accents);
2. The *realizational* dimension (the phonetic implementation of these intonational primitives);
3. The *semantic* dimension (the functionality of the categorical elements or tunes, i.e., how they are used to signal meaning);
4. The *frequency* dimension (the frequency of use of the categorical elements).

The *systemic* dimension comprises the categorical or phonological elements of intonation, i.e., the intonational primitives, which can differ between languages and be a source of cross-language influences. An example of a cross-language difference on this dimension is the so-called 'early peak' (H!H*L), which has been reported for nuclear accents in German German (Féry 1993; Peters 2018) and Austrian German (Schmid and Moosmüller 2013; Ulbrich 2005) but not in British English (Grabe 2004). The term early peak is used to describe an intonation contour where the pitch maximum is reached on a metrically weak syllable immediately *preceding* the accented syllable. The accented syllable itself is falling or low. Figure 1 gives a schematic representation of how an early peak (H!H*L) may look like and how it contrasts with a falling pitch accent (H*L) where the peak occurs *on* the accented syllable[5]. In Austrian German early peaks are said to occur in conditions of narrow contrastive focus (Schmid and Moosmüller 2013; Moosmüller et al. 2015), where females were observed to use it more often than males (Schmid and Moosmüller 2013). However, such a gender-related preference may be restricted to narrow contrastive focus only, as it has not been reported in larger studies on Austrian German examining other contexts (Moosmüller et al. 2015; Ulbrich 2005). Languages or language varieties can also differ in the boundary tones they use, with some languages using complex boundary tones (such as LH% or HL%), others using simple low or high boundary tones at the start or end of intonation phrases, and some languages such as Mandarin sometimes omitting final boundary tones (see Jun 2005, 2014, for overviews).

The *realizational* dimension comprises the gradient or phonetic elements of intonation, i.e., how the intonational primitives such as pitch accents and boundary tones are phonetically realized. Cross-language differences on this dimension typically involve how pitch accents are lined up ('aligned') with segments in time (i.e., whether they occur early or late in a prominent syllable), the extent to which pitch accents are truncated at the utterance end (i.e., whether they are fully realized or 'cut off' when there is little voiced material available to realize falling or rising pitch accents), or what their relative height ('scaling') is within an individual's pitch range. For instance, the languages in the current study display differences in alignment patterns and overall pitch range but are relatively similar in the extent to which pitch accents are realized at the utterance end. That is, in prenuclear rising pitch accents in statements, speakers of Standard Southern British English (SSBE) typically

show a rise in pitch that begins close to the onset of the accented syllable (Ladd et al. 1999). In contrast, speakers of Austrian German begin prenuclear rises considerably later, i.e., well within the stressed vowel (Mennen and Chousi 2018). As for pitch range, speakers of SSBE typically deploy a wider pitch range than speakers of German German (Mennen et al. 2012) who, in turn, are found not to differ from speakers of Austrian German (Ulbrich 2005). Hence it can be concluded that speakers of Austrian German tend to use a narrower pitch range than speakers of SSBE. As for truncation patterns, both SSBE and Austrian German are found to compress rising and falling pitch patterns under time pressure (Siddins and Mennen 2019). Boundary tones may also differ in how they are cross-linguistically realized. For instance, Willems (1982) found that native speakers of British English realize the initial boundary tones at the start of their intonation phrases on a mid-level pitch, whereas native Dutch speakers start their intonation phrases on a low-level pitch. The *semantic* dimension is concerned with the use of categorical elements of intonation to convey meaning. For instance, languages may differ in how they mark informational and contrastive focus. In some languages (e.g., Germanic languages), focus is signalled by accenting new and contrastive information, while deaccenting given information (Nooteboom and Terken 1982). In other languages (e.g., Spanish), no intonational distinction is made between utterances with broad (where focus is on the whole phrase or sentence) and narrow focus (where the focus is on one part of the phrase or sentence), and the nuclear pitch accent[6] is always placed at the end of the intonational phrase (Hualde 2005). Japanese and Korean, on the other hand, signal focus by placing a boundary tone before or after the word in focus and deaccenting everything that follows (cf. Jun 2014). With respect to the two languages in the current study, previous research suggests that English and German differ in how they signal sentence-internal continuation, with German, including Austrian German (Moosmüller et al. 2015), favouring a rising pitch accent (L*H) and English speakers, including speakers of SSBE, typically employing a falling (H*L) pitch accent (see Chen 2007, for an overview). Finally, the *frequency* dimension concerns the frequency with which a specific intonation category is used in a particular language or dialect. For instance, while English and German both have rising and falling pitch accents in their respective inventory, the latter is used considerably more frequently in English than in German (Mennen et al. 2012, p. 2258)[7]. This is also the case for the language varieties in the current study, with Austrian German speakers using rises more frequently, at least in statements (Moosmüller et al. 2015), than SSBE speakers, who favour the use of falls (Mennen et al. 2012). Cross-language differences have also been observed in the frequency of use of boundary tones. For instance, a higher frequency of high boundary tones (H%), used also in utterances that are not intended as questions, is found in some varieties of English, particularly in younger generations (including Australian English, like New Zealand English, Belfast English or Glaswegian English) than in other varieties of English (e.g., Cruttenden 1997).

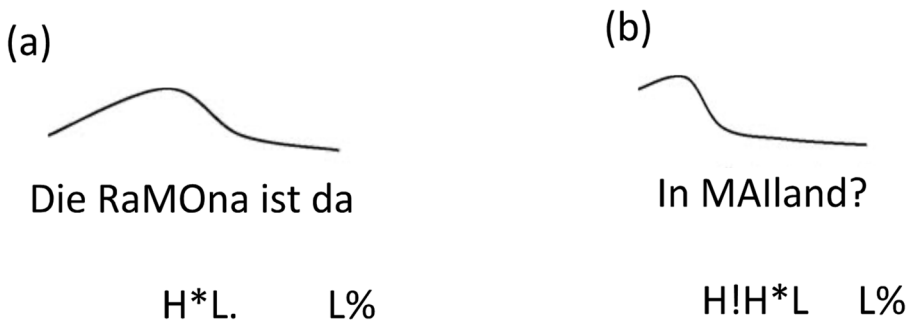


Figure 1. Schematic contour of the sentence (**a**) "Ramona is there" showing a falling (H*L) pitch accent with the peak on the accented syllable; and (**b**) "In Milan?" showing an early peak on the weak syllable 'in' before the accented syllable with low pitch. Capitals indicate accented syllables.

Drawing parallels to models of segmental learning, in particular the SLM (Flege 1995) and SLM-r (Flege and Bohn 2021), and based on previous findings (e.g., Atterer and Ladd 2004; de Leeuw et al. 2012; Mennen 2004, 2007; Mennen et al. 2010; Mennen et al. 2014), the LILt formulates a number of assumptions and hypotheses, which, in turn, generate testable predictions. While the LILt predominantly focuses on L1-to-L2 influences in intonation, it also allows for an explanation of L2-on-L1 influences. In particular, it assumes that a bilingual's L1 and L2 intonation systems are not entirely isolated but exist in a common space. This causes the intonation systems to interact with each other, which may result in bidirectional influences, such that L2-on-L1 effects are observed alongside L1-on-L2 effects (cf. Mennen 2015). Whether and where such influences are likely to occur depends to a large degree on the cross-language similarity in the various dimensions of intonation. According to the LILt, if an intonation category in the L2 is sufficiently different from any other L1 category already available in the L1, for instance when a pitch accent is part of the inventory of the L2 but not the L1, the chances that L2 learners will establish a new L2 category (i.e., chances of it being incorporated into their L2 inventory) are high. In such a case, the L2-on-L1 effect is likely to be completely absent. Alternatively, if a new L2 category is established, there may be a need for the new L2 category and already existing L1 categories to deflect away from each other in order to maintain contrast in a shared phonetic space. This could lead to an L2-on-L1 effect that is dissimilatory in nature. It is not entirely clear which factors guide the occurrence of the first or the latter scenario, i.e which circumstances will lead to there being no effect on the L1 and which will lead to a shift of the L1 category to maintain contrast. The SLM offers "crowding" of the bilinguals' "combined L1-L2 phonetic space" when new L2 categories are added as a reason for the occurrence of the latter scenario (Flege 2002, p. 225). It is not specified though, neither by the SLM(-r) nor the LILt, at which point it becomes necessary "to augment inter-category distances in the common L1-L2 phonetic space of bilinguals" (Flege and Bohn 2021, p. 21), although one has to assume that when the L2 category is sufficiently different from any already existing categories in the shared phonetic space, there would be little need for dissimilation and thus the former scenario would be more likely.

If, on the other hand, the cross-language differences are gradient in nature, with differences in the phonetic implementation of the same intonational category, cross-language interaction is expected to occur and result in an assimilation or merging of L1 and L2 properties. This, in turn, may result in a shift of the L1 category towards the L2 category and the use of intermediate values somewhere between those found in the L1 and the L2. Cross-language influences may therefore not be equally pervasive on each dimension of intonation, with research suggesting that the realizational dimension may be more permeable to cross-language influences than the systemic dimension (Graham and Post 2018; Mennen 2007; Ueyama 1997). With regard to external factors, the LILt draws on models of segmental learning (Flege 1995; Flege and Bohn 2021) and suggests that factors such as—amongst others—the age of arrival (AoA) in an L2-speaking country, length of residence (LoR), or amount of L1 and L2 use, may play a role in the degree to which cross-language influences in intonation will be observed, although the evidence so far is extremely limited. The few studies that have explored the role of AoA in intonation suggest that there may be age effects on L2 intonation learning, with more successful acquisition of L2 intonation in learners who had arrived in the L2 environment at an earlier age (Chen and Fon 2008; Huang and Jun 2011; Mennen 2004). Similarly, studies suggest that experience with, and exposure to, the L2 may influence the degree of success, although acquisition of the various dimensions of intonation does not appear to proceed at the same rate (Graham and Post 2018; Jun and Oh 2000; Mennen et al. 2010, 2014; Trofimovich and Baker 2006).

Finally, although the LILt is a fairly recent working model that is subject to change when more data become available (Mennen 2015), a number of recent studies have shown its effectiveness in establishing cross-language similarity along the four dimensions of intonation, in predicting where cross-language influences are likely to occur, and whether such influences change under the influence of language experience and exposure (Albin 2015;

Busà and Stella 2015; Graham and Post 2018; Pešková 2020; Sanchez 2020; Schauffler 2021). However, as these studies all focused on the acquisition of L2 intonation, the effectiveness of examining these four dimensions of intonation for predicting where L2-on-L1 effects are likely to occur remains to be established.

1.3. Research Questions and Predictions

The main objective of this study is to arrive at a better understanding of the malleability of native language intonation in migrants who are being long-term immersed in an L2 environment. The first question posed in this study is whether L2-induced changes are observed in the intonation of late English-Austrian German sequential bilinguals by comparing their intonation patterns with those produced by monolingual SSBE speakers living in England and monolingual Austrian German speakers living in Austria. Based on the research studies reviewed above, we hypothesize that the late sequential bilinguals in our study will manifest L1 modifications of intonation due to L2 learning experience.

The second question posed is whether the L2-induced changes to L1 intonation are evidenced in each of the four dimensions of intonation, or whether some dimensions or sentence types are more permeable to L2 influences than others. As we saw in the research reviewed earlier, cross-language influences are only expected to occur when cross-linguistic differences exist between the L2 learners' two languages. This is the case for each dimension of intonation of the languages examined in our study. On the systemic dimension, SSBE and Austrian German are very similar in their respective inventories of pitch accent categories, differing only in the so-called 'early peak, which is present in Austrian German (Schmid and Moosmüller 2013) but not in SSBE (Grabe 2004). There is a suggestion in the literature that early peaks are predominantly used by female speakers, although this gender-preference may be restricted to contexts of narrow contrastive focus (Schmid and Moosmüller 2013). On the realizational dimension, the research reviewed earlier suggests that Austrian German and SSBE differ in the pitch range habitually used by its speakers (wider in SSBE than in Austrian German), and the alignment of prenuclear rising accents in statements (earlier in SSBE than in Austrian German). Cross-language differences are also found on the frequency dimension, with Austrian German speakers using rises more frequently than SSBE speakers. On the semantic dimension, there are cross-language differences in the type of pitch accent used to indicate sentence-internal continuation, with SSBE speakers using predominantly falling pitch accents and Austrian German speakers preferring the use of a rising pitch accent to signal continuation. If these cross-language differences are confirmed in our study, L2-induced influences on the L1 should—in principle—be evidenced on each dimension of intonation (but see below for our expectations for the systemic dimension), at least for the pitch accents. Given that there is no previous literature available on cross-language differences between SSBE and Austrian German in boundary tones, we are not able to make any specific predictions here.

The third question our study addressed is whether any observed L1 modifications in intonation will take the form of assimilation (with L1 values that have shifted towards the L2 when compared to monolingual SSBE speakers), or dissimilation (with L1 values shifted away from both monolingual SSBE and Austrian German groups). In light of the cross-language differences and the previously discussed literature, we hypothesize that gradient differences will cause the L1 and L2 intonation systems to interact, resulting in assimilation, which in turn will result in intermediate values between the L1 and the L2. We therefore predict that on the realizational dimension, the bilingual speakers in our study will produce values for pitch range and alignment that are intermediate between the two monolingual groups. On the frequency level, where the cross-language differences are also gradient, we also expect to find intermediate frequencies of use of rising (L*H) and falling (H*L) pitch accents between those of the two monolingual groups. Similarly, on the semantic dimension cross-language differences are gradient in nature, with SSBE speakers showing a preference for a falling pitch accent and Austrian German speakers favoring a rising pitch accent to indicate sentence-internal continuation. We therefore predict that

the bilingual speakers in our study will show evidence of assimilation and start using L*H more frequently to signal continuation than monolingual SSBE speakers, showing intermediate values for the frequency of use of L*H in sentence-internal continuations between those found for the two monolingual groups. In contrast, if the cross-language differences are categorical, and the L2 category is sufficiently different from any other L1 category available, there is likely to be no effect of the L2 on the L1. Based on the assumptions of the SLM(r) and the LILt, we therefore predict that there will be no L1 modification in the systemic dimension, as there is no reason why the acquisition of a new L2 pitch accent that does not exist in the L1 would influence any of the existing L1 categories, unless there is a need to maintain contrast between the new L2 category and already existing L1 categories in a shared phonetic space (see Flege 2002). In the latter case, we would expect the L2-induced influence on the L1 to be dissimilatory in nature.

2. Materials and Methods

2.1. Participants

Three groups of adults participated in this study: (i) late sequential English–Austrian German bilinguals (BIL, N = 8, 4 females, 4 males); monolingual speakers of SSBE residing in England (SSBE, N = 8, 4 females, 4 males); and monolingual speakers of Austrian German residing in Austria (AUT, N = 8, 4 females, 4 males). The participants in the BIL group were all raised as monolingual speakers of SSBE who moved to Austria in adulthood and now reside in Austria where they acquired Austrian German as an L2. Their average age of arrival (AoA) in Austria is 32.4 years (range: 19 to 59), their average length of residence (LoR) in Austria is 17.3 years (range: 3 to 38). The bilingual speakers reported that they did not speak any foreign languages other than Austrian German on a daily basis or above high-school level.

We also obtained global foreign accent ratings (FARs) of selected speech samples (comprising the same sentences used in the current study, cf. Section 2.2) produced by the participants in the BIL group mixed with 3 of the monolingual SSBE control speakers, by asking 25 monolingual SSBE listeners not familiar with any varieties of German in an online rating experiment to decide whether a speaker in a given sample sounded native or not (binary decision), followed by an indication of how confident they were of their choice on a 3-point scale: uncertain, semi-certain, or certain. Together, this resulted in a 6-point foreign accent scale, ranging from "1" = "certainly native", to "6" = "certainly non-native". This two-staged rating is a commonly used method in studies on L1 attrition of speech (e.g., Bergmann et al. 2016; de Leeuw et al. 2010; Mayr et al. 2020). The ratings showed that the group of BILs were perceived as sounding significantly less native than the SSBE controls (confirmed by a cumulative link model for ordinal regression: $\chi^2[1] = 389.3$, $p < 0.001$), receiving average FARs of 2.8 and 1.2, respectively. This shows that, on average, the group of BIL speakers is perceived as moderately accented in their L1.

Participants in the monolingual groups formed our control groups. They are monolingual speakers of either SSBE or Standard Austrian German, and have never lived outside England or Austria, respectively. While they all have some knowledge of other languages, none of them reported more than high school level knowledge, and therefore can be considered "functional monolinguals" with little active knowledge or use of foreign languages (Best and Tyler 2007, p. 16).

2.2. Speech Materials and Recordings

There were two sets of speech materials, one for English and one for German. Each set consisted of twelve neutral sentences with various grammatical structures, including statements (e.g., There is phenomenal interest in the products.), wh-questions (e.g., Where is the manual?), yes/no questions (e.g., Do you live in Ealing?), declarative questions (questions without inversion, e.g., You live in Ealing?), and sentences containing sentence-internal continuation (e.g., Do you like Malaga or Malta best?). In order to ensure—as much as possible—a smooth fundamental frequency (f0) contour, care was taken to have

sonorants, or in a few cases voiced obstruents, flanking the stressed vowels of the words we expected to bear the pitch accents. The sentences from the English set came from a study on alignment patterns in prenuclear rises (Atterer and Ladd 2004, see further Section 2.4) or from the Intonational Variation in English (IViE) corpus (cf. Grabe 2004). The German set was specifically designed to match the English set as much as possible in syntactic structure, length, number, and distribution of content words, and expected place of pitch accents.

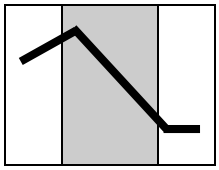
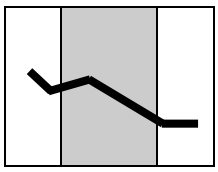
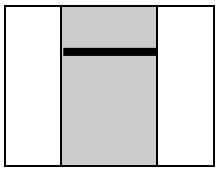
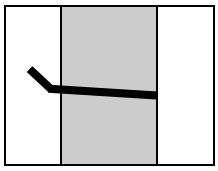
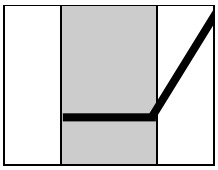
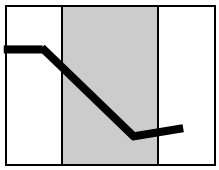
Participants were asked to read out two repetitions of each sentence in their respective L1s[8]. Due to contact restrictions during the COVID-19 pandemic, these recordings took place in the participants' own environment and using their own computer equipment. While this was not ideal (cf. Sanker et al. 2021), all recordings were carefully checked and, where necessary due to poor audio quality or misreading, participants were asked to re-record sentences. The latter was done just once, so as not to overburden the participants. In case the recordings still contained misreadings or were of poor audio quality, or the speaker failed to re-record the item, we discarded it, as happened in 4 cases. The two repetitions of each sentence were presented on the participants' computer monitor via WikiSpeech, an online tool designed to create web-based speech databases (Draxler and Jänsch 2008). All sentences were presented in random order and interspersed with materials designed to test segmental changes to L1 speech, not reported here, with a 1.5 s pause between items. Thus, a total of 480 utterances (20 sentences × 8 participants × 3 groups) were elicited, of which we had to discard 4 (as described above). The remaining 476 utterances were annotated by hand using the same pool of tonal labels (as further explained in the following section), and generating a corpus of 2534 tonal labels, encompassing prenuclear and nuclear pitch accents and phrase-initial and phrase-final boundary tones, for subsequent analysis.

2.3. Intonational Description

Since our study compares intonation in different languages (Austrian German and SSBE) and in different groups (monolinguals versus bilinguals), it is essential to use the same system of intonational description in each comparison, as we may otherwise not be comparing like with like. As we have seen earlier, language-specific annotation systems have emerged that are grounded in the AM framework. These not only differ in their labelling conventions but are also often based on different underlying assumptions. The most crucial difference concerns assumptions about the left-headedness or right-headedness of bitonal pitch accents. Whereas left-headed systems see the pitch movement as starting on the accented syllable, and therefore account for the movement **from** the accented syllable onwards (e.g., Féry 1993 and Peters 2018, for German; Grabe 2004 and Grabe et al. 2000, for British English), right-headed systems see the movement **towards** an accented syllable as important (e.g., Baumann et al. 2000 for German; Beckman and Pierrehumbert 1986 and Beckman et al. 2005, for American English). These two approaches are sometimes respectively referred to as "off-ramp" versus "on-ramp" analyses (Gussenhoven 2004, pp. 127–28). Using two systems with different underlying assumptions in our study would unnecessarily complicate the comparison of the different languages and groups. We therefore decided to base the labels in our study largely on the tonal labels from Grabe's (2004) IViE system, which, in turn, is modified from Gussenhoven's (1983, 2004) left-headed approach to the description of English and Dutch intonation. This system was deemed particularly suitable because it has been extensively used in previous studies of intonational varieties of British English (Grabe 2004; Grabe et al. 2000) and German (Peters 2018) and has also successfully been used in a cross-language comparison of the two languages (Grabe 1998).

All data were thus transcribed using the same pool of labels, although not all labels were used for each language, sentence type, or participant group, as will become clear in the Section 3. These labels were found to suffice for a description of our data from the two languages and groups under investigation. A list of the labels that were used for pitch accents (panel a) and boundary tones (panel b) in our analysis is given in Table 1, along with a short description and schematic representation of their common shape.

Table 1. Labels used in our study, along with a description and schematic representation. Panel (a) lists the pitch accents and accent modifications. Panel (b) lists the boundary tones. The grey parts represent metrically strong (accented) syllables; the white parts represent unstressed syllables.

Panel (a): Pitch Accents		
Pitch Accents	**Description of Commonly Observed Shape**	**Schematic Representation**
H*L	High fall: a high tonal target on accented syllable followed by a low tonal target. The fall starts on the same or immediately following syllable	
!H*L	Downstepped fall: a high tonal target on accented syllable followed by a low tonal target, which is downstepped to a lower level compared to preceding high targets	
H*	High level: a high tonal target on accented syllable which remains high until the following high tonal target	
!H*	Downstepped high: a high tonal target on accented syllable which is downstepped to a lower level compared to preceding high-level targets. The contour remains at this level until the following high tonal target	
L*H	Low rise: a low tonal target on accented syllable followed by high tonal target. The rise takes place in the same or immediately following syllable.	
H!H*L	Early peak: a high tonal target that is associated with a metrically weak syllable immediately preceding the accented syllable. The accented syllable itself is falling or low.	
Panel (b): Boundary Tones		
Boundary Tones	**Description**	
%H or %L	High/low beginning of intonational phrase (IP)	
H% or L%	Rising/low ending of IP	

The intonation labelling was conducted by one main annotator, who is trained in IViE-style transcriptions. Annotations were inserted into Praat (Boersma and Weenink 2022) and were based on a combination of an auditory and visual inspection of the data, giving initial priority to auditory impressions. Intermediate phrase boundaries were determined on the existence of a pause, lengthening, or pitch reset, or a combination of these cues. After an annotation of the first set of repetitions of all sentences and speakers, a second annotator, also trained in intonation labelling, went through the annotated data, and identified possible disagreements. These were discussed and resolved, after which

the main annotator proceeded with annotating the second set of repetitions. In order to establish inter-annotator consistency, 35% of the second set of repetitions (given that the 2nd annotator had already seen the first set of repetitions) were annotated by a second annotator also trained in intonation labelling, after which inter-annotator agreement was calculated by means of Cohen's κ (Cohen 1960). Agreement on the choice of tonal labels was 0.69, which corresponds according to Landis and Koch (1977) to a "substantial" agreement strength. In addition, the main annotator also re-labelled 12% of the data she had already annotated. Intra-rater agreement strength (Cohen's κ: 0.92) on the choice of tonal events corresponds to an "almost perfect" agreement—again following Landis and Koch (1977). As these agreement levels are within the same order of magnitude as inter-rater and intra-rater agreement for other studies using AM based annotation systems (cf. Breen et al. 2012; Escudero et al. 2012; Yoon et al. 2004), we therefore proceeded with the labels provided by the main annotator. An example of our annotations is shown in Figure 2.

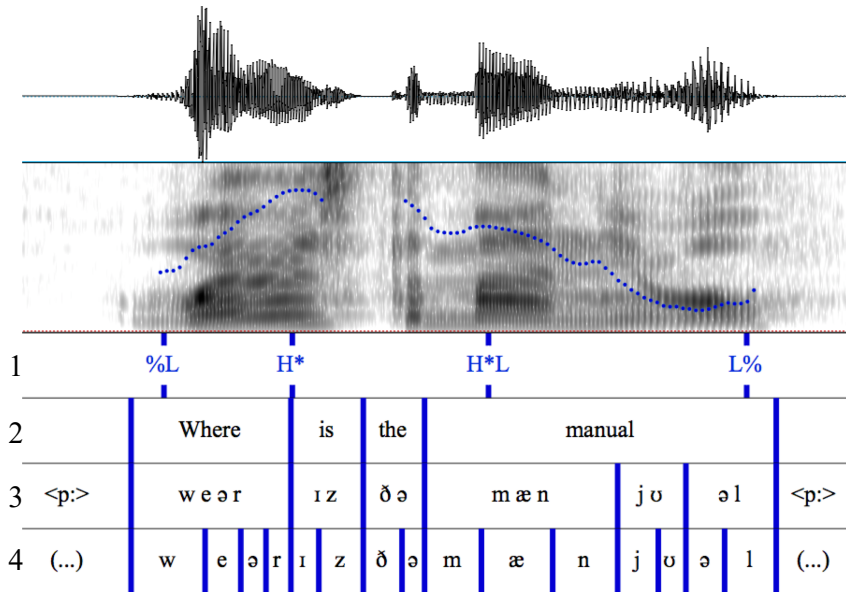


Figure 2. Example of a sentence produced by one of the SSBE speakers, annotated for intonation. Tier 1 shows the labels for boundary tones and pitch accents. Tier 2 shows the orthographic transcription. Tiers 3 and 4 show IPA transcriptions and delimination of the syllables and segments, respectively.

2.4. Measures and Analysis

All recordings were digitized at 16 kHz. The audio recordings were automatically segmented and labelled, using the orthographic prompts used for the recordings, in Web-Maus, a web application that aligns recordings to their corresponding orthographic texts by means of text-to-phoneme conversion and forced-alignment algorithms (Kisler et al. 2017). The resulting phonetic segment boundaries were checked and hand-corrected where needed.

A number of measures was used to examine the production of the various dimensions of intonation. These measures were examined in the whole corpus, except for measures of alignment and sentence-internal continuation, which were examined only in the statements and sentences containing sentence-internal continuation, respectively (see below). To test the systemic and frequency dimensions, the labels for pitch accents and boundary tones were compared between the groups of speakers and sentence types. For the realizational dimension, we examined two aspects of phonetic implementation for which cross-language differences are reported between SSBE and Austrian German, namely pitch range and alignment (how pitch accents are lined up with segments in time). Therefore, these are likely candidates for L2-induced changes to L1 speech in the realizational dimension of intonation. We used Praat (Boersma and Weenink 2022) to calculate measures of pitch range

and alignment. For pitch range, we measured f0 in our corpus, with a pitch range setting of 50 to 400 Hz for males and 75 to 560 Hz for females, i.e., for both genders in a three-octave range, by means of the "To pitch (ac)..." routine in Praat. The parameter octave-jump cost was increased to 0.5 in order to penalize large frequency jumps; all other settings were left at default values for this routine. We then used a Praat script to obtain the speaker-specific 90% pitch range, i.e., the difference between the 95th and 5th percentile of the measured pitch range in semitones. As mentioned above, alignment was measured in the statements (N = 96) of our corpus. These statements, some of which were taken from Atterer and Ladd (2004), were designed to elicit a pitch rise on the first content word. In order to ensure that a prenuclear rise was elicited on the test word, care was taken to use "either an adjective followed by a noun, or a noun followed by a genitive construction" (Atterer and Ladd 2004, p. 182). In all cases, the stressed syllable of the test word was always preceded and followed by two or more unstressed syllables. While this construction generally attracted a prenuclear rise on the test word and a nuclear accent on the following noun, in some cases the following noun was deaccented. These cases (N = 5) were discarded. In the remaining 91 sentences, we measured the alignment of the start and end of the prenuclear rise. For the alignment of the start of the rise, the distance in milliseconds (ms) between the beginning of the initial consonant of the test word bearing the prenuclear accent (labelled as C0) and the start of the prenuclear rise was measured. For the alignment of the end of the rise, the distance between the end of the prenuclear rise and the start of the vowel of the post-accentual syllable (labelled as V1) was taken as our measure. Figure 3 shows an example of the alignment measures in one of the test words in our corpus. As the use of sonorants in the test syllables ensured a relatively smooth f0 trace, it was generally unproblematic to locate the local f0 peaks and valleys.

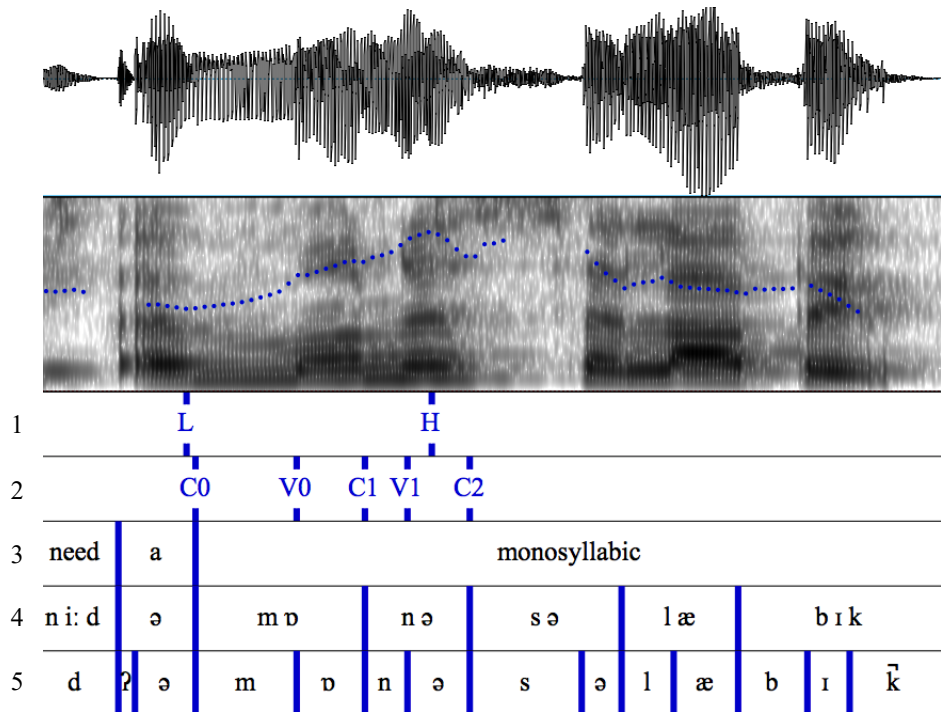


Figure 3. Example of the alignment measures in the test word *monosyllabic* in our corpus (extracted from the utterance "I need a monosyllabic word for my crossword puzzle"). Tier 1 shows the start (L) and end of the rise (H). Tier 2 shows the start of the initial consonant (C0) and vowel (V0) of the test word bearing the prenuclear accent, the start of the consonant (C1) and vowel (V1) of the post-accentual syllable, and the end of the post-accentual vowel (C2). Tier 3 shows the orthographic transcription. Tiers 4 and 5 show IPA transcriptions and delimination of the syllables and segments, respectively.

Finally, in order to test the semantic dimension, we examined how sentence-internal continuation is signalled in our groups of participants. Previous studies have argued that English and German differ in how they signal sentence-internal continuation, with German, including Austrian German (Moosmüller et al. 2015), favouring a rising pitch accent (L*H) and English speakers typically employing a falling (H*L) pitch accent (see Chen 2007, for an overview). Therefore, we used the labels for nuclear pitch accents and the frequency with which they occur at the end of the first intonational phrase (e.g., in the sentence '*Do you like Malaga or Malta best?*' we investigated the nuclear pitch accents occurring in the intonational phrase '*Do you like Malaga*') in all the sentences with sentence-internal continuation in our corpus (N = 94) as our measure for examining differences between the groups in the semantic dimension.

3. Results

3.1. Systemic Dimension

Based on the existing literature, we expected that the inventory of pitch accents and boundary tones in SSBE and Austrian German would be very similar (Grabe 1998), with the exception of the early peak which is reported to be present in Austrian German (Schmid and Moosmüller 2013) but not in SSBE (Grabe 2004). This is indeed what we found when we compared all prenuclear and nuclear pitch accents and boundary tones used in our corpus. Both SSBE and AUT groups used the pitch accents H*L, !H*L, H*, !H* and L*H, as well as high and low initial (%H, %L) and final (H%, L%) boundary tones. The only cross-language difference was found in the use of H!H*L (early peak), a pitch accent which was present in the AUT speakers' inventory but not in that of the SSBE monolinguals. In terms of their distribution across the different sentences types, we found that all pitch accents occurred in each sentence type (albeit to a different extent, as will be reported in Section 3.2), except for H!H*L which was only used in questions. As both monolingual groups used H*L, !H*L, H*, !H*, L*H, and initial and final high and low boundary tones, it is no surprise that these pitch accents and boundary tones are also used by the BIL group and, just as in the two monolingual groups, also occurred in each sentence type. However, the BIL group's L1 inventory was found to also contain the early peak (H!H*L), a pitch accent which is not used by the SSBE monolingual group. Similar to the monolingual AUT speakers, the early peak was only used in questions.

As there is a suggestion in the literature that there may be a gender-specific distribution in the use of early peaks (H!H*L) in Austrian German, we checked whether this was the case in our data. As mentioned above, early peaks were only used in questions. We therefore ran Chi-Square tests in the question data only with *percentage of occurrences of H!H*L* (i.e., H!H*L as opposed to non-H!H*L) as dependent variable and *gender* as independent variable, separately for the AUT and BIL groups. This showed no effect of gender, neither for the AUT group ($\chi^2[1] = 0.19$, n.s.) nor the BIL group ($\chi^2[1] = 0.29$, n.s.). While the bilingual speakers used early peaks to a lesser extent than the Austrian speakers did (as will be discussed in more detail in the next section), its use was not restricted to just a few bilinguals but used across all speakers.

3.2. Frequency Dimension

We first established whether the overall number of pitch accents was the same across the speaker groups: we ran an ANOVA[9] with the *number of pitch accents per speaker and group* as dependent variable and *speaker group* (levels: SSBE, BIL, and AUT) as independent variable. This revealed that the groups differ in the overall number of pitch accents used ($F[2,21] = 7.9$, $p < 0.01$). Post-hoc pairwise t-tests with Bonferroni correction revealed, however, that AUT speakers have a lower number of pitch accents than the SSBE ($p < 0.05$) and BIL ($p < 0.05$) speakers, but that there is no significant difference in the number of pitch accents between SSBE and BIL speakers. We then proceeded with examining the frequency with which the pitch accents and boundary tones were used by the three groups of speakers. Figure 4 shows the overall frequency of use of the pitch accents and boundary tones in the

whole corpus by the three groups of speakers. It can be seen that the overall frequency of use of some pitch accents and boundary tones differs between the groups. In particular, SSBE speakers produced more falling (H*L and !H*L taken together) than rising (L*H) pitch accents (71.7 % vs. 4.2%), whereas the reverse was true for AUT-controls (20.7% versus 54.6%). This was found to be significant in a Chi-Square test with *percentage of pitch accent* (i.e., percentages of falling and rising pitch accents) as dependent variable, and *speaker group* (as above) as independent variable ($\chi^2[2] = 71.4$, $p < 0.001$). Post-hoc pairwise Chi-Square tests with Bonferroni-correction (correction factor 3 for the three tests) showed that falling and rising pitch accents were used in different amounts in SSBE vs. AUT ($p < 0.001$), SSBE vs. BIL ($p < 0.001$), and in AUT vs. BIL ($p < 0.01$). The level pitch accents (H* and !H* taken together) were produced to a greater extent by the SSBE (24.1%) than by the AUT speakers (10.8%), and BIL speakers' frequency of use is intermediate between that of the SSBE and the AUT speakers (at 17.7%). The early peak (H!H*L) was used by the AUT speakers in 13.8% of cases, whereas it did not occur in the SSBE speakers, and the BIL speakers were found to produce it in 8.7% of their utterances. A Chi-Square test with *percentage of pitch accent* (i.e., percentages of falling (H*L and !H*L), rising (L*H), level (H* and !H*), and early peak (H!H*L) pitch accents) as dependent variable and *speaker group* as independent variable confirmed that the frequency of use for the four pitch accent categories were generally very different for the three speaker groups ($\chi^2[6] = 90.2$, $p < 0.001$). Post-hoc tests with pair-wise comparisons (with Bonferroni-correction, i.e., with a Bonferroni factor of 3, due to the three pair-wise comparisons) of the speaker groups showed highly significant differences between BIL and SSBE and AUT and SSBE speaker groups ($p < 0.001$ each), and significant differences between BIL and AUT speakers ($p < 0.05$).

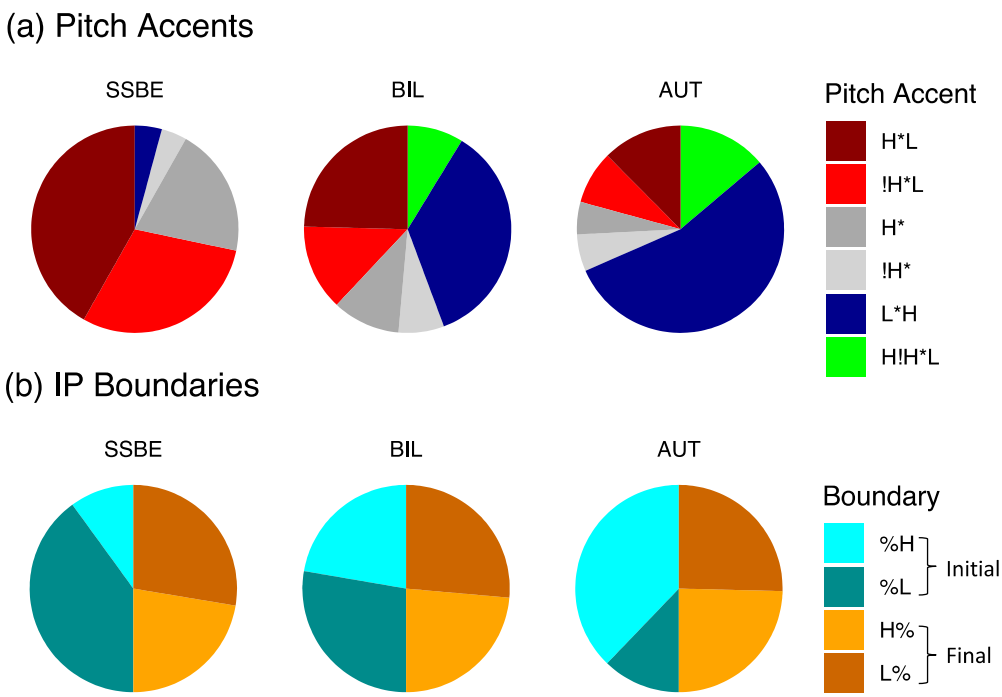


Figure 4. Overall frequency of use of pitch accents (panel **a**) and boundary tones (panel **b**) by the three groups of speakers.

As for the boundary tones, we found that SSBE speakers typically started (in 80.0% of the cases) their intonation phrases with a low boundary tone at the start of their intonation phrases (%L), whereas the speakers in the AUT group mostly used a high boundary tone (75.6%) at the start of their intonation phrases (%H). The BIL speakers' frequency of use of initial boundaries was found to be in between those for the two monolingual groups, with 44.6% use of a high boundary tone (%H) and 55.4% use of a low boundary tone (%L) at the start of their intonation phrases. These differences were found to be significant in a

Chi-Square test with *percentage of high and low initial boundary tones* as dependent variable and *speaker group* ($\chi^2[2] = 62.4$, $p < 0.001$). Post-hoc tests with Bonferroni correction revealed that all three pairwise speaker group comparisons showed significant differences (BIL vs. SSBE: $p < 0.01$, BIL vs. AUT and SSBE vs. AUT: $p < 0.001$). A Chi-Square test with *percentage of high and low final boundary tones* as dependent variable and *speaker group* showed no significant differences in the frequency of use of the boundary tones at the end of intonation phrases ($\chi^2[2] = 0.4$, n.s.), with a nearly 50/50 split for all three groups (SSBE: 44.7% H% vs. 55.3% L%; BIL: 47.2% H% vs. 52.8% L%; AUT: 49.2% H% vs. 50.8% L%).

We also observed differences in the frequency of use of the intonational primitives across sentence types. Due to the limits on article length, we restricted our analysis of the intonational primitives in the different sentence types to an analysis of nuclear accents. Table 2 shows the nuclear accents in each sentence type and participant group. In statements, the most frequently used nuclear pitch accent by all three groups is that of H*L (SSBE 96.9%, AUT 82.9%, BIL 90.9). AUT speakers additionally use L*H (in 14.3% of statements), whereas this nuclear pitch accent does not occur in the statements produced by SSBE speakers. The BIL speakers, on the other hand, use the nuclear accent L*H in their English nearly as often (in 9.1% of statements) as AUT speakers use it in their German statements. A Chi-Square test with *percentage of nuclear pitch accents* (i.e., with the percentages of H*L, L*H, and H*) as the dependent variable and *speaker group* showed a significant effect of speaker group ($\chi^2[4] = 20.7$, $p < 0.001$). Pairwise comparisons showed that BILs and AUTs did not show significantly different use of tonal categories (the other two pair-wise comparisons, i.e., SSBE vs. BIL and SSBE vs. AUT, resulted in (Bonferroni-corrected) $p < 0.001$).

Table 2. Nuclear accents and their usage in % by SSBE, BIL, and AUT speakers in statements (ST), wh-questions (WHQ), yes/no questions (YNQ), declarative questions (DQ), and sentence-internal continuation (CONT).

NUCLEAR	ST			WHQ			YNQ			DQ			CONT		
ACCENT	SSBE	BIL	AUT	SSBE	BIL	AUT	SSBE	BIL	AUT	SSBE	BIL	AUT	SSBE	BIL	AUT
H*L	96.9	90.9	82.9	96.7	78.1	9.4	96.8	29.4	0	84.4	15.7	0	46.9	12.5	0
H!H*L	0	0	0	0	12.5	31.3	0	38.2	62.5	0	78.1	71.9	0	0	0
H*	3.1	0	0	0	0	0	0	0	0	15.6	3.1	0	0	0	0
L*H	0	9.1	14.3	3.2	9.4	59.3	3.2	32.4	37.5	0	3.1	28.1	53.1	87.5	100

In wh-questions, both monolingual groups use the falling nuclear accent H*L, but to a very different degree. While SSBE speakers use it in nearly all of the wh-questions that were produced (96.7%), AUT speakers use it in just 9.4% of cases. The BIL speakers use considerably more falling nuclear accents than the AUT speakers, but less than the SSBE speakers (78.1%). Early peaks (i.e., H!H*L) were not observed in the wh-questions produced by the SSBE speakers, but are used in nearly a third of the cases (31.3%) by the AUT speakers. Despite this nuclear accent not being part of the L1 English inventory, the BIL speakers used it in 12.5% of cases, albeit to a lesser extent than the AUT speakers. Again, a Chi-Square test with dependent variable *percentage of nuclear pitch accents* (i.e., with the percentages of H*L, L*H, and H!H*L) and independent variable *speaker group* showed a significant effect of *speaker group* ($\chi^2[4] = 181.8$, $p < 0.001$); all three post-hoc pairwise comparisons with Bonferroni correction resulted also in $p < 0.001$).

In yes/no-questions, we again see clear and—as shown by a Chi-Square test—significant differences in *percentage of nuclear pitch accents* (the dependent variable with, in this case, the following three categories: H*L, L*H, and H!H*L) ($\chi^2[4] = 204.4$, $p < 0.001$) between the three *speaker groups*. Where the most frequent nuclear accent is H*L in the SSBE speakers (with a frequency of use of 96.8%), it is not used at all by AUT speakers, and the BIL speakers are, again, in-between (with a frequency of use of 29.4%). The reverse is true for the early peaks H!H*L, which is the most frequently used nuclear accent in yes/no questions by the AUT speakers (62.5%), but not used at all by the SSBE speakers, with the BIL speakers in-between the two monolingual groups (38.2%). In addition to their use

of H!H*L, the AUT speakers also use L*H, although with 37.5% it is used less often than H!H*L. SSBE speakers use L*H in yes/no questions on occasion (3.2%), whereas the BIL speakers use it almost as often as the AUT speakers (32.4%). Post-hoc tests with Bonferroni corrections, comparing speaker groups in pairs (i.e., SSBE vs. AUT, SSBE vs. BIL, and BIL vs. AUT), showed highly significant differences between all three pairwise tests ($p < 0.001$ each). In order to test as to whether there was a difference between the use of L*H vs. all other tonal categories in this context (H*L and H!H*L) combined, we conducted another Chi-Square test, with the dependent variable *percentage of nuclear pitch accents* (L*H vs. non-L*H) and independent variable *speaker group*, which showed an effect of speaker group ($\chi^2[4] = 204.4$, $p < 0.001$). Pairwise post-hoc comparisons showed significant differences for SSBE vs. AUT and SSBE vs. BIL, but not for AUT and BIL speakers ($\chi^2[1] = 0.4$, n.s.).

In declarative questions we again find a clear effect of *speaker group* in a Chi-Square test with dependent variable *percentage of nuclear pitch accents* (categories: H*L, H!H*L, L*H, and H*) ($\chi^2[6] = 263.7$, $p < 0.001$). Pairwise comparisons for SSBE vs. BIL, SSBE vs. AUT, and BIL vs. AUT showed highly significant differences for each ($p < 0.001$ each). In 28.1% of the cases, AUT speakers use a L*H nuclear accent in declarative questions, whereas L*H is not present in this type of questions of SSBE speakers. The BIL speakers show minimal use of L*H in declarative questions (3.1%). While H*L is the most frequently used nuclear accent by SSBE speakers (84.4%), it is not used at all by the AUT speakers, and the BIL speakers have a frequency of use that is in-between the two monolingual groups (15.7%). Instead of a H*L, AUT speakers' most frequently used nuclear accent is H!H*L (71.9%), a nuclear accent which is not used at all by the SSBE speakers. The H!H*L is also the most frequently used nuclear accent by the BIL speakers, with frequency of use patterns that are even slightly higher (78.1%) than those of the monolingual AUT speakers, i.e., overshooting the AUT norm. We also wanted to test whether there were speaker group related differences between the early peak (H!H*L) use and the use of all other categories combined. To test this, we conducted a Chi-Square test with *speaker group* and dependent variable *percentage of nuclear pitch accents* (H!H*L vs. non-H!H*L), which revealed significant results ($\chi^2[2] = 150.8$, $p < 0.001$). Post-hoc comparisons with Bonferroni correction showed that this difference is significant for SSBE vs. AUT and SSBE vs. BIL (each $p < 0.001$), but not for BIL vs. AUT ($\chi^2[1] = 0.72$, n.s.).

Finally, while it can be seen that the L*H is the only nuclear accent used by AUT speakers in sentence-internal continuations, SSBE speakers alternate between a L*H and a H*L nuclear accent (in 53.1% vs. 46.9% of cases, respectively). Once again, BIL speakers were found to show patterns of use in their L1 that are in-between the monolingual groups, with 87.5% usage of L*H (i.e., a much higher frequency of use than that of monolingual SSBE speakers) and 12.5% usage of H*L (much lower than that of the monolingual SSBE speakers). We tested this difference statistically by means of a Chi-Square test with *speaker group* and the dependent variable *nuclear pitch accents* (H*L vs. L*H) and found it to be statistically significant ($\chi^2[2] = 74.3$, $p < 0.001$). All three pairwise-comparisons (AUT vs. SSBE, SSBE vs. BIL, and AUT vs. BIL) were also highly significant ($p < 0.001$ each).

3.3. Realizational Dimension

We then analyzed two aspects of the realizational dimension of intonation, i.e., pitch range and prenuclear alignment. Based on the literature, we expected pitch range to be wider in SSBE than in AUT speakers, and the BIL speakers to be somewhere in between. The mean values for the 90% pitch range in semitones by the three groups shown in Figure 5 appear to confirm this. We ran an ANOVA with *90% pitch range* as the dependent variable and *speaker group* (as above) as independent variable. No significant effect of *speaker group* was found ($F[2,21] = 2.0$, n.s.). Subsequent post-hoc *t*-tests with Bonferroni correction also revealed no statistically significant pairwise difference between the group pairs, although there are tendencies for AUT vs. BIL and for AUT vs. SSBE.

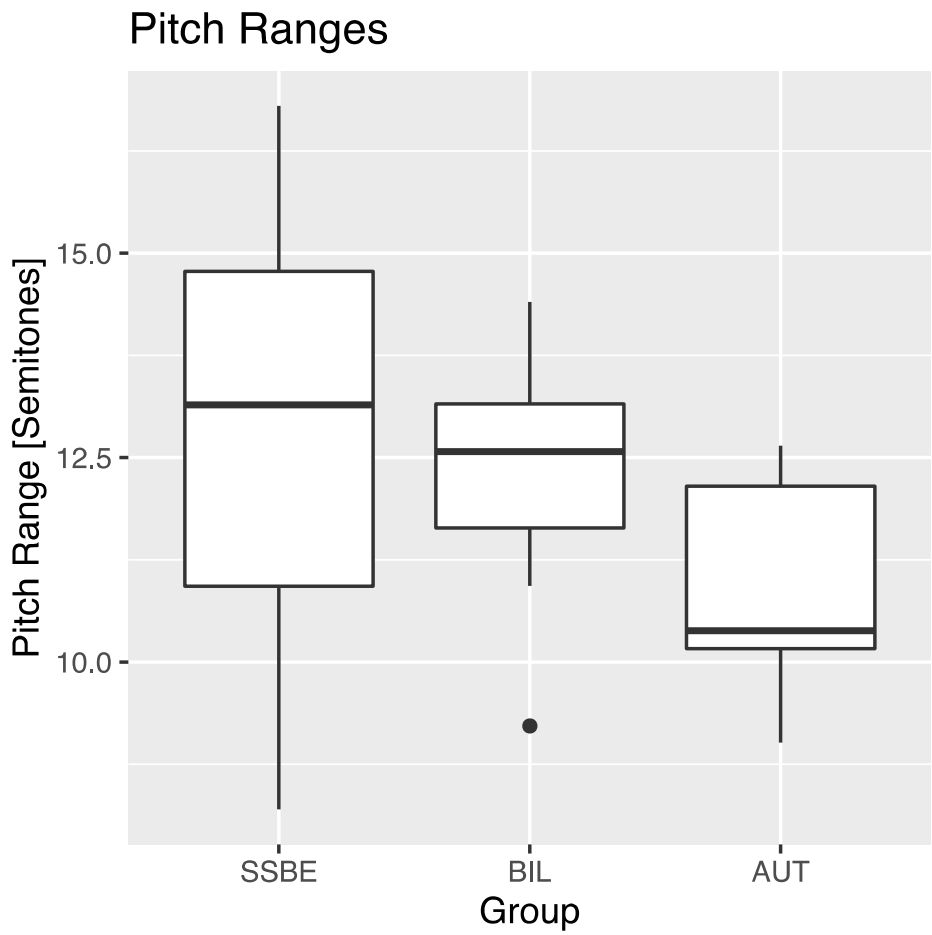


Figure 5. 90% pitch range in semitones of the three participant groups.

For alignment, two one-way ANOVAs with *speaker group* (SSBE, BIL, AUT) as independent variable were run, one with the start of the rise (measured as the temporal difference between the start of the rise and the initial consonant of the syllable bearing the prenuclear accent) as dependent variable, and the other with the end of the rise (measured as the temporal difference between the end of the rise and the beginning of the post-accentual vowel) as dependent variable. Results are plotted in Figure 6a,b, respectively. For alignment of the start of the rise, it was confirmed that the differences were highly significant ($F[2,21] = 64.4$, $p < 0.001$). Post-hoc *t*-tests with Bonferroni-correction showed significant differences between the monolingual SSBE and monolingual AUT groups ($p < 0.001$), between SSBE monolinguals and BIL ($p < 0.001$), and between the AUT and BIL ($p < 0.01$) groups. On average, SSBE controls start their prenuclear rises 9.8 ms after the consonant onset (C0) of the accented syllable, whereas AUT controls start the rises well into the accented vowel (137.3 ms after C0). The BIL speakers show intermediate values, with an alignment of 78.8 ms. For alignment of the end of the prenuclear rise (measured as the temporal difference between H and V1), we found no significant differences between the three speaker groups ($F[2,21] = 2.2$, n.s.).[10]

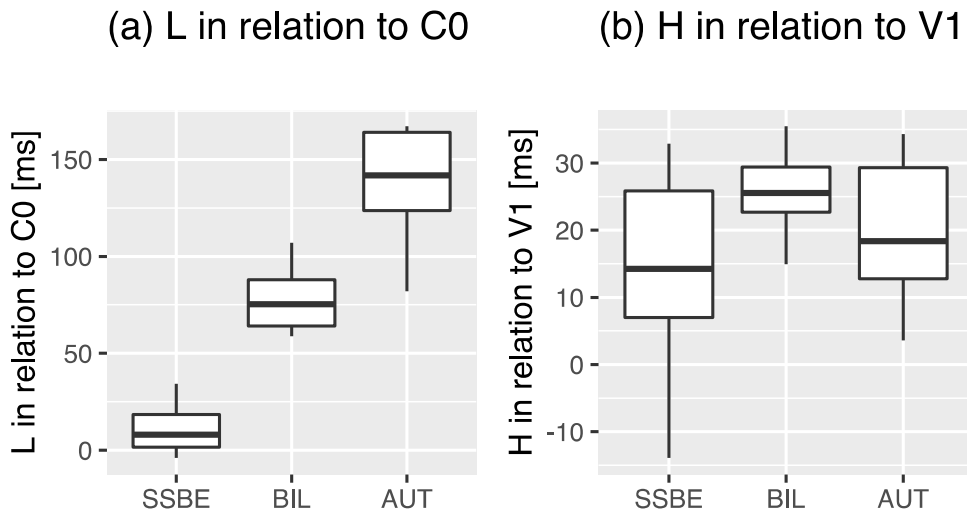


Figure 6. Alignment of (**a**) the start (L) of the rise in relation to the initial consonant of the syllable bearing the prenuclear accent (C0); and (**b**) alignment of the end (H) of the rise in relation to the start of the post-accentual vowel (V1) in ms for the three groups of speakers.

In addition to the planned analyses of pitch range and prenuclear alignment, we decided to also investigate a third aspect of phonetic realization, i.e., how the early peak (H!H*L) was realized. According to the LILt, building on assumptions from the SLM(-r), an L2-on-L1 effect is likely to be completely absent when a pitch accent is part of the inventory of the L2 but not the L1. Yet, our results showed that the BILs in our study used the H!H*L in their L1, despite the fact that this particular pitch accent was completely absent from the tonal inventory of the monolingual SSBE control group. While this suggests that the bilinguals may have fully transferred the L2 category into their L1, it is possible, as suggested by the SLM(-r) and LILt, that it may be realized differently from how it is realized by monolingual speakers because of a need to maintain contrast within a shared phonetic space. For this particular pitch accent, however, we think this scenario is unlikely given that a pitch accent where the pitch maximum is reached on a metrically weak syllable immediately *preceding* the accented syllable makes it sufficiently different from any other existing categories in the L1-L2 shared phonetic space, and therefore a need to 'exaggerate' its realization seems unnecessary. However, to make sure, we decided to nevertheless examine whether there were possible realizational differences between early peaks in the AUTs' Austrian German productions and the early peaks in the BILs' English productions. This was examined by calculating the f0 differences (in semitones) between the metrically weak syllable bearing the early peak (measured as the mean f0 value in this syllable) and the following accented syllable (again, measured as the mean f0 in this syllable). Given the tendencies for differences in general pitch range between the BIL and the AUT groups reported above, we normalized the H!H*L ranges for their speaker-specific pitch range by expressing the f0 differences (in semitones) as a proportion of the same speakers' pitch range (also in semitones). Figure 7 shows a comparison of the normalized early peak ranges. A *t*-test revealed no significant differences between the groups in the normalized early peak ranges ($t[12.7] = 1.4$, n.s.). In other words, no differences between the BILs' realization of H!H*L in their L1 and the realization by AUT speakers were found, suggesting that the BILs have fully transferred this L2 category into their L1.

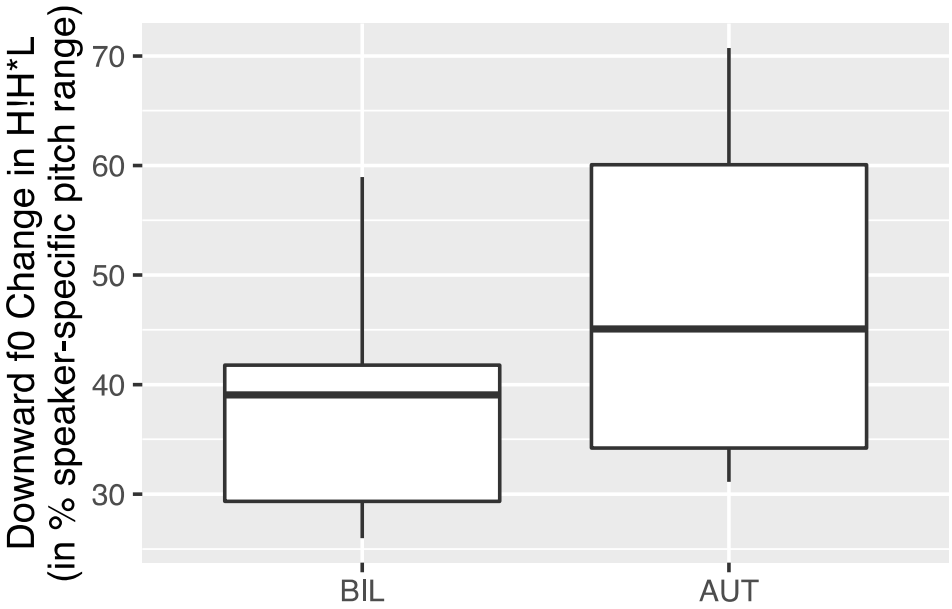


Figure 7. Downward f0 change in H!H*L pitch accents, normalized to speaker-specific pitch ranges.

3.4. Semantic Dimension

Based on the literature discussed earlier, we expected SSBE speakers to show a preference for a falling pitch accent to indicate sentence-internal continuation, AUT speakers to prefer a rising pitch accent, and the BIL speakers to be intermediate between the two monolingual groups. A Chi-Square test with *percentage of use of falls or rises* as dependent variable, and with the three *speaker groups* as independent variable showed significant cross-language differences ($\chi^2[1] = 74.3$, $p < 0.001$). These confirmed that whereas AUT speakers show a preference for the use of L*H (100%), the SSBE-controls used rises and falls in approximately equal measure (53.1% L*H vs. 46.9% H*L). The BILs were once again in-between both monolingual groups with 87.5% L*H and 12.5% H*L (cf. also Table 2 in Section 3.2). Post-hoc chi-squared tests with Bonferroni correction showed that all three pairwise comparisons were significant (SSBE vs. BIL and SSBE vs. AUT: $p < 0.001$, AUT vs. BIL: $p < 0.01$).

4. Discussion

This study aimed to gain a better understanding of the plasticity of native language intonation due to long-term immersion in an L2-speaking environment. To this end, we examined the four dimensions of intonation in the LILt proposed by Mennen (2015) in the read L1 speech of late English–Austrian sequential bilinguals who emigrated to Austria in adulthood. As such, this study is the most comprehensive investigation of L1 attrition of intonation, as no previous studies have considered whether and how L1 modifications manifest in all dimensions of intonation. The results revealed widespread L2-induced influences on the L1 intonation of the bilinguals in each dimension of intonation and in each sentence type, although the extent of the L2-on-L1 effect varied. The form the observed L1 modifications in intonation took was consistently one of assimilation, with intermediate values between the L1 and the L2, or complete assimilation to L2 properties. We will consider the implications of these findings below.

First, let us consider the pervasiveness of the L2-on-L1 effect and the fact that it was evidenced on each dimension of intonation. The LILt assumes that cross-language influences in intonation are—at least to some extent—influenced by the existence of cross-linguistic differences in the intonation systems of the L1 and L2, such that no L2-on-L1 effect would be expected where there are no cross-language differences. This is confirmed by the results, which suggest that the extent of the L2-on-L1 effect largely depends on the degree of cross-language differences. Without exception, wherever the L1 and L2 showed cross-

language differences, an L2-on-L1 effect was found in the bilinguals' first language, and this was apparent in both pitch accents and boundary tones. That is, the L2-on-L1 effect for the boundary tones was restricted to the frequency of use of high (%H) and low (%L) boundary tones at the start of their intonation phrases, reflecting the cross-language differences that only occurred in initial boundary tones. For pitch accents, the L2-on-L1 effect was restricted to just one pitch accent (the early peak) on the systemic dimension, whereas the effect was more pervasive on the frequency and realizational dimension and in some sentence types compared to others, reflecting the extent of cross-language differences. The findings of our study therefore confirm that LILt's method of classifying and characterizing cross-language intonation differences on four intonation dimensions is not only an effective method for predicting where cross-linguistic influences in the L2 are likely to occur (Albin 2015; Busà and Stella 2015; Graham and Post 2018; Pešková 2020; Sanchez 2020; Schauffler 2021) but can also predict where L2-induced influences in L1 intonation may be likely.

Let us now turn to the form of the observed L1 modifications in intonation. Based on assumptions from the LILt and the SLM(r), we predicted that the form L1 modifications would take would depend on whether the cross-language differences in intonation are categorical or gradient in nature, with gradient aspects being more vulnerable to cross-language influences than categorical ones (Graham and Post 2018; Jun and Oh 2000; Mennen et al. 2010; Sanchez 2020). We hypothesized that when cross-language differences are gradient, bilinguals are likely to identify them as variants or 'allotones' of the L1 tonal category. This would result in the L2-on-L1 effect to be one of assimilation. This is indeed what we found: the L2-on-L1 effect observed for the gradient cross-language differences in our study was consistently one of assimilation. While we have no data for how the bilinguals actually produced related tonal categories in their L2, the occurrence of assimilatory L2-on-L1 effects suggests that the bilinguals are likely to have merged the gradient cross-language differences between the L1 and L2 into a composite L1-L2 phonetic category, given that cross-language influences "provide a reflex that is diagnostic of L2 category formation or its absence" (Flege and Bohn 2021, p. 42). The values that we found for gradient aspects of intonation were sometimes half-way between the two monolingual control groups, other times closer to the L1 or approximating the L2 norms, reflecting different degrees of the L2-on-L1 effect. Interestingly, in a few cases we found that the bilingual's frequency of use fell within the Austrian German monolingual norms, suggesting that the bilinguals had fully merged the L1 and L2 properties. This was found for the frequency of use of nuclear rises (L*H) in statements and yes-no questions, and the use of early peaks (H!H*L) in declarative questions, where the bilinguals were found to use these pitch accents in English as often as the monolingual Austrian controls did in Austrian German. Full assimilation has also been reported for segments, although it is considered to be unusual. For instance, de Leeuw et al. (2018b) present a case of a German-English bilingual whose realization of the L1 rhotic had assimilated entirely into the monolingual norm of the English retroflex. While this was presented as a case of "extreme phonetic attrition" (de Leeuw et al. 2018b, p. 163) caused by prolonged reduced L1 use, our results suggest that it may not be as unusual as previously thought, at least not for intonation. Possible reasons for why full merging may have been observed in our data will be explored below.

For categorical cross-language differences, the LILt assumes that bilinguals are likely to establish a new L2 category as long as it is sufficiently different from any other category available in the L1, as would be the case when a category is part of the inventory of the L2 but not the L1. The only categorical cross-language difference between Austrian German and SSBE is on the systemic dimension and concerns the early peak (H!H*L), which is present in the inventory of monolingual Austrian German speakers but is not used by the monolingual SSBE speakers. The early peak is different from any other pitch accents in Austrian German and SSBE due to the association of a high tone with a metrically weak syllable immediately preceding the accented syllable. This particular language-specific tune-text association, where a high tone occurs on an a metrically weak syllable preceding

the syllable that is actually accented, is thought to be unusual in most Western European languages (Ladd 1996; Mennen 2015), although it also occurs in German German. Given this difference from any other pitch accents in the bilinguals' L1, we expected that the early peak would not be identified by bilinguals as an instance of one of their already existing L1 pitch accents, and we therefore assumed that there would be no L2-on-L1 effect. To our surprise, all bilinguals in our study transferred the early peak into their L1, although they used it significantly less often than the monolingual Austrian German controls. Moreover, a comparison of the phonetic realization of early peaks by the bilingual speakers in their L1 and the early peaks produced by the monolingual Austrian German speakers in our study showed no significant differences in phonetic realization. This suggests that the early peak has been transferred fully into the L1 of the bilingual speakers.

Even so, why did the bilingual speakers transfer the early peak into their L1 in the first place? Neither the LILt nor the SLM(-r) can explain this in the current version of these models. Perhaps Markedness Theory can provide a possible explanation. The Markedness Differential Hypothesis (Eckman 1977) proposes that aspects from the L2 that are different and marked, i.e., infrequent in the world's languages, will pose more difficulties for L2 learners than aspects that are different but less marked. Conversely, "those forms that are less marked in the L2 are more likely to replace more marked forms in the L1" (Gürel 2004, p. 54). As, according to Ladd (1996) and Mennen (2015), a tonal target on a metrically weak syllable such as in the early peak (H!H*L) is unusual in West European languages, it may therefore be more marked than other pitch accents. Yet, the marked early peak is transferred to the bilinguals' L1. We therefore conclude that typological markedness cannot explain our findings.

Perhaps we need to consider the possibility that L1 attrition of intonation is just different from what is typically observed in L1 attrition at the segmental level. While we occasionally may observe full merging at the segmental level when the L2 and L1 differ in gradient aspects of their pronunciation, full assimilation of categorical differences, i.e., where the L2 is sufficiently different from any already existing L1 categories, has to our knowledge never been reported for segments. The equivalent in segmental terms would be if, for instance, an L2 Welsh learner from England started to use a lateral fricative in their English. That is not something we consider likely to happen and it therefore suggests that the process of L1 attrition of intonation is different from that of segments. A possible explanation may be that intonation is more malleable—more so than segments—because of its weaker link with orthography as compared to segments. In fact, "intonation allows for a high degree of variation in the choice and distribution of tonal categories" or their phonetic realization, due to the fact that noticeable variations may not be perceived as foreign but only lead to "a slightly different interpretation" (Jilka 2000, p. 58). This would allow bilinguals more flexibility in the use of L2 pitch accents in their L1.

It is therefore not unreasonable to assume that the bilingual speakers in our study may have transferred the early peak to fulfil a semantic or pragmatic function that is expressed in the L2 but not the L1. We found that the monolingual Austrian German speakers used the early peak *only* in questions. In fact, when inspecting the use of early peaks in the different question types (see Table 2), we see that it is used increasingly more frequently when the number of syntactic and/or lexical markers of interrogativity in the question types decreases. In questions with a question word and inversion (WHQs), i.e., where there are two lexical/syntactical markers of interrogativity, the early peak is used least often (31.3%). In questions with inversion (YNQs), which is another marker of interrogativity, the early peak is used more often (62.5%). In declarative questions (DQs), where no lexical or syntactical markers of interrogativity are present, the early peaks are most frequently used (71.9). The same is true for the bilinguals, who also use early peaks least often in WHQs (12.5%), followed by YNQs (38.5%), and use it most often in DQs (78.1%). This suggests that, just like the monolingual Austrian German speakers, the bilingual speakers may be using the early peak as a marker of interrogativity, and that its use may be constrained by the number of other (i.e., syntactic or lexical) markers of interrogativity present in an

utterance (see Haan 2002, for a similar discussion on the trade-off between prosodic and syntactic and/or lexical markers of interrogativity). It is possible that bilingual speakers may have felt the need to mark these degrees of interrogativity in their L1 due to immersion in an L2 environment. This may also explain why the frequency of occurrence of early peaks in DQs by the bilinguals is on a par with that of the monolingual Austrian speakers. We are, however, unsure what could explain the equal frequency of use of rises (L*H) in the statements and YNQs of the bilinguals and monolingual Austrian speakers. Unlike the early peak, the L*H is not used exclusively in questions. Therefore, it is not—at least not on its own—a marker of interrogativity. While it is possible that there is a specific semantic or pragmatic meaning that is associated with the use of L*H in statements and YNQs that the bilinguals have attempted to transfer to their L1, further research is needed to explore what particular meaning this is and to what extent it differs from L*H in other sentence types.

Our study highlights a few areas that are in need of further research. We deliberately did not investigate the influence of predictor variables (such as AoA, LoR, L2 proficiency, amount of L1 use, and amount of L2 use, etc.) on L2-induced influences in L1 intonation, as a full exploration of their role would require larger participant numbers and datasets than were currently available. We know virtually nothing on how L2-induced changes to prosodic aspects of L1 pronunciation (or segmental features for that matter) are related to the production of similar features in the L2, how such influences progress over time (but see Kornder and Mennen 2021) and which factors may influence their occurrence. For instance, would assimilation be more apparent in bilinguals who have only recently moved to an L2-speaking country? Can we expect more frequent use of early peaks in bilinguals with high L2 proficiency? Such questions highlight the need for controlled studies into the effect of predictor variables on L2-induced influences on L1 intonation in its various dimensions. In addition, our study investigated intonation in read speech as this gave us control (in terms of, for instance, expected stress patterns, number of pitch accents, or phonetic content) over the utterances that we intended to compare within and between languages. Intonation in read speech is, however, different from intonation in spontaneous speech (e.g., Blaauw 1994; Howell and Kadi-Hanifi 1991; Laan 1997) and future studies are necessary to investigate to what extent L2-induced influences are also found in spontaneously produced L1 intonation. Another aspect that may need further investigation is the extent to which the typological relationship between the bilinguals' L1 and L2 may influence the observed L2-induced changes in L1 pronunciation. While we do not assume that languages from different language families necessarily differ more in their respective phonological features than closely related languages (after all, we also find considerable cross-language differences in the intonation of the two Germanic languages under investigation in our study), it would be important to also examine L2-induced influences in languages with more extensive cross-language differences in intonation. In particular, it would be interesting to investigate whether more extensive cross-language differences in the systemic dimension would exert the same effect on the L1 as that observed in our study, where the categorical cross-language differences on the systemic dimension were restricted to just a single pitch accent. We assume that when bilinguals use an L2 pitch accent which does not form part of the L1 inventory (such as the early peak), this will be perceptually salient to native listeners and may contribute to them being perceived as non-native. It is possible that when more categorical intonation differences are transferred into the L1, the impression of non-nativeness may increase. However, there are no studies that directly link listener judgements of non-nativeness to specific L2-induced deviances from the L1 norm and it remains an open question whether categorical changes contribute more to the impression of non-nativeness than gradient changes or whether this impression arises from an accumulation of the various changes that may be present in a bilingual's L1.

In closing, the present study demonstrates that an individual's native language intonation system is not protected against L2 influences. In fact, the permeability of L1 intonation is not restricted to its phonetic realization as might be suggested by previous studies, but is found to occur across the board, affecting every dimension of intonation. This highlights

the need for studies that go beyond investigations of just one or two aspects of L2-induced modifications in L1 speech. Instead, studies should compare a wider range of prosodic and segmental areas of pronunciation within the same group of individuals. Such studies will provide a more holistic view of the areas of pronunciation that are susceptible to L1 attrition and those that may be less permeable.

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Institutional Review Board Statement: This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Ethics Committee of the University of Graz (protocol code GZ. 39/37/63 ex 2019/20; date of approval: 27 February 2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data are not publicly available due to ongoing data analyses and because the participants did not give permission for their data to be shared.

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Conflicts of Interest: The authors declare no conflict of interest.

Notes

1 Note that cross-language interaction in pronunciation is observed in all types of bilinguals (see for instance Amengual 2019), including simultaneous bilinguals (i.e., individuals growing up speaking both languages since birth), early sequential bilinguals (i.e., individuals brought up monolingually before attending school in the majority language when they become bilingual), and late sequential bilinguals (i.e., those individuals who become bilingual after the age of puberty). The focus of this paper is on cross-language influences in the pronunciation of late sequential bilinguals.

2 In this study, listeners were asked to indicate on which aspects of pronunciation they based their judgement of non-nativeness. The comments were classified as referring to segmental (pertaining to 64.7% of comments) or prosodic aspects of pronunciation (pertaining to 35.3% of comments), and then further divided into particular segmental (e.g., specific vowels or consonants) or prosodic features (e.g., stress, speaking rate, intonation). For prosody, intonation was mentioned most (in 22.4% of the comments), whereas rhythm/stress and speaking rate were mentioned considerably less often (in 6.9% and 6%, respectively).

3 Note that the SLM originally referred to this as a common "phonological space". However, in the SLM-r, Flege and Bohn (2021, p. 21) acknowledge "that use of this term was a misnomer" and now prefer to refer to it as "common phonetic space." This is also the term we use in the present paper.

4 The original dimensions proposed by Ladd (1996, p. 119) were meant to describe four types of dialect differences: (1) the phonetic implementation ('realizational differences'); (2) the inventory of boundary tones and pitch accents ('systemic differences'); (3) the distribution of boundary tones and pitch accents ('phonotactic differences'); and (4) functionality ('semantic differences'). Mennen (2015) adapted them to describe types of cross-language differences in intonation. Therefore, the dimensions in Mennen (2015) differ from those proposed by Ladd.

5 Some researchers (e.g., Féry 1993; Peters 2018) present this accent type not as a separate pitch accent but as a modification of the H* or H*L pitch accent which retracts the peak to a preceding syllable, and is used to express additional meaning. In their view, early peaks are not seen as part of the systemic dimension of intonation but rather belong to the realizational dimension of intonation. Other researchers (e.g., Baumann and Grice 2006; Grice and Baumann 2002; Niebuhr 2007), however, treat the early peak as a distinct pitch accent, and thus as belonging to the systemic dimension of intonation. In other words, there is disagreement as to whether the retraction of the peak results from the same phonological representation or from different phonological representations. Controversies of this kind are typically resolved by conducting perception experiments and relying on native speaker intuition in acceptability judgment tasks. Niebuhr (2007) showed that German listeners linked early peaks (H!H*L, which they represent as H+L* in their framework) to different contexts than medial peaks (H*L, which they represent as H*), showing that there is a clear meaning differentiation between these pitch accents, thus corroborating the existence of

separate categories in German intonation. We therefore adopt their interpretation of the early peak as a distinct pitch accent and treat it as belonging to the systemic dimension.

6 In languages such as English and German, nuclear prominence is typically rightmost, that is the last prosodic word in a phrase bears the nuclear accent and is therefore the most prominent within that phrase (e.g., Ladd 1996).

7 While this study was on cross-language differences in pitch range between speakers of English (SSBE) and German (Northern Standard German), it also took linguistic measures linked to pitch accents and boundary tones. Their results showed that the German speakers more often showed low pitch accents compared to the English speakers.

8 The only exception to this was for the statements where participants read out four different sentences once. This was done because the statements were also used to test the alignment of prenuclear rises, and we wanted our data to be as comparable as possible with previously reported data from studies on English and German (Atterer and Ladd 2004; de Leeuw et al. 2012; Ladd et al. 1999). The total number of sentences per sentence type, however, was the same given that there was one repetition of four sentences for the statements and two repetitions of two sentences for the other sentence types.

9 Before running ANOVAs or *t*-tests we always tested whether its requirements were met by testing the normal distribution of the data by means of a Shapiro-Wilk tests, and using Levene's Test for Homogeneity of Variance. We will not report this further, unless requirements were not met.

10 It is sometimes argued that alignment is best expressed as a proportional measure, for instance as a ratio of the accented syllable (e.g., Silverman and Pierrehumbert 1990). We therefore calculated the alignment of the start of the rise and that of the end of the rise as a proportion of the syllable duration. This did not change our results. An ANOVA with *proportional alignment of L* as dependent variable and speaker group as independent variable showed a significant effect of speaker group ($F[2,21] = 80.9$, $p < 0.001$) and post-hoc *t*-tests with Bonferroni correction showed significant differences between the monolingual SSBE and AUT ($p < 0.001$), between SSBE and BIL ($p < 0.001$), and between AUT and BIL ($p < 0.01$). For *proportional alignment of H*, no effect was found ($F[2,21] = 0.24$, n.s.).

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