

**How and when does the second language influence the production of native speech sounds: A literature review**

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**Abstract**

In bilinguals and second language learners, the native (L1) and non-native (L2) languages co-exist and interact. The L1 influences L2 production via ‘forward transfer’, as is seen with foreign accents. However, language transfer is bidirectional: even brief experience with an L2 can affect *L1* production, via ‘backward transfer’. Here, we review the growing literature on backward transfer at the phonetic level and identify various factors that modulate it. Indeed, a multitude of interrelated factors have been shown to determine the

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strength of backward transfer, including L2 related factors (age of L2 acquisition, L2 pronunciation skill and proficiency, stage of learning, immersion), L1 related factors (amount and circumstances of L1 use) and factors related to both L1 and L2 (language similarity and individual differences). Controlled longitudinal, laboratory studies are required in conjunction with naturalistic ones to tease apart the influences of these different factors on L1 speech.

**Key words:** backward transfer, L2 influence, L1 production, L1 attrition, L2 immersion

## **1. Introduction**

Learning a foreign language at all ages is highly promoted in today's society, and bilingualism is increasingly common in today's globalised world. Bilingualism research has shown exponential growth over the last 20 years (Kroll & Bialystok, 2013), and in this literature, work on how the native language (L1) influences second language (L2) in perception and production, known as 'forward transfer', is well represented. There exists less work, however, on the phenomenon of 'backward transfer' (Cook, 2003), or on how learning an L2 affects the *L1* such that it differs from monolingual norms. Indeed, although it is well established that the L1 influences the L2, for example in studies showing foreign accents in late bilinguals (Best & Tyler, 2007; Piske, MacKay, & Flege, 2001), there is growing evidence that conversely, experience with an L2 also affects different levels of L1 processing (e.g., phonetic perception: Mora & Nadeu, 2012; phonetic production: Chang, 2012, Major, 1992; the lexicon, i.e., word borrowing: Thomason, 2001; lexical and

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semantic access: Baus, Costa, & Carreiras, 2013; Lu, 2011; Bice & Kroll, 2015; morphosyntax: Wierzbicka, 1992; syntax: Wang, 2014; intonation: Andrews, 1999).

Here, we review studies on backward transfer, and attempt to outline the different factors that have been shown to influence the nature and extent of phonetic change in native speech production. To date, there exists no systematic review of this highly interesting topic. To isolate one or the other factor in terms of its relative influence on the strength of backward transfer is challenging due to the fact that under naturalistic circumstances, factors such as age of acquisition (AoA) of the L2, L2 pronunciation skill and proficiency, stage of L2 learning (i.e., in novice learners versus advanced learners), and immersion, amount and quality of L1 use are co-dependent and intertwined. Our review shows that although naturalistic studies are imperative for understanding backward transfer, controlled longitudinal laboratory studies are a necessary, complementary approach that will help to tease apart the relative contribution of the different factors.

The effects of the non-native language on the L1 can be positive (e.g., richer L1 semantics and syntax), negative (e.g., L1 loss, or attrition, L2 accent during L1 speech) or neutral (for details see Cook, 2003). Its impact on the L1 can be detected earlier or later in learning, depending on the linguistic level that is examined, with effects on higher levels being observed later (Kecskes, 2008). At lower, lexical and phonetic processing levels, the influence of the L2 on the L1 is identifiable already after a short period of immersion in an L2-speaking country. For instance, naming latencies for low-frequency L1 words are slower after four months of immersion in an L2-speaking environment (Baus et al., 2013), and this has been attributed to the less frequent use of the L1 during L2 immersion (see also Linck, Kroll, & Sunderman 2009). At the phonetic level, it has been shown that L1

speech sound production drifts toward the phonetic properties of the L2 after 5 weeks of L2 classes (Chang, 2012). Drift in L1 phonetic production has also been shown after only one hour of articulatory training with non-native sounds (Kartushina, Hervais-Adelman, Frauenfelder, Golestani, 2016), indicating that even brief experience with the L2 already changes phonetic production in the L1. In contrast to these low-level effects, higher levels of L1 processing (e.g., morphosyntactic, pragmatic ones) have been shown to be affected after longer periods of L2 exposure/experience. For instance, deviation from the word-order rules of the L1 towards those of the L2 has been noted after 16 years of immersion in an L2-speaking environment (Waas (1996) in Pavlenko, 2000). The effects of L2 experience on L1 phonetic production have been studied more extensively than those at other levels of L1 processing, and will be the focus of this paper.

### ***1.1. Language-contact phonology***

It is largely accepted in the L2 literature that in bilinguals, the L1 and L2 coexist and interact constantly. In an article entitled “The bilingual is not two monolinguals in one person”, Grosjean (1989) has argued in favour of a holistic view of bilingualism which states that two languages form a complete linguistic entity, and has argued strongly against a ‘monolingual view’ of bilingualism. Similarly, in the Speech Learning Model (SLM) which was developed to account for L1-L2 phonetic contact, Flege (1995) has claimed that “phonetic categories established in childhood for L1 sounds evolve over the lifespan to reflect the properties of all L1 or L2 phones identified as a realization of each category” (1995, p. 239). Likewise, the WEAVER++ model claims that bilinguals can have shared phonemes for the L1 and L2, but that processes such as grammatical rules determine the phonetic realization in L1 and L2 (Roelofs & Verhoef, 2006). In the Bilingual Category

Hypothesis, Flege predicts that sounds produced by bilinguals differ from monolingual norms due to bi-directional influences between languages (Flege, 1995). The SLM moreover asserts that greater experience with an L2 leads to a greater influence of the L2 on the L1 (Flege, 1995). Other researchers have also suggested that L2 learning may lead to a restructuring of a shared L1-L2 acoustic-phonetic space, leading to deviation from monolingual norms for the L1 categories (Leather & James, 1996).

Only few studies have explored the phenomenon of backward transfer on the perception of L1 speech sounds (Flege & Eefting, 1987a, 1987b; Lev-Ari & Peperkamp, 2013; Mack, 1989; Mora & Nadeu, 2012). The results of these studies are inconclusive. Whereas some show no change in the perception of L1 sounds (Flege & Eefting, 1987a), or monolingual-like performance on some perception tasks but not on others (e.g., on discrimination but not on identification, Mack, 1989), others report perceptual assimilation of L1 categories toward similar L2 ones (Flege & Eefting, 1987b; Mora & Nadeu, 2012; Lev-Ari & Peperkamp, 2013). There does not appear to be, however, a robust relationship between changes in L1 production and perception (Lev-Ari & Peperkamp, 2013). Related to the issue of production-perception interactions is whether actual speech production is required or whether auditory exposure (i.e., perception) suffices in order for L1 production to change. At least one study has shown that auditory exposure to L2 alone does not lead to a drift in L1 phonetic production, suggesting that L2 production is necessary for L1 production to change (Fowler, Sramko, Ostry, Rowland, & Hallé, 2008).

### ***1.2. Research approaches to studying L2 effects on L1***

Different measures have been used in psycholinguistics and phonetics to quantify the effects of L2 on L1 speech production. Some studies have measured production latencies (e.g., Alario, Goslin, Michel, & Laganaro, 2010; Ivanova & Costa, 2008; Linck et al., 2009; Roelofs, 2003), and others have used goodness ratings (i.e., by native speakers) and/or acoustic analysis of L1 productions. The former have served to draw conclusions about more abstract, cognitive dimensions related to language organization, lexical representation and access in bilinguals. The studies having measured production latencies suggest that bilinguals' phonological and lexical systems interact and interfere with one another constantly, leading to slower word production latencies in the L1 and L2, compared to monolingual speakers of the respective languages (Ivanova & Costa, 2008). The slower latencies are attributed to the inhibition of the dominant L1 (Linck et al., 2009). This interference appears to be stronger in late bilinguals, who have been shown to be more sensitive to the syllable frequency of L2 words when speaking their L1, presumably because of the shared underlying representations for the two languages (Alario et al., 2010; see also Roelofs, 2003).

The numerous phonetic studies that performed perceptual and acoustic analysis of L1 productions (Chang, 2012, 2013; Flege, 1987; Fowler et al., 2008; Guion, 2003; Kartushina et al., 2016; Lev-Ari & Peperkamp, 2013; MacLeod, Stoel-Gammon, & Wassink, 2009; Major, 1992; Mora, Keidel, & Flege, 2015; Mora & Nadeu, 2012; Sancier & Fowler, 1997; Sundara, Polka, & Baum, 2006) have provided a quantitative assessment of how the L2 affects L1 phonetic production. These will be the focus of this paper. Some of these studies have compared the productions of L1 and L2 sounds in bilinguals to those of monolinguals of the respective languages (Flege, 1987; Fowler et al., 2008; Guion, 2003;

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Lev-Ari & Peperkamp, 2013; Mora et al., 2015; Mora & Nadeu, 2012; Sundara et al., 2006), and others have compared L1 phonetic production between different groups of L2 speakers (e.g., in classroom settings or during immersion (Linck et al., 2009)). A few longitudinal studies also exist where L1 speech sound production was assessed in the same individuals before and after a period of immersion in an L2-speaking country (Chang, 2012, 2013; Sancier & Fowler, 1997), or before and after laboratory training with non-native sounds (Kartushina et al., 2016).

## **2. Factors affecting degree of L2 influence on L1 phonetic production**

The literature on L2 learners and bilinguals reveals that the nature and amount of change that L1 phonetic categories can undergo depend on several factors. The majority relate to the experience with the L2 per se, such as age of L2 acquisition (AoA), L2 pronunciation skill and proficiency, stage of L2 learning (novice versus advanced), and immersion in an L2-speaking country. Other factors relate to the L1 itself, such as the amount and circumstances of L1 use, and the speech register of L1 use (casual versus formal). Last, there are factors related to both the L1 and L2, including the similarity between L1 and L2 phonemes and also words (i.e., cognates), and more general factors related to individual differences. These various factors, and especially the AoA, L2 pronunciation skill and proficiency, stage of L2 learning and immersion, along with the amount of L1 use are generally tightly intertwined under naturalistic learning circumstances. To our knowledge, few, if any studies, have attempted to isolate one or the other factor in studying L2 influences on L1 phonetic production. Despite this difficulty of isolating the role of specific factors, we believe that a descriptive, qualitative overview of the different factors is useful in order to better understand the nature of L2 effects on L1,

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and the factors that trigger them. Table 1 in the Appendix provides a summary of the different studies that have examined backward transfer in the domain of phonetic production, using perceptual and acoustic analyses of L1 productions.

## **2.1. L2-related factors**

### ***2.1.1. Age of L2 acquisition (AoA)***

It is well established that for L2 pronunciation, ‘earlier is better’; simultaneous (i.e., speakers who acquired their L1 and L2 at the same time) or very early bilinguals are perceived as not having an accent in their L2 by native speakers (Flege, 1999). Studies that have assessed L1 phonetic production in bilinguals suggest that the same applies to the L1. Simultaneous bilinguals who have continued to systematically use both languages produce both L1 and L2 speech in a manner that does not differ phonetically from the speech of monolingual speakers of the respective languages (Guion, 2003; MacLeod et al., 2009; Sundara et al., 2006; see, however, Fowler et al., 2008 for contradictory results). For instance, simultaneous French-English bilinguals produce the French /t/ and English /t<sup>h</sup>/ tokens with VOTs (i.e., Voice Onset Time) that are like those of monolingual speakers of these languages (Sundara et al., 2006). Importantly, simultaneous bilinguals produce similar cross-language sounds distinctly (Fowler et al., 2008; Guion, 2003). Similar results have also been reported in very early bilinguals<sup>1</sup> who acquired their L2 before the age of three (Barlow, Branson, & Nip 2013) and who grew up in bilingual communities (e.g., French-English communities of Canada, see MacLeod et al., 2009). Another study has also shown that very early bilinguals (mean AoA of 2.4 years) do not show altered L1 production, and that only later bilinguals (mean AoA of 8.3) apply the phonological rules



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of the L2 when speaking their L1 (Barlow, 2014). Consistent with the above, the results of the studies having measured production latencies support the idea that simultaneous and very early bilinguals have separate representations for the L1 and L2. Early bilinguals are not sensitive to the syllable frequency of the L2 when speaking their L1, whereas late bilinguals are (Alario et al., 2010; Roelofs, 2003).

The above studies suggest that very early experience with two phonological systems allows bilinguals to partition their acoustic-phonetic space so as to be able to (1) accommodate the phonetic categories of both their languages, (2) keep these categories separate and (3) produce them in a monolingual-like fashion in both languages (see Fig.1 for a schematic representation of L1 and L2 sounds in monolinguals compared to simultaneous and very early bilinguals).

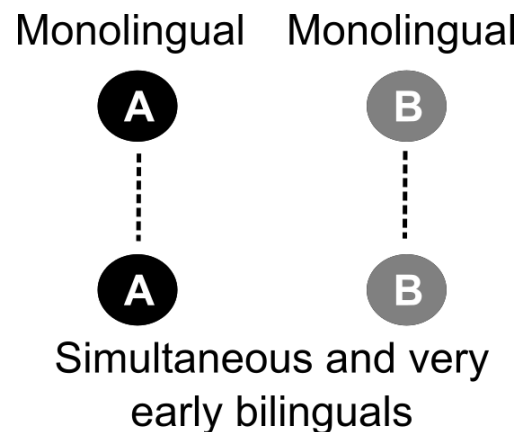


Fig. 1: Comparison of phonetic productions of monolinguals in two different languages (A and B) with those of simultaneous or of very early bilinguals (AoA below three) in these two languages: L1 and L2 categories of bilinguals are similar to monolingual productions. Note that for this and for the following figures, the black circles refer to one particular

speech sound in one language (A) and the grey ones refers to a similar speech sound in the other language (B).

In contrast to simultaneous and very early bilinguals, later L2 acquisition can lead to a reorganisation of the L1 phonetic space. Early Quichua-Spanish bilinguals having learnt Spanish between the ages of 5 and 7, for example, showed a change in their production of the L1 Quichua /ɪ/ vowel: they tended to produce it using a higher tongue position (lower first formant, F1) than monolingual Quichua speakers (Guion, 2003). This change relative to L1 norms was attributed to (1) the need to enhance the difference between the Quichua /ɪ/ and the Spanish /e/ vowels (i.e., deflection from one non-native phoneme), and (2) assimilation of the Quichua /ɪ/ vowel to the more raised (higher) Spanish /i/ vowel (i.e., drift toward another non-native phoneme). Similarly, deflection of L1 categories from monolingual norms (and from L2 categories) has been reported in early Spanish speakers of English (AoA between 5 and 6 years): these individuals produced the Spanish /p/, /t/ and /k/ consonants with shorter VOTs (average value = 18 ms) than monolingual Spanish speakers (average value = 26 ms) (Flege & Eefting, 1987b). This shortening of the Spanish voiceless consonants was attributed to the need to increase the phonetic contrast with the English /p/, /t/ and /k/ consonants, which have long VOTs (average value = 87 ms). Analogous phonetic deflection has been reported for L2 categories: early Italian-English bilinguals produced the English /e<sup>1</sup>/ vowel with a longer duration as compared to L1 monolingual speakers of English (Flege, Schirru, & MacKay, 2003). See Fig. 2 for a schematic representation of L1 and L2 sounds in early bilinguals. Another study, however, has shown that when the L2 is learnt somewhat later, around the age of eight, the nature of L1 drift is assimilatory; although there was no overall drift in the

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L1 sounds, participants used L2 phonological rules to produce L1 speech sounds, e.g., the L1 Spanish /l/ in Spanish-English bilinguals varied in darkness depending on the context, as occurs in English (Barlow, 2014). The results of these studies suggest that early bilinguals have a tendency to deflect L1 and L2 categories away from each other when a novel category is created for similar L2 sounds, but that when the L2 is learnt somewhat later the influences can be of an assimilatory nature

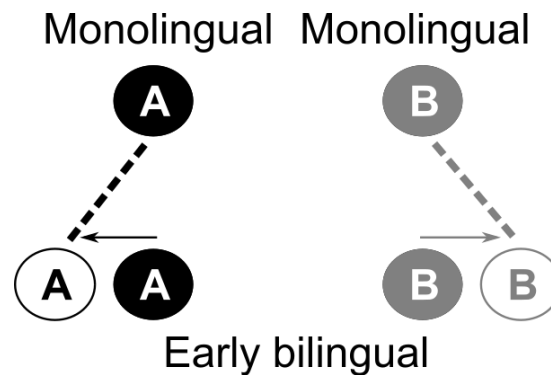


Fig. 2: Comparison of the phonetic productions of monolinguals in two different languages (A and B) with those of early bilinguals (AoA between three and seven): bilinguals' A and B categories (filled circles) deflect away from one another and from L1 norms, in order to form new categories (represented by unfilled circles).

Late bilinguals (AoA above the age of eight) tend to merge similar cross-language sounds into one category, which is used to produce both the L1 and L2 sounds (Flege, 1987; Flege & Eefting, 1987a; Flege et al., 2003; Guion, 2003). This has been attributed to perceptual assimilation (or to 'equivalence classification'), whereby new L2 categories fail to be formed (cf. SLM in Flege, 1995). The production of L1 categories seems to be unaffected, i.e., the L1 categories remain unchanged. In late Quichua-Spanish bilinguals

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having learnt Spanish between the ages of 15 and 25 for example, the Quichua /i/ and the Spanish /i/ and /e/ vowels are not produced distinctly; individuals use the Quichua /i/ category to produce the two similar Spanish vowels (Guion, 2003; see Flege et al., 2003 for similar results in late Italian-English bilinguals). Other studies, however, have shown that the L2 can still influence L1 production if it is learnt between the ages of 14 and 22, but not if it is learnt at a later age (De Leeuw, Schmid, & Mennen, 2007, 2010). In very late bilinguals (i.e., AoA after about 20), L1 pronunciation appears to no longer be modulated by AoA, but instead other factors such as the quantity and quality of L1 use predict L1 production authenticity (see section on L1-related factors for more on these factors) (De Leeuw et al., 2010). See Fig. 3 for a schematic representation of L1 and L2 sounds in late bilinguals.

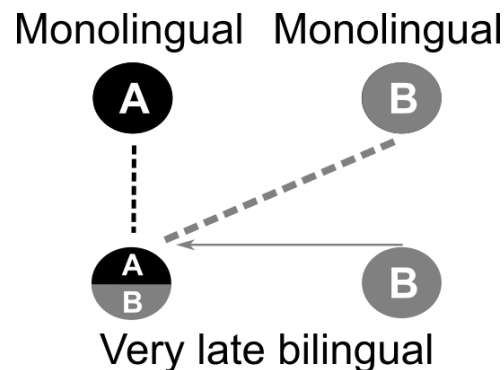


Fig. 3: Comparison of phonetic productions of monolinguals in two different languages (A and B) with that of a very late bilingual (AoA between 15-25): L2 sounds (B) are assimilated, in production, to similar L1 ones (A), i.e., one category is used to produce both L1 sounds and similar L2 sounds.

In sum, the literature on how AoA modulates the ways in which L2 learning can affect L1 pronunciation appears to show that when early bilinguals are successful at

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creating new categories for L2 sounds, similar L1 categories tend to deflect away from or to drift towards these new L2 sounds. This shows that the phonetic productions of early bilinguals, even those in their L1 differ from those of monolinguals. The exception to this appears to be when the two languages are acquired simultaneously or very early; here bilinguals define the speech categories for both languages in a monolingual-like fashion, with no drift in L1 speech sound categories (Guion, 2003; Barlow, 2014). In contrast, very late bilinguals are more likely to perceptually assimilate similar L2 sounds to existing L1 categories, in line with the SLM (Flege, 1995). Perceptual assimilation blocks L2 category formation, consequently, late bilinguals tend to use L1 phonetic categories (e.g., Guion, 2003) to produce similar L2 sounds.

### ***2.1.2. L2 pronunciation skill and proficiency***

The effect of L2 proficiency on L2 and L1 speech production has been extensively studied. Some studies use the term proficiency to refer to the ability to speak the L2 without an accent, whereas others use it to refer to overall L2 language ability, generally determined by the amount of exposure and experience with the L2. Unless otherwise specified, the papers reviewed below use proficiency to refer to L2 pronunciation skill. Although it is likely that speakers who have acquired their L2 earlier are more proficient in L2, these two factors (i.e., AoA and L2 proficiency) are not always highly related: certain speakers with little L2 experience can still produce L2 sounds in a native-like manner (Flege & Schmidt, 1995).

L2 proficiency has been shown to affect the degree to which L1 speech is L2-accented. Specifically, it appears that when L2 is not proficient, L1 speech production is

not modified and remains close to monolingual norms. For example, a study on English-French bilinguals who were not good at pronouncing speech in their L2 (according to ratings by native French speakers) showed that the English /d-/t/ and /i-/ɪ/ sounds were produced according to monolingual English norms (Mack, 1989). Inversely, as noted in the section on AoA, proficient L2 speakers show deflections of L1 categories away from similar L2 ones (Flege & Eefting, 1987a, 1987b; Guion, 2003). For instance, Flege and Eefting (1987a) assessed the production of the Dutch and English /t/ stops in Dutch speakers of English in the Netherlands. The results revealed that only those L2 speakers whose English production was judged as being the most native-like by native English speakers showed a deflection in the production of the Dutch category away from the English one. The L1 Dutch VOT had become shorter (17 ms) than the prototypical Dutch one (23 ms), which is itself shorter than the English /t/ VOT counterpart (90 ms).

Other studies have shown that bilinguals with good L2 pronunciation show a drift of L1 phonetic categories *toward* similar L2 ones (Major, 1992). For instance, native American-English speakers having moved to Brazil and having lived there for 12-37 years showed a drift in the production of the English /t<sup>h</sup>/ toward the similar Portuguese /t/ consonant (Major, 1992). The amount of drift depended on how well they produced speech in Portuguese; the better they mastered Portuguese (i.e., with VOTs closer to those of native speakers), the more Portuguese-like their English productions were. Consistent with the above, several studies having examined L2 proficiency more generally, as indexed by the amount of experience and skill with the L2, have also shown that in proficient bilinguals who use L2 dominantly, there is drift of native phonetic categories *toward* similar L2 ones (Flege, 1987; Mora et al., 2015).

Together these studies show that the level of L2 pronunciation skill and overall L2 ability affect the extent of L2-accentedness during L1 production. L2 speakers who are highly experienced with the L2 and who use it dominantly tend to show a drift in their L1 categories toward similar L2 ones, but other studies show that in good L2 speakers there is deflection of the L1 and L2 sounds away from one another relative to monolingual norms. It remains to be elucidated why in some cases there is deflection of L1 sounds away from newly acquired L2 ones, whereas in other cases the L1 sounds drift towards the L2 ones. It is possible that in those proficient L2 speakers who are immersed in the L2 environment, the L2 serves as a ‘magnet’ which attracts L1 phonetic production (e.g., as in the study by Major, 1992), whereas that in individuals who are not immersed in the L2 environment (e.g., as in the study by Flege & Eefting, 1987a), L1 phonetic production is deflected away from L2 sounds as a means of keeping the two phonetic repertoires distinct. Immersion is very often associated with L2 dominance, and with more code-mixing (i.e., language-mixing), factors which together favour the assimilation, in production, of the L1 towards the L2 (see below for more on these factors). Carefully designed studies are needed to explore these ideas.

### ***2.1.3. Novice learners and limited exposure***

As we have seen above in the section on L2 pronunciation skill and proficiency, advanced L2 speakers (i.e., proficient ones who produce L2 accurately) can show deflection of L1 sounds away from or drift of L1 sounds towards L2 ones, and it has been found that people who are relatively more proficient in their L2 show relatively more change in their L1 production (Flege, 1987). However, even novice L2 speakers can show drift of L1 towards L2 sounds (e.g., see Sancier & Fowler, 1997, for case study following

4-months of immersion in the L2-speaking environment). Several recent longitudinal studies have shown that drift of L1 sounds can occur even in individuals who have had even less experience with L2 (Chang, 2012, Kartushina et al., 2016). For example, Chang (2012) tested native American-English (AE) speakers who were taking a Korean language course in Korea on their production of English sounds longitudinally, with repeated testing over the 5 week course. The participants were naïve about the Korean language before this course. It was found that the production of L1 sounds drifted towards the phonetic properties of newly learnt, Korean sounds (Chang, 2012). Chang speculated that this surprising result in novice learners arose from a novelty effect whereby the L2 is encoded robustly because it constitutes a novel and perceptually salient experience. In a follow-up study, Chang (2013) compared this L1 production data in the novice learners to that of experienced Korean learners who were also enrolled in the same 5 week Korean language course but who had previous experience with Korean (some of them were heritage speakers, and all of them had previously studied the language and/or had previously stayed in Korea for extended amounts of time). This second study showed that, as predicted by the novelty effect account, the novice learners showed more phonetic drift in their production of L1 consonants and vowels than the experienced learners (Chang, 2013).

A longitudinal laboratory training study has shown that drift in L1 phonetic production can occur in novice learners even after only one hour of production training with non-native vowels (Kartushina et al., 2016). Native French speakers were trained to produce the Russian /i/ and the Danish /ɔ/ vowels over the course of 3 days, for a total of one hour of training per vowel. Training involved providing trial-by-trial visual feedback regarding the acoustic properties (i.e., F0, F1 and F2) of the produced sounds, along with



information about the acoustic properties of the target vowel. The production of the French /ø/, /y/, /i/ and /o/ vowels, which are acoustically similar to the non-native ones, was assessed before and after training. It was found that after training, there was drift in the production of the acoustically closest French /ø/ vowel and a trend for such drift in the next closest French /y/ vowel towards the Russian /i/ vowel. There was no drift for the French /i/ which was the least close to the Russian vowel. There was no drift of the French /o/ towards the trained Danish vowel, most likely because these vowels overlapped acoustically. There was also evidence, however, for highly correlated training-related changes in F1 and F2 between the trained Danish vowel and the similar French one, suggesting training-related drift of the two vowels in the same direction within participants (Kartushina et al., 2016). This study shows that very brief training with non-native speech sounds can result in a drift in the production of acoustically similar L1 sounds, with relatively greater drift for vowels that are acoustically the closest to, but not overlapping with, the trained vowels.

These findings and those by Chang (2012, 2013) appear to be at odds with those described in the section on L2 pronunciation skill and proficiency which show that L2 influence on the L1 is more pronounced at advanced levels of L2 experience/proficiency. This discrepancy can be attributed mainly to two facts. First, the novelty bias in novice learners compared to experienced speakers (see above), and, second, absence of L1 attrition in experienced speakers in Chang's (2013) study. It is likely that highly proficient bilinguals, reported in the section on L2 pronunciation, experienced L1 attrition due to their dominance in L2; leading therefore to greater changes in L1. This interpretation is consistent with the findings reviewed below (see sections on immersion and on the amount

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of L1 use) showing that speech sound production in both the L1 and L2 is sensitive to the relative use of these languages, and that L1 phonetic drift is more likely to take place when the L1 is used less often, that is in an L2-dominant context (e.g., immersion). Taken together, the findings on the stage of L2 learning suggest that (1) drift may be greatest at the very onset of L2 learning, partly due to novelty effects, demonstrating that the L1 is a dynamic and plastic system susceptible to very limited experience with an L2, that (2) at somewhat later stages of L2 learning the amount of drift in L1 categories diminishes, but that (3) during the later stages of L2 mastery, which is often concordant with L1 attrition, L1 categories once again drift towards or away from the L2 ones which have now become the dominant and most frequently used ones. Evidence for rapid L1 phonetic drift has recently been obtained in perception: brief exposure to L2 sounds results in a shift in L1 category boundaries in novice learners (Tice & Woodley, 2012), demonstrating that L2 learning can change L1 phonetic processing not just in production but also in perception. More generally these results are in line with the novelty bias phenomenon observed in the domain of general cognition (for more details see Chang, 2013).

#### ***2.1.4. Immersion in an L2-speaking environment***

Immersion in an L2-speaking environment has also been shown to affect the production of L1 speech sounds, even in late L2 speakers. As described in the previous sections on ‘novice learners and limited exposure’ and on ‘L2 pronunciation skill and proficiency’, speakers who are immersed in an L2-speaking country show a drift in their production of native sounds toward L2 ones, as reported by accent ratings and acoustic analyses (Chang, 2012, 2013; Flege, 1987; Major, 1992; Sancier & Fowler, 1997). For instance, a case study has reported that after a 4-month stay in the US, the productions of

a native Brazilian Portuguese speaker were perceived by native Portuguese listeners as being AE accented (Sancier & Fowler, 1997). Acoustic analysis of the Portuguese productions confirmed this: the VOTs of the /p/ and /t/ consonants had become 6 and 5 ms longer, respectively, approaching those of the AE /p<sup>h</sup>/ and /t<sup>h</sup>/. Similarly, in a different study, native AE adult speakers who had been living in Brazil for 12-35 years since the ages of 22-36 shortened their VOTs when producing /p<sup>h</sup>/, /t<sup>h</sup>/ and /k<sup>h</sup>/ stops in their L1 (Major, 1992). As seen in the section on novice learners and limited exposure, shorter periods of stay (i.e., 5 weeks) in an L2-speaking country can also change native speech sound production (Chang, 2012).

Prolonged stays in an L2-speaking country have not only been shown to result in a drift of L1 towards L2 speech sounds but in some cases to a merging of both L1 and L2 categories into one intermediate category (Flege, 1987; Major, 1992; Mayr, Price, & Mennen, 2012). For example, in native French speakers living in Chicago, analysis of the VOTs of the French (short-lag) /t/ and of the English (long-lag) /t<sup>h</sup>/ word-initial stop consonants from English and French words revealed that the VOTs of these two similar cross-language consonants were not representative of the prototypical /t/ sound of either language. Instead, they were very similar for the two languages (51 and 49 ms for French and English, respectively), with longer (i.e., more English-like) values in French, and with shorter (i.e., more French-like) values in English compared to the respective monolingual norms (French norm = 33 ms and English norm = 77 ms) (Flege, 1987).

As noted in the section on novice learners and limited exposure, it is difficult to tease apart the effects of immersion from those of other factors such as the frequency of L1 and L2 use since, a priori, L2 speakers generally use their L2 more and their L1 less

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when they are immersed in an L2-speaking country. Despite this, at least one study has shown that immersion with continued L1 use can still affect L1 production (Chang, 2012, see previous section). Also, in another study (see section on AoA above), an attempt was made to dissociate the effects of AoA and immersion, and it was found that when the period of immersion is very long (e.g., on average 37 years), factors such as the quality and quantity of L1 use are better determinants of whether L1 production is accented than is the amount of immersion (De Leeuw et al., 2010). In sum, it appears that well-established, native phonetic categories are sensitive to the linguistic environment and that they may change following immersion in an L2-speaking environment, but factors such as the quality and quantity of L1 and of L2 use, and L2 proficiency/experience also play a role.

## **2.2. L1-related factors**

### ***2.2.1 The amount and circumstances of L1 use***

It is well-known that the amount of L1 use affects L2 production: early and late bilingual speakers who use the L1 more frequently produce L2 speech in a more L1-accented manner (Flege, 1987; Flege, Bohn, & Jang, 1997; Guion, Flege, & Loftin, 2000; Piske et al., 2001). It has been hypothesized that: “a certain threshold of L1 use must be reached before a measurable influence on the L2 is noted. After this threshold is reached, the greater the L1 use, the greater the influence on L2 production” (Guion et al., 2000, p. 40). Interestingly, the amount of L1 use has also been shown to affect the extent to which speaking a second language influences *native* speech production in bilinguals (De Leeuw et al., 2010; Mora et al., 2015; Mora & Nadeu, 2012). In early bilinguals, the production of L1 speech sounds appear to drift toward similar L2 categories if the L1 is used less

frequently than the L2 (Mora et al., 2015; Mora & Nadeu, 2012). For instance, early Catalan-Spanish bilinguals who had been using their native Catalan less frequently than Spanish showed a drift in their production of the Catalan /ɛ/ vowel toward the similar Spanish /e/ vowel (Mora et al., 2015). Another study, however, did not find evidence for drift in L1 sounds towards L2 ones in early bilinguals who used the L1 less (Guion et al., 2000), but in this particular study certain methodological and circumstantial factors might account for the non-findings<sup>2</sup>. As noted in the section on immersion, drift of L1 towards L2 sounds can also occur in late bilinguals after prolonged immersion (e.g., on average 12 years) in an L2 speaking country, where the L1 is no longer dominantly used (Flege, 1987). As also noted in the section on immersion, two studies have examined the contribution of several factors in determining the degree of accent in the *native* language in people who had been immersed in the L2-speaking environment for a long time (an average of 37 years) (de Leeuw et al., 2007; de Leeuw et al., 2010). It was found that the quality and quantity of L1 use influenced the degree of foreign accent in L1 speech more than did the AoA and length of residence (De Leeuw et al., 2007). Additional analyses also revealed that speakers who used their L1 in language contexts in which little L1-L2 language-mixing occurred were perceived by native Dutch speakers as having less of a foreign accent when speaking Dutch (De Leeuw et al., 2010). In other words, not only the quantity but also the quality, or circumstances of L1 use predicts the accentedness of L1 productions.

Other work related to the quality, or circumstances of L1 use has shown that language-mixing (sometimes referred to as ‘language-switching’ or as ‘code-mixing’) affects L2 but not L1 phonetic production. Anoniou and colleagues have shown that very early bilinguals produce sounds from their L1 and from their L2 in a monolingual-like way

(Antoniou, Best, Tyler, & Kroos, 2010) unless language-switching occurs (Antoniou, Best, Tyler, & Kroos, 2011). During language-switching, the L2 sounds were affected (i.e., they were produced with more L1-like VOTs) even though these participants were L2-dominant, but L1 sounds were not affected (Antoniou et al., 2011). Similar results have been reported in early bilinguals (mean age of acquisition 6.8): during a language-switching task, L2 productions were more accented (especially when producing cognates) but L1 production did not change (Goldrick, Runnqvist, & Costa, 2014).

It appears, however, that L1 speech can be affected even in simultaneous bilinguals if the L1 speech they were exposed to during early childhood was inconsistent or if it was accented (Bosch & Ramon-Casas, 2011). A recent study has shown that the speech of Catalan-Spanish bilinguals who learnt both languages simultaneously produced the Catalan /e/-/ɛ/ vowels more variably and less accurately (i.e., more mispronunciations: producing /e/ in words involving the /ɛ/ vowel, and vice versa) than those who were raised monolingually in Catalan during their first year of life. These results were attributed to inconsistent phonetic input during early childhood in the simultaneous bilinguals since these individuals were exposed to the Catalan /e/-/ɛ/ pronounced by bilingual Spanish-Catalan parents whose Catalan was spoken with a Spanish-accent (here, Spanish-like Catalan /ɛ/ vowel).

Together, the results of the studies in this section indicate that L1 and L2 speech sounds are sensitive to the amount and circumstances of use of the respective languages in bilinguals. Regardless of the order in which languages are acquired, the frequency of language use (either L1 or L2) promotes or compromises the production authenticity in

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both languages, with relatively less use of the L1 (which comes hand in hand with L2-dominance) resulting in a greater influence of the L2 on L1 production.

### ***2.2.2. Speech register of L1 use (casual versus formal)***

Bilingual speakers' production of non-native sounds has been shown to vary across different language tasks. Those tasks that require relatively greater attention to speech (i.e., elicited speech, as for example in word reading tasks) are performed better in terms of L2 speech production accuracy than those that require less self-monitoring (i.e., spontaneous speech) (Dickerson & Dickerson, 1977; Sato, 1985; see Tarone, 1983 for more details on different L2 speech styles). For example, it has been shown that Japanese individuals produced the English /r/ consonant with almost 100% accuracy in a word reading task but with only 50% accuracy during conversation (Dickerson & Dickerson, 1977).

Similarly, sensitivity to variations in speech style has been reported for L1 speech production in bilinguals (Major, 1992). AE speakers living in Brazil for 12-35 years showed drift in their production of the L1 /p/, /t/ and /k/ stops toward Portuguese stops, and this drift was larger in casual speech (i.e., conversation) than in formal, elicited speech (i.e., word reading). Moreover, there was a correlation between the amount of L1 drift and L2 proficiency in casual but not in formal speech, suggesting that proficient speakers might suppress the influence of the L2 in formal but not in casual speech. These findings suggest that the L2 system affects L1 more in less monitored contexts, when its interfering influence is not easily suppressed. Moreover, they indicate that the authenticity of L1 phonetic production is lost first in casual speech, and then in formal speech, if at all. The

robustness of the latter speech style may be due to less L1-L2 contact in formal speech contexts. Other studies, however, did not show differences in L1 production during sentence reading and during free conversation (Lev-Ari & Peperkamp, 2013; see also Flege, 1987). The discrepancies between the results of the studies might be explained by the differences in the speakers that were tested. The participants in Major's study were all English teachers at an English language Institute in Brazil, whereas those in the Lev-Ari and Peperkamp study were English-French bilinguals residing in France. The former most likely strived to maintain their formal speech as authentic as possible since it was their 'working tool'.

### **2.3. Factors related to both L1 and L2**

#### ***2.3.1. Phonetic and lexico-phonetic similarity between L1 and L2***

The similarity between languages seems to be an important factor that modulates the degree of L2 influence on L1. However, to our knowledge, no study to date has specifically tested the impact of different second languages on the same L1. One study explored the strength of accent in two groups of native German speakers after a long period of immersion in Anglophone Canada or the Dutch Netherlands (De Leeuw et al., 2010). German is considered to be linguistically more similar to Dutch than to English. There was, however, no significant difference in the strength of the accents between the groups, suggesting that the linguistic similarity between the L2 and L1 does not modulate the amount of influence of the L2 on L1 phonetic production. Other studies have shown that the impact of the L2 is stronger on cognates (i.e., on L1 words that are similar in two languages) than on non-cognates. This has been shown for languages that are linguistically



similar such as Spanish and Catalan (Mora & Nadeu, 2012), but also for languages that are linguistically different such as English and Spanish (Amengual, 2012; Brown & Amengual, 2015). For instance, Spanish-English bilinguals produced a more English-like Spanish /t/ (i.e., with longer VOT) in the context of cognate words compared to those produced in the context of non-cognates (Amengual, 2012). These results show that those L1 words that are similar to L2 ones are more susceptible to L2 influences, and suggest that L2 influences on L1 production will be more common for language combinations that have more cognates. But again, no study has explicitly examined this question with respect to L1 phonetic production by comparing different language combinations.

Other learning studies have shown phonetic drift in the production of L1 sounds even for linguistically dissimilar languages and in contexts that are independent of lexical similarity. For example, as noted in the section on stage of L2 learning, it has been shown that native American-English speakers, after 5 weeks of learning Korean, changed their production of English vowels and consonants such that they became acoustically closer to similar Korean L2 sounds (Chang, 2012). Also as seen in the section novice learners and limited exposure, a laboratory phonetic training study has shown that drift in the production of L1 categories toward similar non-native sounds can occur in an absence of lexical context, i.e., when only isolated sounds are learnt. This study showed that after training with the Russian /i/ vowel, French speakers showed a larger drift toward this trained vowel during the production of French vowels that were acoustically similar to the Russian /i/ (Kartushina et al., 2016).

Together, the results of the above studies suggest that inter-language influences are modulated by language similarity at different linguistic levels, with greater similarity at

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acoustic and at lexico-phonological levels resulting in greater influences of the L2 on the L1. The latter results suggest that the predictions of the SLM regarding greater cross-language influence between similar than dissimilar sounds (Flege, 1995) extend beyond the phonetic level to the lexical level. More research is needed, however, to specifically test how inter-language similarity at different linguistic levels (e.g., phonetic, lexical, grammatical, prosodic) modulates the amount of L2 influence on L1 speech.

### ***2.3.2. Factors related to individual differences***

Previous research on L2 acquisition has shown that individual differences in perceptual abilities (Perrachione, Lee, Ha, & Wong, 2011), in empathy levels (Hu, Ackermann, Martin, Erb, Winkler, & Reiterer, 2013), in sensori-motor control (Simmonds, Wise, Dhanjal, & Leech, 2011), in motivation (Bongaerts, van Summeren, Planken, & Schils, 1997) and in the compactness (i.e., inverse of variability) of native phonetic production (Kartushina & Frauenfelder, 2013; Kartushina, Hervais-Adelman, Frauenfelder, & Golestani, 2015) can help explain individual differences in the acquisition of L2 sounds. Some recent studies on the effects of the L2 on L1 production have also shown that the amount of change in L1 varies greatly across speakers (e.g., native-like production in both the L1 and L2 for some L2 learners (e.g., de Leeuw, Mennen, Scobbie, 2012; Major, 1992)). Taken together these studies point to large inter-individual variation with respect not only to L2 learning, but also to L2 effects on L1.

A lab training study described above revealed a relationship between individual differences in the production of L1 speech sounds and the amount of drift that these sounds undergo after brief training with non-native sounds (Kartushina et al., 2016). Specifically,

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after training, the amount of drift for the L1, French /ø/ vowel towards the newly learnt non-native Russian /i/ vowel was greater for individuals who were more variable in their production of the L1 vowel before training. This suggests that speakers with more robust L1 category representations are less susceptible to L2 influences.

There also exist relationships between the amount of L1 drift and individual differences in more domain-general skills; in late English-French bilinguals, it has been found that individuals with low inhibitory control as measured by a retrieval-induced-inhibition task show greater drift in their production of the English voiceless /k/, t/, and /p/ stops towards French-like VOTs than individuals with high inhibitory control (Lev-Ari & Peperkamp, 2013). The authors interpreted these results as suggesting that individuals with high inhibitory skill activate language-specific items whereas individuals with low inhibitory skill are more likely to co-activate both languages, leading to stronger influences of the L2 onto the L1. Interestingly, there was also evidence that in individuals with more L2 exposure, the level of inhibitory skill played a relatively greater role in explaining influences of the L2 onto the L1. More research is needed to explore the role of individual differences in linguistic and non-linguistic domains and how these modulate the nature and circumstances of L1 drift.

### **3. Directions for future research**

The studies that have been described in this paper demonstrate that the L1 phonetic system is dynamic and plastic, and that it can be modified following both short and longer amounts of experience and learning with a second language. These studies generally are consistent with SLM predictions regarding the presence of inter-language phonetic

influences in bilinguals. This model does not, however, fully account for the results of recent studies showing that under certain circumstances (e.g., when the two languages are learnt simultaneously), bilinguals' speech does not differ from monolinguals' norms. Further, it is apparent that factors well beyond phonetic similarity, such as lexical similarity (e.g. cognates) and factors related to individual differences more generally modulate cross-language phonetic influences.

Future research on the changes that the L1 can undergo as a function of language (e.g., bilingual/L2) learning and experience could go in at least two different directions. First, it could explore L1 phonology as a system, composed of segmental and supra-segmental components, in line with the idea that cross-language influences are modulated by language similarity beyond the phonetics of individual speech sounds. Indeed, recent studies suggest that the changes that the L1 system undergoes are systemic (Chang, 2012, 2013), with cross-language interactions operating at a system-wide level rather than at the level of individual sounds (Mayr et al., 2012). Secondly, our understanding of cross-language influences would benefit from more careful exploration of additional acoustic characteristics of speech sounds. For instance, studies examining the plasticity of L1 phonetic categories should test not only for change in the mean values of the relevant formants (e.g., F1 and F2), but should also examine possible changes in the distribution, or in the intra-individual compactness of vowel tokens in the acoustic space. Recent findings have shown that training naïve participants in the production of non-native speech sounds improves not only the accuracy of production but also its compactness (i.e. increases the stability, or reliability) (Kartushina et al., 2015). Further findings have shown that the compactness of *L1* speech sound production partly predicts how well non-native speech

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sounds are perceived (Kartushina & Frauenfelder, 2013) and produced (Kartushina & Frauenfelder, 2014). Future studies could explore whether changes in the compactness of the L1 categories occurs in order to allow more ‘space’ for the accommodation of the newly learnt sounds in the phonetic repertory.

Other future research avenues include exploration of the temporal dynamics of cross-language phonetic influences. Careful longitudinal studies could track the long-term evolution of L1 categories from when individuals are novice learners through to when they are proficient bilinguals. Such an approach would help to distinguish the very rapid changes in L1 phonology which may arise from novelty and/or recency effects from the changes that have typically been observed following longer-term, cumulative L2 experience. Another important issue to be addressed relates to whether the changes to L1 categories during and following L2 learning are stable. In particular, it would be important to determine what happens when L2 learning and use ceases: do L1 categories regain their L1 (monolingual-like) characteristics, or do the modified L1 categories retain their new features?

Finally, as mentioned above, factors such as the AoA, proficiency, stage of learning, immersion and amount and quality of L1 and L2 use are usually inter-dependent in naturalistic studies (see Table 1 in the Annex) and rarely controlled. Carefully designed experiments in which one of these factors is manipulated while the others are controlled as well as possible (e.g., by comparing early and late learners having the same proficiency levels, etc.) are required. In addition to such tightly matched samples, well-controlled longitudinal laboratory or classroom studies will make it possible to track L2-L1

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interactions over time and to better understand the relative contributions of these factors to cross-language influences in bilinguals.

#### **4. Conclusions**

It is well established that second language phonetic production (i.e., pronunciation, or accent) is influenced by the L1. The growing literature reviewed in this paper demonstrates that similarly, *L1* phonetic production (or accent) can change following the learning of a second language. The presence, extent and nature of this L1 phonetic modification is largely determined by factors such as the age of L2 acquisition, proficiency, stage of learning, immersion, and by amount and quality of L1 and L2 use (which in turn, are related to L1 attrition). Furthermore, drift can be observed both following short amounts of speech sound training or following the longer-term learning and consolidation of a second language. In sum, the literature shows that both L1 and L2 are plastic and susceptible to change at any age. It is interesting to note that (1) the factors that modulate the degree of influence of L2 on L1 are mostly the same as those that modulate the influence of L1 on L2 (e.g., Piske et al., 2001), and that (2) the influence of the L1 on the L2 is stronger than reverse. Our review also shows that the ways in which specific factors modulate the influence of L2 on L1 are not necessarily linear as a function of time, which might explain some of the apparent inconsistencies in the literature. The bidirectional influence of L1 and L2 is in line with language-contact phonology models in which the two languages coexist and interact in bilinguals at a system-wide level. Further research is needed to better elucidate the mechanisms and temporal dynamics of these bilingual phonetic interactions using controlled laboratory studies.

<sup>1</sup> Here we use the term ‘very early bilingual’ to refer to people who learned their L2 before the age of three, ‘early bilingual’ to those who learned their L2 before the age of seven, and ‘late bilingual’ to those who learned their L2 after the age of eight.

<sup>2</sup> Three reasons could account for the discrepancies between the results in Quichua-Spanish bilinguals and those obtained in the studies reported above. First, in order to assess L1 production, Guion and colleagues used a sentence repetition task. The use of this task is likely “to circumvent lexical processing... and thus might not fully engage the speakers’ linguistic system” (MacLeod et al., 2009, p. 376). Second, in the study by Guion and colleagues, the produced sentences were assessed for the degree of accentedness by near-monolingual native Quichua speakers, whereas in the above-described studies, more objective, acoustic analyses of specific L1 sounds were performed. The latter analyses are more sensitive in terms of capturing fine acoustic differences in the production of similar cross-language sounds, ones that might not be perceived by L1 speakers in the context of a sentence listening task. Last, as mentioned by the authors, it is possible that in the Quichua-Spanish study, native speech evaluations were biased due to social pressure and cultural expectation; it is deemed important for the Quichua social identity for speech to sound native and unaccented: “The appearance of a Spanish accent in Quichua might well threaten individuals’ identity as Quichua speakers and community members” (Guion et al., 2000, p. 40).

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## Annexe 1

Table 1. Studies reviewed in this paper that have examined backward transfer in the domain of phonetic production, using perceptual and acoustic analyses of L1 productions.

<b>Study</b>	<b>L1/L2</b>	<b>L2 AoA</b> (age in years)	<b>Learning context</b>	<b>Length of experience with L2/residence in L2-speaking country</b>	<b>Remarks</b>	<b>Factors tested</b>	<b>Confounded factors</b>	<b>Outcome for L1 phonetic production</b>
Antoniou et al., 2011	Greek/English	on average at 3.5	at school and in immersion	on average 23.5 years of immersion	code-switching affects L2 (assimilation to L1) but not L1	testing conditions (code-switching or not)	amount of L1 use, experience with L2	does not differ from monolinguals
Barlow et al., 2013	Spanish/English	before the age of 3	not specified	on average 1.7 years of experience	L2 assimilation to Spanish in the onset context (i.e., the same /l/ for English and Spanish), but not postvocally	number of spoken languages	L2 experience, amount of L1 use, possibly immersion and AoA	does not differ from monolinguals
Barlow, 2014	Spanish/English	on average at 2.4	at school	on average 18 years of experience		AoA, phonetic context	immersion, amount of L2 use, AoA and L2 experience, and L2 proficiency	no difference in L1 phonetic production

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		on average at 8.3		on average 12 years of experience	the English allophonic velarization rule was transferred to the Spanish phonological system			L2 phonological rules are used to produce L1 speech sounds
Chang, 2012	English/Korean	on average at 22 years	novice learners, language course in L2 country	6 weeks of language course, 4 hours per day	changes are systemic	immersion, L2 experience	not specified	drift toward L2 similar sounds
Chang, 2013	English/Korean	from 0 to 20	at home or school	from 40 class hours to 20 years	drift is less important in experienced than in novice learners	immersion, L2 experience	L2 experience, AoA, L2 proficiency	drift toward similar L2 sounds
De Leeuw et al., 2007	German/Dutch or German/English	between 14 and 22	immersion	on average 36 years of immersion	L1 is more accented if less contact with the L1; no differences in L1 (German) between the German/Dutch and German/English bilinguals	amount of L1 use (L1 contact), age of immigration, length of residence	length of residence, AoA and L2 experience	drift, L1 speech is perceived as L2-accented

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De Leeuw et al., 2010	German/Dutch or German/English	after 20	immersion	on average 37 years of immersion	L1 is more accented if language-mixing occurred more and/or the L2 was used more frequently	amount of L1 use (L1 contact), age of immigration, length of residence	length of residence, AoA and L2 experience	drift, L1 speech is perceived L2-accented
Flege, 1987	English/French	after 15-18	at school and 9 months in immersion	on average 7 years of experience	they were tested 3-6 months after immersion period	amount of formal education in L2, length of residence in an L2-speaking environment, frequency of L2 use in the period preceding the study.	amount of L2 use, experience with the L2 and immersion in L2-speaking country (length of residence)	does not differ from monolinguals

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		after 15-18	at school, and in particular immersion	on average 11.7 years of immersion	the L2 is used dominantly; greater L1 drift in more proficient L2 speakers			drift toward L2 similar sounds
Flege & Eefting, 1987a	Dutch/English	at 12	at school	6 years at school and more years at university	their production in L2 was judged as native-like (highly proficient)	L2 proficiency	L2 experience and L2 proficiency	deflection from similar L2 sounds
				on average 6 years	they stopped studying English after the six years required in high school.			does not differ from monolinguals
Flege & Eefting, 1987b	Spanish/English	between 5 and 6 years	at private school and in immersion	on average 7.1 years at school	differences between similar L1 and L2 sounds are nevertheless maintained	AoA, L2 experience	Immersion, L2 experience and amount of L2 use	deflection from L2 similar sounds

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				on average 9.7 years of immersion in L2 speaking country and 6.4 years at school	differences between similar L1 and L2 sounds are larger than those of speakers with less experience			deflection from similar L2 sounds
				on average 3.5 years at school	these are children, deflection from monolingual norms is bigger than in adult bilinguals			deflection from similar L2 sounds
Fowler et al., 2008	French/English	simultaneous	in bilingual communities	mean age of the participants was 25.6 years	differences between similar L1 and L2 are nevertheless maintained	AoA, language proficiency	amount of language use and proficiency	drift toward similar L2 sounds

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Goldrick et al., 2014	Spanish/English	at average at 6.8	at school	on average 14 years of experience	language-switching affects L2 (assimilation to L1) but not L2; in particular, cognates	cognate status, testing conditions	not specified	L2 does not affect L1 phonetic production
Guion, et al., 2000	Quichua/Spanish	at the age of 6	at school and raised in bilingual communities	from 14 to 19 years of immersion	the amount of L1 use had no effect on the perceived strength of accent in L1 (but it did in L2); the L1 speech is perceived as being identical to monolinguals	amount of L1 use	Amount of L1 use and experience in L2	does not differ from monolinguals
Guion, 2003	Quichua/Spanish	simultaneous	at home	mean age of the participants was 29.4 years		age of L2 acquisition	length of experience with L2 and	does not differ from monolinguals

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		between 5 and 7	at school	on average 25.4 years of experience	deflection from similar L2 sounds, then L2 category is correctly established		proficiency in L2	drift toward similar L2 sounds
		between 15 and 25	at school and work	on average 19.5 years of experience	they did not establish L2 categories			does not differ from monolinguals
Kartushina et al., 2015	French/Danish	between 20 and 27	novice learners, phonetic training experiment	1 hour spread over 3 days of training	drift depends on the similarity between L1-L2 sounds: close L1 sounds drifted more	experience with isolated L2 sounds only	not specified	drift toward L2 similar sounds
Lev-Ari & Peperkamp, 2013	English/French	after 15	NA	at least 3 years (range 4-49) of immersion	larger drift in speakers with lower inhibitory skill	speech style, inhibitory skill	immersion, amount of L1 use and L2 experience	drift toward similar L2 sounds
Mack, 1989	English/French and French/English	before 8	at home or school	both languages were used regularly since learning the L2	speakers were dominant in English	L1 and L2 proficiency, AoA	amount of English use and proficiency	does not differ from monolinguals



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MacLeod et al., 2009	French/English	between 0 and 4	in bilingual communities	on average 35 years of immersion		number of mastered languages	amount of L2 use and experience with L2	does not differ from monolinguals
Major, 1992	English/Portuguese	between 22 and 36	immersion	between 12 and 37 years of immersion	better L2 proficiency is associated with more L2-accented L1 speech	L2 proficiency, speech style	immersion, length of residence, amount of L2 use and L2 proficiency	drift toward similar L2 sounds; this drift was larger in casual speech (i.e., conversation) than in formal, elicited speech
Mayr, Price, & Mennen, 2012	Dutch/English	between 13 and 18.	immersion at the age of 32	30 years of residence	changes are systemic	immersion in the L2 speaking-country, amount of L2 use	immersion, experience with L2 and amount of L2 use	drift toward similar L2 sounds
Mora & Nadeu, 2012	Catalan/Spanish	after 4 or 5	in bilingual communities	since birth	drift is observed if the L2 is used more frequently than the L1	amount of L2 use, cognate status	amount of language use and proficiency	drift toward similar L2 sounds, in particular in cognates

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Mora et al., 2015	Catalan/Spanish and Spanish/Catalan	before the age of 6	in bilingual communities	since birth	drift is larger in bilinguals who used Catalan less	amount of Catalan use	amount of language use and proficiency	drift toward similar Spanish sounds
Sancier & Fowler, 1997	Portuguese/English	at 15	immersion	4-month stay	drift was reversed after 2.5 months of immersion in L1-speaking country	immersion in the L2-speaking country	immersion and amount of language use	drift toward similar L2 sounds
Sundara et al., 2006	French/English	simultaneous	at home and school, and in bilingual communities	on average 24 years of immersion	bilinguals use only a subset of acoustic cues used by monolinguals to differentiate L1/L2 sounds	number of mastered languages	length of experience with L2 and proficiency in L2	does not differ from monolinguals