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A novelty effect in phonetic drift of the native language

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ABSTRACT

Previous findings on adult second-language (L2) learners showed systematic phonetic changes in their production of the native language (L1) starting in the first weeks of L2 learning [Chang, C. B. (2012). Rapid and multifaceted effects of second-language learning on first-language speech production. *Journal of Phonetics, 40*, 249–268]. This "phonetic drift" of L1 production in novice L2 learners was consistent with reports of phonetic drift in advanced L2 learners; however, the fact that novice learners showed relatively pronounced drift was unexpected. To explore the hypothesis that this pattern is due to a novelty effect boosting the encoding and retrieval of elementary L2 experience, the current study compared the inexperienced learners analyzed previously (learners with no prior knowledge of the L2) to experienced learners enrolled in the same language program. In accordance with the hypothesis, experienced learners manifested less phonetic drift in their production of L1 stops and vowels than inexperienced learners, suggesting that progressive familiarization with an L2 leads to reduced phonetic drift at later stages of L2 experience. These findings contradict the assumption that L2 influence on the L1 is weakest at early stages of L2 learning and argue in favor of viewing the L1 and L2 both as dynamic systems undergoing continuous change.

1. Introduction

A recurrent finding of behavioral research over the last century has been that humans tend to distinguish between similar experiences in memory, giving greater weight to more salient experiences than to less salient experiences (Ayçiçegi-Dinn & Caldwell-Harris, 2009; Bjork & Bjork, 1992; Ebbinghaus, 1885/1913). This tendency is related to two cognitive biases in the processing, storage, and retrieval of information—both non-linguistic information, as in mobiles and faces (Fagen, Rovee, & Kaplan, 1976; Field, Cohen, Garcia, & Greenberg, 1984), and linguistic information, as in words and sentences (Johnston & Kapatsinski, 2011; Poppenk et al., 2008). These biases are referred to here as the NOVELTY BIAS and the RECENCY BIAS (see, e.g., Bjork & Whitten, 1974; Simone, Ahrens, Foerde, & Spinetta, 2006). As discussed in more detail below, the novelty and recency biases have both been shown to influence the perception and/or production of spoken language; consequently, both are relevant to the topic of this paper: change in spoken language production.

Changes in speech production—in particular, the changes in native-language (L1) production that occur in conjunction with acquiring a second language (L2)—are the subject of an increasing amount of research on L2 speech and L1 attrition (see, e.g., de Leeuw, Schmid, & Mennen, 2010; Flege, 1987b; Major, 1992; Schmid, 2013). The contribution of the current study is in exploring the role of general information processing biases in explaining the trajectory of L2 influence on L1 production. This introduction begins with some background on these biases, before examining how they relate to patterns documented in the literature on bilingual speech production.

1.1. Biases in information processing

The first bias to be considered is the novelty bias, which predisposes an individual to attend to relatively new information. The positive relationship between novelty and salience is widely documented in studies of infant cognition (e.g., Houston-Price & Nakai, 2004; Hunter & Ames, 1988; Saffran, Aslin, & Newport, 1996, 1999). These studies have shown that following extensive exposure to a stimulus, infants tend to be drawn to a novel stimulus they were not exposed to over the familiar one. The amount of stimulus exposure required for a "novelty effect" to obtain decreases as the age of the infant increases (Hunter & Ames, 1988); thus, it should come as no surprise that novelty effects are found in children and adults as well. Among four- and six-year olds, for example, novelty influences attention, expressed preference, and choice of visual stimulus (Hutt, 1975). According to Koran,

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Morrison, Lehman, Koran, and Gandara (1984), there is also "considerable curiosity research indicating that both children and adults are attracted to novel as well as complex stimuli."

Adults' inclination to attend to novel stimuli is strong, as shown in an array of studies demonstrating that their performance in a focal task suffers to a significantly greater degree with novel distractors than with familiar distractors, even when they are given specific instructions to ignore the distractors (Parmentier, 2008; Parmentier, Ljungberg, Elsley, & Lindkvist, 2011; Ruhnau, Wetzel, Widmann, & Schröger, 2010; Wetzel, Widmann, & Schröger, 2009). Novel distractors in these studies are typically auditory, and the distraction effect associated with auditory novelty is mediated by the informational value of the sounds (Parmentier, Elsley, & Ljungberg, 2010). Although this effect has been argued to arise not from an auditory distractor's overall rarity, but rather from "the violation of the cognitive system's expectation based on the learning of conditional probabilities and, to some extent, the occurrence of a perceptual change from one sound to another" (Parmentier, Elsley, Andrés, & Barceló, 2011, p. 374), the effect is thought to originate in "the shifts of attention occurring between attention capture and the onset of the target processing" (Parmentier, Elford, Escera, Andrés, & Miguel, 2008, p. 409), shifts that are automatic and affect task performance beyond the trial in which the distractor is presented (Parmentier & Andrés, 2010; Parmentier, Turner, & Elsley, 2011).[1]

Another example of the novelty bias in processing information is the phenomenon known as "novel popout", which refers to the relatively greater localizability of novel items in the context of familiar items. In short, when individuals are given a brief glimpse of an array of items, novel items (those to which participants have received little exposure prior to the task) tend to be better localized when presented with familiar items than when presented with other novel items (Johnson & Schwarting, 1996, 1997; cf. Christie & Klein, 1996). This effect was found with linguistic materials (visually presented words) and has been explained in terms of the preferential processing of novel items. Notably, novel popout appears to facilitate the processing of speech as well, as suggested by experimental results showing that phonemes are detected more quickly when they occur in certain novel contexts—namely, those that violate an assimilation rule of the listener's native language and are associated with low listener expectations (Weber, 2001).

Although much of the literature on novelty is concerned with its effects on attentive behavior and pre-attentive neural activity, many empirical studies have demonstrated that novelty effects extend to encoding and retrieval (Ayçiçegi-Dinn & Caldwell-Harris, 2009; Habib et al., 2003; Nyberg, 2005). The medial temporal lobe of the brain, which plays an important role in forming new declarative memories, shows greater activity for novel events and contexts compared to familiar ones (Martin, 1999); at the same time, the magnitude of encoding-related activation in brain regions sensitive to novelty is predictive of subsequent memory for an event (Kirchhoff, Wagner, Maril, & Stern, 2000). Taken together, these findings suggest that novelty results in deeper memory encoding. The neural patterns are, moreover, consistent with behavioral results showing better recognition of novel (unfamiliar) actions that are verbally encoded compared to familiar actions (Knopf, 1991) and better recognition of novel words compared to familiar words (Tulving & Kroll, 1995). In a study by Kormi-Nouri, Nilsson, and Ohta (2005), novelty was found to result in better recognition performance in terms of both hits and false alarms; for participants of different language backgrounds (Japanese and Swedish); for different types of materials (verbs and nouns, high-frequency and low-frequency); and for different types of encoding in a preceding familiarization phase (enactment and non-enactment).[2]

The positive relationship between novelty and memory was captured in a NOVELTY/ENCODING HYPOTHESIS (Tulving & Kroll, 1995; Tulving et al., 1996) as follows: "(1) novelty assessment represents an early stage of long-term memory encoding; (2) elaborate, meaning-based encoding processes operate on the incoming information to the extent of its novelty, and therefore (3) the probability of long-term storage of information varies directly with the novelty of the information" (Tulving, Markowitsch, Craik, Habib, & Houle, 1996, p. 71). Although some researchers have noted problems with the interpretation of novelty effects documented in the literature (e.g., Poppenk, Köhler, & Moscovitch, 2010; Poppenk, McIntosh, Craik, & Moscovitch, 2010), the bulk of the neural and behavioral evidence on the processing of novel vs. familiar information suggests that beyond the case of young infants and limited stimulus exposure, humans tend to find novel stimuli salient, such that new experiences are more likely than old experiences to consume processing resources and be encoded in long-term memory. The fact that neural activations occurring in response to novel linguistic stimuli are located similarly to those that occur in response to novel pictures suggests, furthermore, that linguistic novelty is detected by regions of the brain involved in general novelty assessment (Tulving et al., 1996) and, thus, that the novelty/encoding hypothesis is highly relevant to the processing of linguistic information.

While the novelty bias has to do with the relative familiarity of information, the recency bias has to do with the temporal order in which information is received by an individual. In so-called "serial position effects", items presented first in a study list display an advantage in later recall (the "primacy effect"), as do items presented last (the "recency effect") (Ebbinghaus, 1885/1913). These kinds of serial position effects have been widely demonstrated in recall of linguistic units ranging in size from parts of words to sentence-level utterances. The recency effect has generally been found to be larger than the primacy effect, such that recently presented items are remembered the most reliably of all items in a stimulus set (Deese & Kaufman, 1957; Gupta, Lipinski, Abbs, & Lin, 2005; Murdock, 1962). Although most studies demonstrating a benefit of recency for memory retrieval have used linguistic materials, similar effects have been found with non-linguistic materials (e.g., spatial positions; Bonanni, Pasqualetti, Caltagirone, & Carlesimo, 2007). This suggests that the recency bias may be a general aspect of memory, which is consistent with findings showing that, in comparison to temporally distant experience, very recent experience influences an individual's behavior to a disproportionately large degree (Bjork & Bjork, 1992).

In a sense, the recency effect on memory is virtually inevitable because of the passage of time. Given a positive relationship between time and the fading of memories, at any given point in time recent memories have faded less than older memories, since less time has passed since their inception. The fading of memories corresponds to the notion of "exemplar decay" in an exemplar approach to speech perception and production (Goldinger, 1998; Johnson, 1997, Chapter 8; Pierrehumbert, 2001; Wedel, 2006). In this framework, linguistic representations are cast as clouds of previously

[1] Note that such novelty effects have a logical motivation and clear neuropsychological basis: "[n]ovel events are preferentially processed in the brain in order to facilitate adaptive responses to a dynamic, changing world" (Kaufman, 2009; see also Johnston & Schwarting, 1997). This preferential processing is served by low-level neural responses to novelty that are remarkably fast and observed not only in humans, but also in nonhuman primates (Bunzeck, Doeller, Fuentemilla, Dolan, & Duzel, 2009). Novelty assessment, a mechanism that "minimizes the probability that redundant information will be stored in long-term memory" (Habib, 2001, p. 187), is associated with various parts of the brain, including the amygdala, hippocampus, substantia innominata, and substantia nigra/ventral tegmental area (Bunzeck et al., 2007; Habib & Lepage, 2000; Strange, Fletcher, Henson, Friston, & Dolan, 1999; Wright et al., 2003, 2008), as well as with specific event-related potential (ERP) components, including the P3, N1, and N2 components (Dimoska & Johnstone, 2008; Fabiani & Friedman, 1995; Friedman, Kazmerski, & Cycowicz, 1998; Friedman & Simpson, 1994; Goldstein, Spencer, & Donchin, 2002; Knight & Scabini, 1998; Määttä, Pääkkönen, Saavalainen, & Partanen, 2005), although some research suggests that there are differences between children and adults in the neuroanatomical and functional circuitry devoted to the processing of novelty (e.g., Thomas & Nelson, 1996). Neuroimaging data from young adults support the view that the brain distinguishes among different degrees of novelty (Cycowicz & Friedman, 1998) and is affected distinctly, and more robustly, by novelty compared to other affective dimensions such as emotional valence and arousal (Weierich, Wright, Negreira, Dickerson, & Barrett, 2010); in particular, novelty is thought to be "a critical stimulus dimension" for engagement of the amygdala, an essential function of which is "signaling stimulus importance or salience" (Weierich et al., 2010, p. 2871). Furthermore, neural findings on cognitively high-performing adults of various ages suggest that, once cognitive changes associated with aging are taken into account, novelty effects are robust across the lifespan (Daffner et al., 2005, 2006).

[2] Different kinds of novelty, however, seem to facilitate recognition to different degrees. For example, whereas syntactic novelty does not raise recognition performance much above chance, semantic novelty and total novelty (i.e., a completely novel item) each result in significantly better recognition performance (Poppenk et al., 2008).

experienced tokens of words rather than abstract symbolic objects, and these individual speech memories contain many kinds of information including phonetic and socioindexical details associated with the utterance. Crucially, speech exemplars decay over time, such that more recently experienced utterances maintain higher activation levels than less recently experienced utterances. This positive relationship between recency and activation strength helps to explain why recent experience, even if relatively brief, can have measurable effects on an individual's speech production.

1.2. Recency effects in cross-linguistic speech production

The powerful effect of recent experience on an individual's speech production was elegantly demonstrated in a longitudinal case study reported by Sancier and Fowler (1997). Examining a Portuguese–English bilingual who had begun acquiring English in late adolescence, the authors tracked voice onset time (VOT) in the bilingual's production of voiceless stops in Portuguese and English as she traveled between the L2 environment (the U.S.) and the L1 environment (her native country, Brazil). Comparing the speaker's VOTs after stays in the U.S. to those after a stay in Brazil, they found that VOT in both the L1 and the L2 shortened after the speaker had spent months in Brazil immersed in Portuguese (in which voiceless stops have a short-lag VOT); conversely, VOTs lengthened after she had spent months in the U.S. immersed in English (in which voiceless stops have a long-lag VOT). In other words, the speaker's stop production in both languages moved toward the VOT norms of the most recently experienced language—a pattern suggesting the existence of a perceptual linkage between the L1 and L2 stops allowing for bidirectional cross-linguistic influence (Flege, 1995). Crucially, L1 production was influenced by a recent period of immersion in the L2 despite the speaker's greater cumulative experience with the L1. The size of this effect on L1 VOT was small (on the order of 5 ms), but statistically significant; moreover, the effect was perceptible to native Brazilian listeners.

Recent L2 experience can have a measurable effect on L1 production even when brief, as shown in a longitudinal study of novice L2 learners by Chang (2012). Participants in this study, adult native English speakers learning elementary Korean, began manifesting "phonetic drift" of their L1 toward the L2 as early as the second week of language classes. While the VOT of English voiced stops did not change (as it was already very close to the VOT of the perceptually most similar Korean stop series—the fortis stops), the VOT of English voiceless stops lengthened over time, moving toward the longer VOT norms of the, respectively, most similar Korean stop series (the aspirated stops).[3] Drift also occurred in the fundamental frequency (f_0) onset of both stop-initial and vowel-initial English words, which increased toward the higher f_0 levels of Korean for female learners.[4] In addition, female learners showed a slight decrease in the first formant frequency (F_1) of all the English vowels toward the lower overall F_1 level of the target Korean vowel system[5] (as produced by an all-female team of instructors); however, they did not show a similar change in second formant frequency (F_2). On the other hand, male learners—for whom the overall F_1 level of the target Korean vowel system was higher than that of their English vowel system (due to physiological differences between males and females)—showed a complementary tendency to increase the F_1 of the English vowels. Since the formant norms of the Korean vowel system for female talkers were in between those of the English vowel system for female talkers and those of the English vowel system for male talkers, the opposite patterns of F_1 change for male and female learners were actually consistent in both moving toward the formant norms of the target L2 vowel system.[6]

1.3. A novelty effect in cross-linguistic speech production?

Notably, the magnitude of L1 VOT lengthening documented by Chang (2012)—on the order of 20 ms—was substantially larger than that found by Sancier and Fowler (1997). From the perspective of cumulative experience, this result is surprising, since the novice learners examined in Chang (2012) had relatively more L1 experience and relatively less L2 experience than the advanced bilingual examined in Sancier and Fowler (1997), yet their L1 VOT drifted to a greater degree. While this difference in drift magnitude was never accounted for, one possible explanation for the disparity in phonetic drift is the disparity in novelty between the two studies: although the L2 experience precipitating L1 drift was recent in both cases, only in the case of the novice L2 learners in Chang (2012) was the L2 experience also novel.

Could the novelty of these learners' L2 experience be responsible for the fact that they showed more pronounced drift in L1 VOT? It should be noted that such an effect of novelty would run counter to the intuition that L2 influence on the L1 should be subtle or absent in early stages of L2 learning, becoming more pronounced only at advanced levels of L2 proficiency (see, e.g., Major, 1992). However, given the abundance of research demonstrating that novel information enjoys a privileged status in attention, encoding, and retrieval, it was hypothesized that recent experience in a novel L2 would generally be more influential than recent experience in a familiar L2 and, therefore, that greater cross-over influence of recent L2 experience on L1 production would result with a novel L2. It follows from this hypothesis that, compared to novice L2 learners with no prior experience in the L2, intermediate and advanced L2 learners already familiar with the L2 should be less affected by recent L2 experience in their L1 production.

[3] An anonymous reviewer questioned the prediction of perceptual linkage of English voiceless stops to Korean aspirated stops, wondering why English voiceless stops would not be linked to Korean lenis stops (instead or in addition). As discussed in Chang (2010a, pp. 92–93), this prediction follows from perceptual assimilation data on L1 English listeners of Korean (Schmidt, 2007, Chapter 11), which indicate that the aspirated series is the Korean stop type most consistently assimilated to English voiceless stops. Whereas the aspirated series is always assimilated to voiceless segments, the lenis series is more ambiguous, being assimilated to voiced segments 9% of the time on average (range 0–45%). The more varied perception of lenis stops is, moreover, consistent with their diverse production by L1 English learners of Korean, who pronounce them as similar to voiced stops (with negative or short-lag VOT) more than half of the time (Chang, 2010b). In other words, whereas lenis stops show inconsistent identification with an English voicing category, aspirated stops are consistently identified with English voiceless stops. It follows that English voiceless stops are most likely to be perceptually linked to Korean aspirated stops—either exclusively (if it is assumed that L1 categories are linked to L2 categories uniquely) or most strongly (if L1–L2 linkages are not assumed to be unique)—and, thus, that their phonetic drift will be most influenced by the phonetic properties of the aspirated stops.

[4] An anonymous reviewer wondered how it could be concluded that the relevant Korean stop types are associated with a significantly higher vowel onset f_0 than the English stop types (in particular, the Korean aspirated stops vis-a-vis the English voiceless stops). Although there are no published studies reporting well-controlled comparisons between the f_0 norms of English and Korean stops, information on f_0 differences between stop types within each language shows that the f_0 differences in Korean are three to four times greater than those in English. Given that the laryngeally unmarked Korean lenis stops at the bottom of the f_0 range are associated with neither f_0 raising nor lowering, this strongly suggests that the f_0 of the laryngeally marked Korean aspirated stops at the top of the f_0 range is indeed higher than that of English voiceless stops (Chang, 2012, p. 253).

[5] The target Korean vowel system as a whole is higher (i.e., lower in mean F_1) than the English vowel system as a consequence of having fewer non-high (i.e., mid and low) vowels. The mean formant levels of the English and Korean vowel systems as reported in Chang (2012, p. 254) are, for male talkers, 435 Hz for Korean vs. 481–527 Hz for American English (depending on dialect) and, for female talkers, 558 Hz for Korean vs. 583–634 Hz for American English (depending on dialect).

[6] Note that the observed changes in vowel production are not amenable to a coherent explanation based on segment-level L2-to-L1 influence, since they were inconsistent in terms of whether an L1 vowel moved toward or away from the nearest L2 vowel. The unity among the changes in overall direction of movement suggests instead an explanation based on system-level L2-to-L1 influence, a pattern that is also found in other studies (Guion, 2003; Mayr, Price, & Mennen, 2012).

Thus, the research question posed in this study was whether, due to differences in the novelty of the L2 being learned, experienced L2 learners would show less phonetic drift of the L1 during L2 learning than inexperienced L2 learners. This question was examined with respect to the same segment types (stop laryngeal categories and vowel quality categories), the same L1 (English), and the same L2 (Korean) examined in Chang (2012). Given the pronounced drift in the VOT and f_0 onset of English stops produced by inexperienced learners of Korean, English VOT and f_0 were predicted to show drift in experienced learners as well, but to a lesser degree than in inexperienced learners. On the other hand, given the subtle drift in the F_1 of English vowels produced by inexperienced learners, English F_1 was predicted to show little to no drift in experienced learners. In short, compared to inexperienced learners, experienced learners were expected to show significantly less longitudinal change in all of the measured acoustic properties of their L1 speech, possibly resulting in no change being detectable.

The rest of the paper is organized as follows. Section 2 outlines the design of the longitudinal study and the methods used to analyze changes in participants' speech production over time. Section 3 presents comparisons between inexperienced learners and experienced learners in two studies examining English stop consonants (study 1) and vowels (study 2). Section 4 discusses the findings in regard to the role of specific aspects of bilingual experience in influencing speech production, with special attention to relevant findings from a cross-sectional study of bilingual speech production (Flege, 1987b). Finally, Section 5 summarizes the main conclusions and describes avenues for further research.

2. Methods

2.1. Participants

Eleven experienced learners (ELs) of Korean participated in the study to completion. All were adult native speakers of American English (8 females, 3 males; mean age 23 years, SD 2.1) who participated in the same Korean language program as the inexperienced learners (ILs) analyzed in Chang (2012). Unlike the ILs, however, the ELs had significant prior experience with the Korean language through heritage exposure, formal study, and/or extended stays in South Korea.

Seven of the ELs were Korean Americans. Five had been adopted from South Korea to the U.S. (mean age of adoption 1.7 years, SD 2.0) and had thus been immersed in Korean for the first part of their life, for a period ranging from 4 months to 5 years. Three of these adoptees had also pursued formal study of Korean at the university level for 1–4 years, including 1–2 semesters spent in South Korea. The other two Korean Americans had been born in the U.S. and were raised with at least one caregiver engaging them in Korean during childhood. The first of these Korean Americans had been spoken to in Korean extensively until age 5 and then regularly thereafter; the second had been spoken to in Korean extensively until age 3 and then occasionally until age 8, after which point she had sporadic experience overhearing her mother speaking Korean to others. Both had also studied Korean formally—the first, for 6 months in middle school, and the second, for a total of 5 years from childhood through college, including a semester spent in South Korea.

The remaining four ELs were non-Korean Americans who had pursued formal study of Korean during or shortly after college. The amount of study ranged from 4 weeks of regular daily classes (total of 20 class hours) at an American university to 6 weeks of intensive daily classes (total of 60 class hours) at a South Korean university.

All of the ELs also had experience studying foreign languages besides Korean (most often Spanish, French, or Japanese, for a period of 1–10 years); however, they were consistent in reporting no regular use of these other languages for communicative purposes and in identifying English as their native and best language. None, moreover, reported any history of hearing or speech impairments in childhood. All were paid for their participation.

The ELs were compared to the 19 ILs (16 females, 3 males; mean age 22 years, SD 0.9) reported on in Chang (2012). The ILs were native speakers of American English who were “functionally monolingual” (in the sense of Best & Tyler, 2007, p. 16), reporting English to be the only language used at home and no regular use of another language besides English for communicative purposes. Unlike the ELs, the ILs reported no significant prior exposure to Korean or prior study of Korean.

2.2. Learning context

At the time of data collection, all participants were enrolled in a six-week course of intensive Korean instruction at a South Korean university. Participants had on average four hours of class a day, which, according to exit questionnaires, constituted the majority of the time they heard and spoke Korean during the time period of the study. Based on initial language interviews, four of the ELs were placed into a beginner-level class; six into an intermediate-level class; and one into an advanced-level class. All classes were conducted in Korean.

Although participants indicated that the majority of their time spent engaging with the L2 was in class, they were exposed to the L2 outside of class as well since they were living in the L2 environment. Furthermore, many elected to participate in extracurricular activities conducted in Korean, such as martial arts classes and student club meetings. Since it was possible that differences in prior experience with the L2 might lead to systematic disparities in L2 exposure outside of class, the total amount of extracurricular exposure to the L2 was compared between the two groups, taking into account visits to instructors' office hours, language exchanges, culture-focused elective classes, cultural excursions, and interaction with Korean resident assistants in the dormitory. This comparison showed no significant difference between ILs and ELs [$t(23) = -0.248$, *n.s.*], both groups reporting approximately 12 h per week of extracurricular L2 exposure.

2.3. Procedure and materials

Learners (both ILs and ELs) participated five times in an English production experiment, once at the end of each of the first five weeks of instruction in the Korean language program. The experiment was always run by the same experimenter (the author), who provided instructions in English. The task in the experiment was word reading: participants were shown the written form of a monosyllabic English word on screen and asked to pronounce the word out loud (in isolation) when given a cue.

The experiment was generally run in a quiet room in the learners' dormitory using a Sony Vaio PCG-TR5L laptop computer running DMDX (Forster, 2008). Stimuli were randomized and presented in four blocks, such that four tokens were collected of each item. Participants' speech was recorded

Table 1
Speech materials used in the production experiment, by study.

Study	Items
1 (stops)	'*bot*, *pot*, *dot*, *tot*, *got*, *cot*
2 (vowels)	*heed*, *hid*, *hate*, *head*, *had*, *who'd*, *hood*, *hoed*, *hut*, *hawk*, *pot*
Fillers	*sod*, *shot*, *seed*, *sheet*, *wait*, *wet*, *wee*, *all*

at 44.1 kHz and 16 bps using an AKG C420 or C520 head-mounted condenser microphone, which was connected either to the computer via an M-AUDIO USB preamp or to a Marantz PMD660 recording device.

The speech materials for the experiment consisted of 24 monosyllabic English words representing most of the phonemic contrasts of English. The materials were the same in every run of the experiment and are presented in Table 1. To control for coarticulatory effects from adjacent segments, items in study 1 contained stops in the same vowel environment (/a/), while items in study 2 contained vowels in similar consonant environments. In particular, the consonantal contexts for the vowels examined in study 2 were similar to those in items used in previously published studies of English vowels (e.g., Hagiwara, 1997; Hillenbrand, Getty, Clark, & Wheeler, 1995; Peterson & Barney, 1952; Yang, 1996) in order to facilitate comparison with prior findings. In study 1, which examined the VOT and f_0 onset associated with English stops, critical items subjected to analysis were the six words beginning with plosives. In study 2, which examined the F_1 and F_2 of English vowels, critical items subjected to analysis comprised the eleven words with a glottal fricative onset or an aspirated bilabial stop onset. The remaining items were control and filler words, such that in each study less than one-half of the speech materials were critical items subjected to analysis.

2.4. Acoustic analysis

Acoustic data from recordings comprised measurements of VOT in word-initial plosives, f_0 at the onset of the following vowels, and F_1 and F_2 at the vowel midpoint. All acoustic measurements were taken in Praat (Boersma & Weenink, 2011) on a wide-band Fourier spectrogram with a Gaussian window shape (window length of 5 ms, dynamic range of 50 dB, pre-emphasis of 6.0 dB/oct) or the corresponding waveform.

Study 1 examined VOT and f_0 onset. VOT was defined as the time at voicing onset minus the time at the beginning of the release burst interval. The voicing onset was identified with the first point at which a voicing bar with clear glottal striations appeared in the spectrogram. The f_0 at this point was measured by taking the combined wavelength of the first three regular glottal periods in the vowel and converting to a frequency value. The three-period interval was demarcated on the waveform, with an initial period being skipped if it was more than 33% longer or shorter than the following period. However, if the earliest interval of three regular periods occurred more than five periods into the vowel (i.e., the vowel began with an extended interval of irregular phonation), the token was discarded. A total of 1.7% of tokens was discarded by this criterion or because of other pronunciation anomalies.

Study 2 examined F_1 and F_2, which were measured automatically from spectrograms annotated manually for vowel onset and offset. The onset and offset of a vowel were marked, respectively, at the first and last glottal striations showing formant structure. The mean values of F_1 and F_2 were measured over the middle 50 ms of each vowel interval demarcated in this way; the analysis method was linear predictive coding, using the Burg algorithm (Childers, 1978) in Praat. The frequency range and number of formants entered into the formant analysis were obtained by visually inspecting a few spectrograms from the given participant and adjusting the default parameters until tracking of F_1 and F_2 was smooth and accurately followed the formants visible in the spectrogram. To further check the accuracy of the formant measurements, they were inspected for outliers by vowel, potential errors were flagged, and spectrograms of all tokens were inspected individually. When formant tracking was inaccurate, the analysis parameters were adjusted until tracking was smooth, and the erroneous formant measurement was corrected. If formant tracking could not be made satisfactory via adjustment of the analysis parameters, then measurements were taken manually on an average spectrum of the middle 50 ms of the vowel.[7] A total of 1.4% of tokens was discarded because of pronunciation anomalies or speech errors.

Tests of intra-rater reliability indicated that the measurements collected were highly reliable. Six months after the original measurements were taken, approximately 20% of the analyzed tokens were randomly selected and reanalyzed. The two rounds of measurements were closely correlated for all measures, with Pearson's correlation coefficients ranging from $r=0.92$ to $r=0.98$ [ps <0.0001]. The average difference between paired VOT measurements was 3 ms; between paired f_0 measurements, 4 Hz; between paired F_1 measurements, 7 Hz; and between paired F_2 measurements, 15 Hz.

2.5. Statistical analysis

In order to achieve a fair comparison of English stop productions by ILs and ELs in study 1, tokens were divided into VOT bins representing three universal phonetic categories of stop voicing ("prevoiced", "short-lag", "long-lag") in accordance with VOT boundaries estimated from the literature (Keating, 1984; Lisker & Abramson, 1964; Lisker, Liberman, Erickson, Dechovitz, & Mandler, 1977), and analyses focused on the most common phonetic voicing category for each stop type: short-lag (VOT of 0–30 ms) for voiced stops, and long-lag (VOT >30 ms) for voiceless stops. Tokens were divided in this way largely to exclude prevoicing (VOT <0 ms) from the analysis of voiced stops, because although prevoiced tokens of voiced stops were relatively infrequent, they arguably represented a different phonetic voicing category than the typical short-lag implementation of initial voiced stops in English. Consequently, to obtain a clear picture of within-group change and between-group differences in the production of voiced stops over time—one that did not simply represent change in the frequency or robustness of prevoicing—the analysis of voiced stops was limited to tokens representing their typical short-lag realization. In the interest of consistency, the analysis of voiceless stops was also limited to tokens representing their typical long-lag realization (although this resulted in hardly any exclusions, since nearly all tokens of voiceless stops had VOT longer than 30 ms).

To put frequency data for male and female participants on the same scale, frequency values (f_0, F_1, F_2) submitted to statistical analysis were standardized by learner. The standardization was done by calculating an individual's mean for a particular frequency component over the range of

[7] Tokens that were measured manually in this way were few in number, amounting to 0.3% of all tokens.

variation in their productions during the five weeks of the language program and then expressing the raw measurements as z-scores about the individual's mean. This type of standardization allowed for longitudinal analyses within individuals that could be compared across individuals.

To account for inter-speaker differences in speech production, the acoustic data in both studies were analyzed with mixed-effects linear regression (see, e.g., Johnson, 2008, pp. 237–247) using the lme() function in R (R Development Core Team, 2013). All regression models had a random effect for Participant and fixed effects that included Time (point in the language program: weeks 1–5) and Group (IL or EL).[8] Models of VOT and f_0 also included Place (of articulation) as a fixed effect, while models of F_1 and F_2 also included Vowel, since these factors have been shown to have a significant influence on the given dependent variables (e.g., Ladefoged, 2005; Nearey & Rochet, 1994). All possible interactions among predictors were examined as well.

Given the focus on between-group differences in change over time, the crucial factor in each study was the Time × Group interaction. A main effect of Time was expected for those acoustic properties that were expected to change more; however, a main effect of Group was not expected because the groups were not expected to differ in their initial values for any of the measured acoustic properties. Moreover, since there were no previous findings that could inform predictions regarding how much the effect of time would differ between the IL and EL groups, the effect size of the Time × Group interaction was not interpretable. In short, the main prediction in both studies was that the effect of time would be smaller for the EL group; as such, analyses focused on whether Time and Group showed a statistically significant interaction.

3. Results

3.1. Study 1: Stop production

3.1.1. VOT

In both the IL group and the EL group, the mean VOT of English voiced stops hovered around 17 ms and showed no significant change over time (as expected given the comparable VOT norms of the perceptually similar Korean fortis stops). A mixed model analysis of variance (ANOVA) on VOT for voiced stops indicated a main effect of Place as expected [$F(2,1297) = 371.849$, $p < 0.0001$], but no main effect of Time [$F(4,1297) = 1.080$, *n.s.*] or Group [$F(1,28) = 0.001$, *n.s.*]. No interactions were statistically significant, including the Time × Group interaction [$F(4,1297) = 1.958$, *n.s.*]. The effect of Place was attributable to bilabial stops having significantly shorter VOT [$\beta = -3.694$, $t = -13.058$, $p < 0.0001$] and velar stops having significantly longer VOT [$\beta = 4.409, t = 15.071$, $p < 0.0001$] than alveolar stops. In short, the VOT of voiced stops was similar for ILs and ELs and did not change over time for either group.

In contrast to the VOT of voiced stops, the VOT of voiceless stops showed significant lengthening over time in both groups (as expected given the longer VOT norms of the perceptually similar Korean aspirated stops); however, this effect was smaller for ELs than for ILs. A mixed model ANOVA on VOT for voiceless stops indicated a main effect of Place here as well [$F(2,1610) = 12.452$, $p < 0.0001$], with bilabials again having significantly shorter VOT [$\beta = -2.517$, $t = -1.987$, $p < 0.05$] and velars having significantly longer VOT [$\beta = 3.573$, $t = 2.830$, $p < 0.01$] than alveolars. There was also a main effect of Time [$F(4,1610) = 29.503$, $p < 0.0001$], as VOT lengthened from week 1 to week 5. However, there was no main effect of Group [$F(1,28) = 1.578$, *n.s.*]. A significant Place × Group interaction [$F(2,1610) = 4.308$, $p < 0.05$] arose primarily because ELs showed less of an increase in the VOT of velars over the other places of articulation than did ILs. The only other significant interaction was the Time × Group interaction [$F(4,1610) = 2.679$, $p < 0.05$]. In short, VOT in voiceless stops showed both a main effect of Time and an interaction between Time and Group. As shown in Fig. 1, these effects arose because the VOT of voiceless stops lengthened over time for both ILs and ELs, but less so for ELs. Thus, while ILs and ELs started out with VOTs for voiceless stops that did not differ significantly in week 1 [$t(28) = 0.668$, *n.s.*], by week 5 ILs were producing VOTs that were significantly longer than those of ELs [$t(28) = 1.881$, $p < 0.05$].

3.1.2. f_0 onset

Because male and female ILs were found to pattern differently with respect to drift in f_0 in Chang (2012), the first step in the analyses of standardized f_0 was to examine the effect of Gender and any interaction between Gender and Time for ELs. A mixed model ANOVA showed no main effect of Gender on f_0 following voiced stops [$F(1,9) = 1.662$, *n.s.*] or voiceless stops [$F(1,9) = 0.477$, *n.s.*]. However, there was a significant Gender × Time interaction both for f_0 following voiced stops [$F(4,435) = 3.939$, $p < 0.01$] and for f_0 following voiceless stops [$F(4,506) = 2.948$, $p < 0.05$]. As in Chang (2012), these interactions arose because only EL females manifested an increase in f_0 over time. Compared to EL females, EL males lagged behind, showing much less of an increase in f_0 from week 1 to week 5; this was the case both for f_0 following voiced stops [$\beta = -0.636$, $t = -2.646$, $p < 0.01$] and for f_0 following voiceless stops [$\beta = -0.376$, $t = -2.022$, $p < 0.05$].[9] Consequently, analyses of group differences in f_0 drift focused on the more numerous female participants.

Over time, f_0 onset following voiced stops increased significantly for both ILs and ELs, but the magnitude of the net increase from week 1 to week 5 was slightly smaller for ELs than for ILs. A mixed model ANOVA on f_0 onset for voiced stops indicated a main effect of Time [$F(4,1057) = 29.538$, $p < 0.0001$], but no main effect of Place [$F(2,1057) = 2.962$, *n.s.*] or Group [$F(1,23) = 0.423$, *n.s.*]. There was only one significant interaction, which was between Time and Group [$F(4,1057) = 5.579$, $p < 0.001$]. Thus, for f_0 onset following voiced stops, there was both a main effect of Time and a Time × Group interaction. These effects can be seen in Fig. 2: while f_0 following voiced stops increased over time for both ILs and ELs, it increased less overall and less steadily for ELs. Although ILs and ELs did not differ significantly with respect to average f_0 onset values for voiced stops in week 1 or week 5, the overall increase in f_0 onset for ELs (0.479 standard deviations) was indeed smaller than that for ILs (0.650 standard deviations).

Like f_0 onset following voiced stops, f_0 onset following voiceless stops increased significantly for both ILs and ELs, but the magnitude of the net increase from week 1 to week 5 was smaller for ELs than for ILs. A mixed model ANOVA on f_0 onset for voiceless stops again indicated a main effect of Time [$F(4,1330) = 25.489$, $p < 0.0001$], but no main effect of Place [$F(2,1330) = 2.352$, *n.s.*] or Group [$F(1,23) = 0.564$, *n.s.*]. Once again, the only significant interaction was between Time and Group [$F(4,1330) = 5.203$, $p < 0.001$]. In short, the results for f_0 onset following voiceless stops were parallel to those for f_0 onset following voiced stops: a main effect of Time and a Time × Group interaction. As shown in Fig. 3, f_0 following voiceless

[8] All models also included a fixed effect for Token (1–4) in order to check whether there was any systematic change in production of the measured acoustic properties over the course of the experiment. Token did not have a significant effect in any model and is thus not further discussed in the model results presented in Section 3.

[9] The reason for this gender disparity is not important here; however, it is likely related to sociolinguistic differences between the genders in f_0 modulation (see, e.g., Daly & Warren, 2001), as well as the fact that nearly all the teachers in the Korean language program were female (thus providing female learners with a same-gender L2 model, but male learners with a different-gender L2 model).

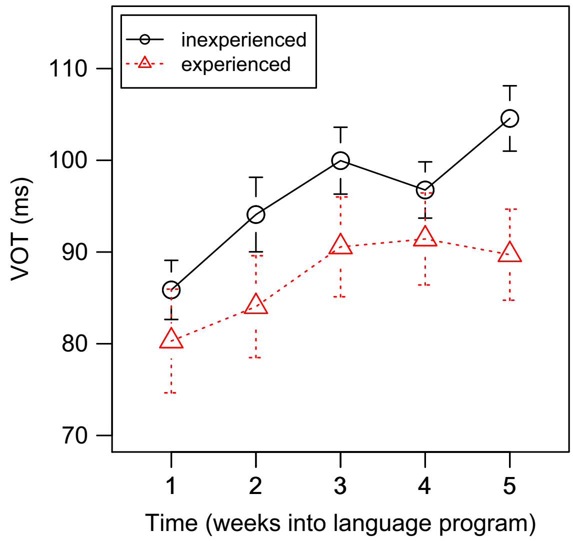

Fig. 1. Mean VOT of English voiceless plosives over time, by group. Inexperienced learners are plotted in circles connected by solid lines; experienced learners, in triangles connected by dotted lines. Error bars indicate 95% confidence intervals of the mean over participants.

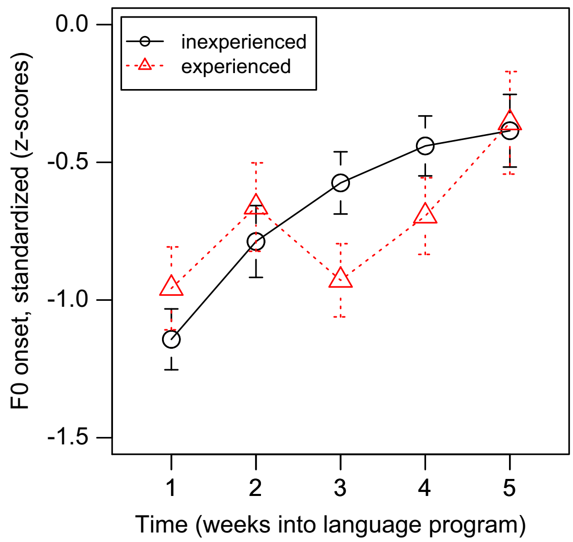

Fig. 2. Mean f_0 onset following English voiced plosives over time for female learners, by group. Inexperienced learners are plotted in circles connected by solid lines; experienced learners, in triangles connected by dotted lines. Error bars indicate 95% confidence intervals of the mean over participants.

stops increased over time for both ILs and ELs; however, the overall increase was smaller for ELs. In week 1, the average f_0 of ELs started above that of ILs, but by week 5 it had fallen behind that of ILs. Consequently, the overall increase in f_0 onset for ELs (0.211 standard deviations) was considerably smaller than that for ILs (0.520 standard deviations)—the same pattern found with f_0 onset following voiced stops.

3.2. Study 2: Vowel production

As with f_0, vowel formants showed different patterns of drift between IL females and IL males in Chang (2012): IL females raised the English vowel system over time (i.e., they decreased mean F_1), whereas IL males tended to lower it.[10] Thus, the first step in the analyses of F_1 and F_2 in study 2 was to check for gender differences in the EL group with respect to shifts in the English vowel system. The development of the English vowel system over time for ELs is shown in Figs. 4 and 5 for females and males, respectively.[11] Although it should be borne in mind that fewer EL males are represented here than EL females, there is a clear difference between the genders in how the English vowel system changed over time. While EL males showed a marked tendency to lower their English vowels (consistent with the pattern for IL males), EL females showed little change overall. This gender difference in drift pattern was consistent with the results of a mixed model ANOVA on standardized F_1, which showed a significant

[10] As summarized in Section 1, these opposite patterns of L1 vocalic drift both moved toward the phonetic norms of the target L2 system, since the overall F_1 levels of the English vowel system for female talkers and male talkers are, respectively, higher and lower than the overall F_1 level of the target Korean vowel system produced by female talkers.

[11] Weeks 2 and 4 are omitted from the vowel plots for the sake of clarity, but were included in all statistical analyses. Error bars here represent the average of individual participants' standard errors for a given vowel, rather than standard errors calculated over the distribution for the entire group. This calculation prevents formant disparities due to physiological differences between male and female participants from inflating the displayed error, allowing for a more accurate representation of the range of variation in the average participant's production of each vowel.

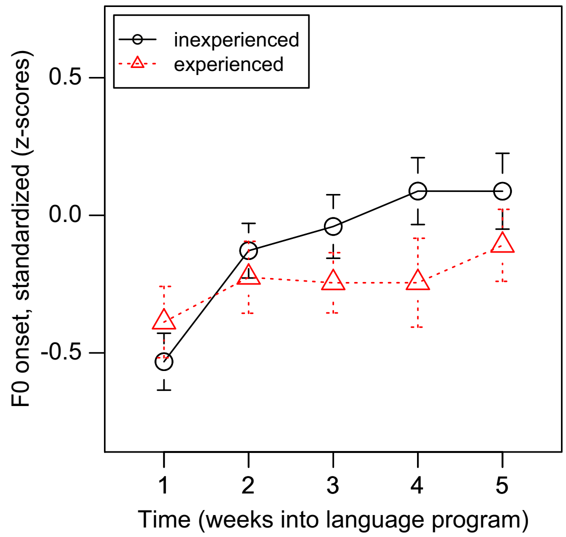

Fig. 3. Mean f_0 onset following English voiceless plosives over time for female learners, by group. Inexperienced learners are plotted in circles connected by solid lines; experienced learners, in triangles connected by dotted lines. Error bars indicate 95% confidence intervals of the mean over participants.

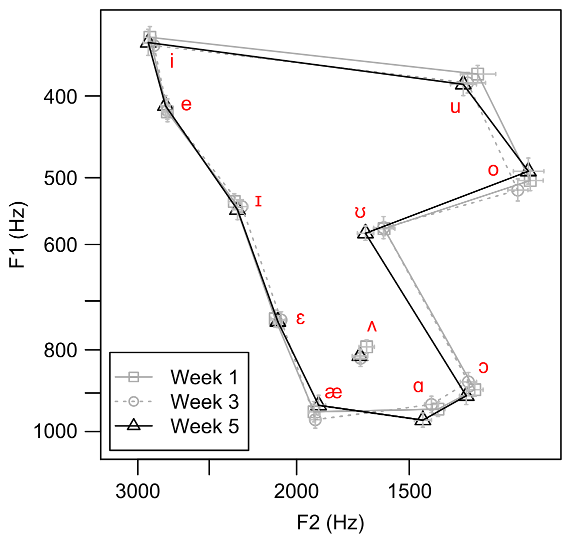

Fig. 4. Mean F_1 by mean F_2 of English vowels over time as produced by experienced female learners of Korean. The scale of both axes is logarithmic. Week 1 means are represented with squares connected by solid gray lines; Week 3 means, with circles connected by dotted gray lines; and Week 5 means, with triangles connected by solid black lines. Error bars indicate ±1 mean standard error.

Gender × Time interaction [$F(4,6037) = 17.116$, $p < 0.0001$]. The gender difference provided cause to focus the investigation of vocalic drift on the more numerous female participants; however, findings for male participants are also included below for the sake of comparison.

In contrast to IL females, EL females did not manifest drift in the F_1 of their English vowels. A mixed model ANOVA on standardized F_1 for female learners indicated a main effect of Vowel [$F(10,4753) = 8292.066$, $p < 0.0001$] and Time [$F(4,4753) = 5.435$, $p < 0.001$], but no main effect of Group [$F(1,22) = 0.019$, *n.s.*]. The Vowel × Group interaction [$F(10,4753) = 2.402$, $p < 0.01$] and Vowel × Time × Group interaction [$F(40,4753) = 1.505$, $p < 0.05$] were both significant, suggesting that the two groups differed in their organization of the vowel space in the F_1 dimension and in the generality of their drift pattern across the vowel system. Crucially, there was also a significant interaction between Time and Group [$F(4,4753) = 9.874$, $p < 0.0001$], which supported the conclusion that the IL and EL groups differed in their pattern of drift in F_1. To examine the group disparity in drift pattern in more detail, separate mixed-effects models were built for the IL and EL groups. These models showed that while the IL group did indeed show significant drift in F_1 [$F(4,3244) = 12.896$, $p < 0.0001$], the EL group did not [$F(4,1509) = 1.885$, *n.s.*]. This disparity can be seen in Fig. 6(a), where it is apparent that EL females differed from IL females in not showing a decline in mean F_1 over time. Notably, the Vowel × Time interaction was not significant in the model for either group, suggesting that patterns of F_1 drift (or the lack thereof) in both groups were broadly characteristic of the vowel system as a whole instead of a few isolated vowels. The pattern of results for male learners differed from that for female learners in that for males, ILs and ELs both manifested an increase in mean F_1 (Fig. 6(b)).

With regard to F_2, there was no significant drift for IL females or EL females. A mixed model ANOVA on standardized F_2 for female learners indicated a main effect of Vowel [$F(10,4753) = 11070.098$, $p < 0.0001$], but no main effect of Time [$F(4,4753) = 0.449$, *n.s.*] or Group [$F(1,22) = 0.490$, *n.s.*]. A Vowel × Time interaction [$F(40,4753) = 1.588$, $p < 0.05$] suggested that some vowels (e.g., /ʊ/) were more susceptible than others to drift in F_2, while a Vowel × Group interaction [$F(10,4753) = 19.955$, $p < 0.0001$] indicated that there were between-group differences in the organization of the vowel space in the F_2 dimension. The Time × Group interaction, however, was not significant [$F(4,4753) = 1.497$, *n.s.*], consistent with the absence of

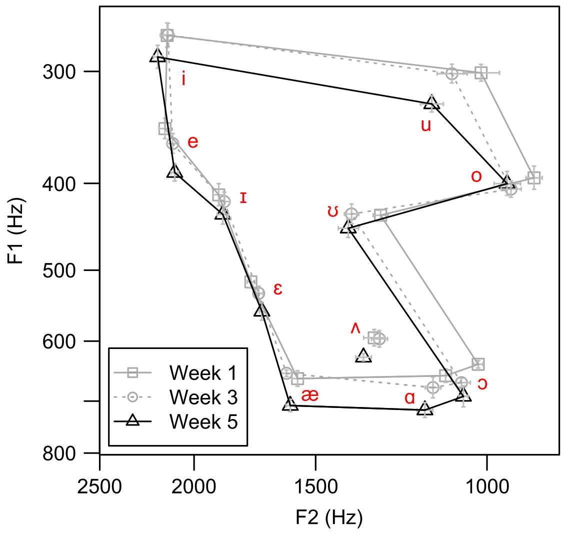

Fig. 5. Mean F_1 by mean F_2 of English vowels over time as produced by experienced male learners of Korean. The scale of both axes is logarithmic. Week 1 means are represented with squares connected by solid gray lines; Week 3 means, with circles connected by dotted gray lines; and Week 5 means, with triangles connected by solid black lines. Error bars indicate ±1 mean standard error.

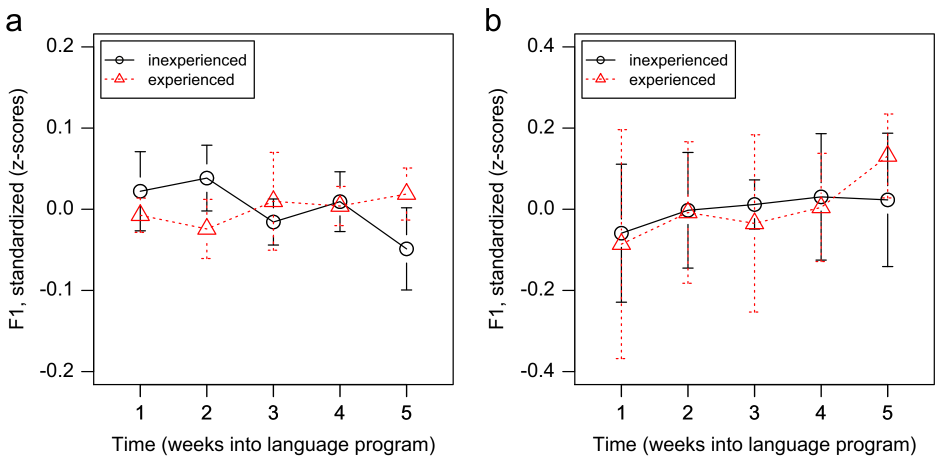

Fig. 6. Mean F_1 of the English vowel system over time for female learners (a) and male learners (b), by group. Inexperienced learners are plotted in circles connected by solid lines; experienced learners, in triangles connected by dotted lines. Error bars indicate 95% confidence intervals of the mean over participants.

substantial F_2 drift in both groups of female learners (Fig. 7(a)). In the case of male learners, on the other hand, mean F_2 was found to increase for both ILs and ELs (Fig. 7(b)).

Since the by-vowel models of F_1 and F_2 values described above suggested overwhelmingly that drift in vowel formants occurred throughout the L1 vowel system, developments in the overall height and backness of the vowel system were examined directly by building mixed-effects models on the composite F_1 and F_2 means shown in Figs. 6 and 7 (i.e., means calculated over the eleven basic vowels of the English inventory). Consistent with the above models containing Vowel as a factor, the model of composite mean F_1 for female learners revealed no main effect of Time or Group [$Fs<1.560$, *n.s.*], but a significant Time × Group interaction [$F(4,88)=2.768$, $p<0.05$], while the model for male learners revealed a main effect of Time [$F(4,16)=3.723$, $p<0.05$], but no main effect of Group and no Time × Group interaction [$Fs<1.221$, *n.s.*]. The model of composite mean F_2 for female learners was also consistent with the by-vowel models in showing no significant effects [$Fs<0.744$, *n.s.*]; by comparison, the model for male learners showed a main effect of Time [$F(4,16)=5.645$, $p<0.01$] and no effect of Group or interaction between Time and Group [$Fs<1.766$, *n.s.*]. In short, male learners did not provide evidence of between-group differences in vocalic drift, although this could be due to the relatively low number of male participants; however, female learners provided clear evidence that there was less vocalic drift among ELs than among ILs.[12]

[12] Although the results for males did not provide evidence of between-group differences in vocalic drift, interestingly they provided evidence that learners—males and females alike—were tracking acoustic properties of the L2 input, not gestures, contra direct-realist models of non-native speech perception (e.g., Best, 1995; Best & Tyler, 2007). This is the only coherent explanation for why, although vocalic drift for both genders was convergent with the L2 in terms of cross-linguistic vowel dispersion (as in Chang, 2012), the drift patterns for males and females moved in opposite directions. Under a gestural account supplemented with speaker normalization (see, e.g., Johnson, 2005), male learners would be expected to drift in the same direction as female learners, since the cross-linguistic differences precipitating the drift would be articulatory in nature and, therefore, parallel for both genders. Under an acoustic account, however, male learners would be expected to drift in the opposite direction as female learners, since cross-linguistic acoustic differences between the target Korean vowel system (as produced by female Korean instructors) and the English vowel system are reversed for male English talkers in comparison to female English talkers (see Section 1). Thus, the acoustic account is better supported by the attested drift pattern for male learners. Note, however, that an acoustic level of L2 processing is not able to explain why males drift in both F_1 and F_2, whereas females drift only in F_1, nor why males drift in F_1 and F_2, but not in f_0—disparities suggestive of basic differences between within- and cross-gender L2 input and among the various frequency components of the L2 speech signal.

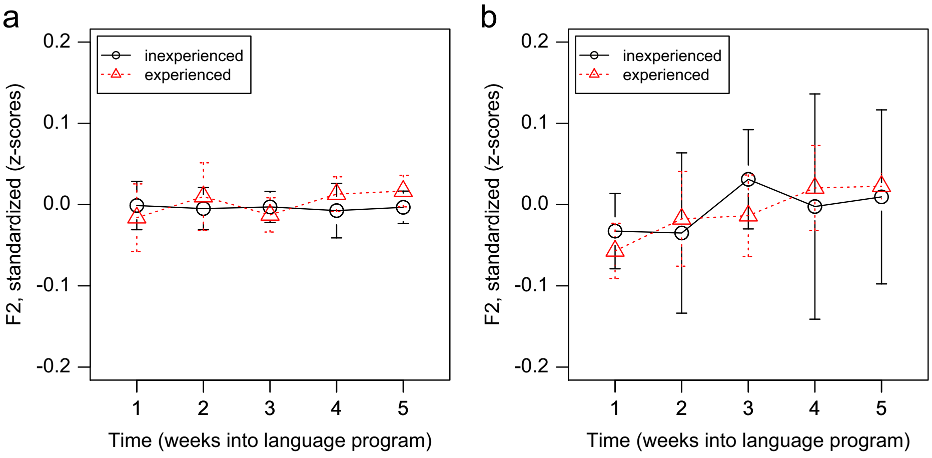

Fig. 7. Mean F_2 of the English vowel system over time for female learners (a) and male learners (b), by group. Inexperienced learners are plotted in circles connected by solid lines; experienced learners, in triangles connected by dotted lines. Error bars indicate 95% confidence intervals of the mean over participants.

4. Discussion

The results of studies 1–2 were consistent in showing that L2 learners with prior exposure to the L2 (ELs) manifested less phonetic drift of the L1 than L2 learners with no prior exposure to the L2 (ILs). In study 1, the VOT of English voiceless stops lengthened less for ELs than for ILs, while the f_0 onset associated with English stops increased less for EL females than for IL females. Furthermore, in study 2, the global F_1 of the English vowel system showed no significant change for EL females, in contrast to the significant decline manifested by IL females. These findings support the hypothesis that the magnitude of L1 phonetic drift during L2 learning is modulated by the relative novelty of the L2 experience: the more novel the L2, the greater the influence of recent L2 experience on the L1.

Before discussing the implications of these findings further, it is important to acknowledge an alternative explanation for the discrepancy between the drift patterns documented by Sancier and Fowler (1997) and Chang (2012). These two studies differed not only with respect to the level of L2 learner, but also with respect to the L1–L2 pair investigated. The L1 and L2 in Sancier and Fowler (1997) were, respectively, Portuguese and English, whereas the L1 and L2 in Chang (2012) were, respectively, English and Korean. Since the VOT norms of the L1 voiceless stop series were different in each case—short-lag in the case of Portuguese, but long-lag in the case of English—the fact that L1 Portuguese VOT in an experienced L2 learner was found to drift less than L1 English VOT in inexperienced L2 learners could be related to the fact that short-lag voiceless stops typically show less variability in VOT than long-lag voiceless stops. However, although differences in L1 phonetic variability provide a reasonable account of the disparity between the results of Sancier and Fowler (1997) and Chang (2012), they do not provide a satisfactory explanation of the disparity between the inexperienced and experienced groups in the current study. For both of these groups, the L1—and, thus, the degree of expected L1 phonetic variability—was the same. Consequently, the persistent differences found between inexperienced and experienced learners here cannot be attributed to differences in L1 phonetic variability.

Instead, the between-group differences found in this study suggest that phonetic drift following from recent L2 experience is reduced as a consequence of familiarization with the L2. To be specific, repeated exposure to an L2 over the course of learning and re-learning habituates an L2 learner to the phonetic properties of the L2, such that further L2 experience becomes less auditorily novel and, therefore, less perceptually salient; because less salient experience is encoded less robustly, this then leads to less cross-over influence of the recent L2 experience on the L1.[13] As alluded to in Section 1, the disparity between effects of recent experience in a novel L2 vs. a familiar L2 seems to be rooted in a bias to direct cognitive resources of attention and memory to novel, rather than familiar, input. In an important sense, this novelty bias is completely logical, since individuals—whether infants or adults—stand to learn more about their world by devoting cognitive resources to novel stimuli. The commonality between infants and adults in this regard is, nevertheless, noteworthy, because it suggests that adult L2 acquirers are subject to some of the same learning principles as child L2 acquirers, consistent with a central tenet of one of the most widely tested frameworks for the analysis of L2 speech, the Speech Learning Model (Flege, 1995).

The current findings, however, are not consistent with the idea that the extent of L2 influence on the L1 is directly related to amount of prior L2 experience, as indexed by L2 proficiency. This idea predicts that L2 effects on the L1 should be most pronounced at advanced stages of L2 learning; on the contrary, the findings of this study suggest that such effects are actually more pronounced at early stages of L2 learning (when the L2 experience is still relatively novel) than at later stages of L2 learning. Moreover, recent research on novice L2 learners of French (Tice & Woodley, 2012) provides convergent evidence from the perceptual domain that the L1 is particularly susceptible to L2 influence at early stages of L2 learning. Nevertheless, the notion of a positive correlation between phonetic drift and amount of L2 experience seems to follow from other empirical data such as those reported by Flege (1987b), who found significant differences in the L1 English production of three groups of Americans varying in terms of L2

[13] An anonymous reviewer proposed an alternative account of the current findings in terms of differences in L2 learning progress rather than differences in L2 novelty. According to this account, ILs show more pronounced L2 influence on the L1 than ELs do because the L2 is undergoing larger changes for ILs (i.e., deviance from L1 norms follows from rate of L2 change). Although the general L2 learning trajectory assumed in this account (an inverse power function) is reasonable, the explanation of the disparity between ILs and ELs in terms of their different locations on this trajectory is based on a dubious link between phonetic parameter *values* (at one point in time) and *change* in phonetic parameter values (between two points in time). Thus, whereas the current account attributes the "too long" VOT values produced for L1 voiceless stops in week 5, for example, to influence from the long VOT values of the perceptually similar L2 aspirated stops, the alternative account must argue that these deviant VOT values are due to influence from information about large changes in L2 VOT. This argument is problematic for several reasons. First, there is no evidence that the linguistic representations drawn upon in speech production (e.g., exemplars) contain information about change in a phonetic parameter (in addition to or instead of information about the phonetic parameter itself), nor is there evidence that such indices of change are calculated online; as such, it is not clear how information about change would be obtained. Second, even if it is assumed that information about change is stored, the storage of this information has no apparent independent motivation. Finally, there is little reason why L2 learners should be more influenced by the rate of change in their inauthentic L2 productions than the null rate of change (i.e., relative stability) of the authentic, target L2 productions they are exposed to in greater frequency through their teachers. Consequently, the current account follows the standard view that speech exemplars contain information about phonetic parameter values—not about changes in phonetic parameter values relative to previous experienced exemplars—which does not support the explanation of phonetic drift disparities in terms of differences in rate of L2 learning.

experience with French. To summarize the relevant results in brief, the amount of L2 influence on L1 VOT was found to increase with overall L2 experience, suggesting indeed that phonetic drift is directly linked to amount of L2 experience.

How, then, can the findings of the current study be reconciled with previous results supporting a positive relationship between phonetic drift and L2 experience? Toward this end, it is important to distinguish between recent experience and cumulative experience, and between short-term changes that follow specifically from recent or ongoing L2 experience and long-term changes that persist after the last, temporally distant L2 experience. As discussed in Section 1 with regard to the findings of Sancier and Fowler (1997), recent L2 experience can exert a measurable effect on L1 production despite an individual's greater cumulative L1 experience because the L2 experience benefits from a recency effect, which serves to increase the overall activation level of the recently experienced L2. Given that Sancier and Fowler (1997) did not draw comparisons with monolingual phonetic norms or collect stand-alone (rather than comparative) ratings of accentedness, the phonetic drift they documented is best described as a short-term change because it is not clear whether their speaker's deviance from L1 norms was still evident after the speaker had spent months back in the L1 environment. In fact, whether phonetic drift generally persists in the long term is an open question, since deviance from L1 norms in advanced L2 learners is typically associated with L1 attrition in an L2 environment (e.g., Mayr et al., 2012; Schmid, 2013); findings of apparently long-term changes in the L1 are thus often confounded with recent L2 experience. Although it is reasonable to think that phonetic drift could persist after an L2 learner is once again immersed in an L1 environment, in this case recent L2 experience would be lacking, so a large amount of cumulative prior L2 experience would likely be required for phonetic drift to persevere.

With the distinction between cumulative experience and recent experience in mind, it is possible to explain the pattern of results in a cross-sectional study such as Flege (1987b) in terms of a decline in phonetic drift in the absence of recent L2 experience (i.e., attrition of L2 influence concomitant with attrition of the L2). Crucially, the three groups of L2 learners of French in this study differed in terms of not only the amount, but also the recency (and, thus, activation strength) of their L2 experience. The group with the most L2 experience consisted of expatriates who had been living in France for several years and for whom French was the "principal language at the time of the study"; the group with intermediate L2 experience comprised instructors of French in the U.S. who "had spent several periods of time in France" and "spoke French frequently in the context of their professional activities"; and the group with the least L2 experience consisted of students in the U.S. who had studied abroad in France for a year, but "had had little opportunity to speak French in the 3–6 months preceding the study" (Flege, 1987b, p. 52). Thus, in comparison to the other two groups, the least experienced L2 group had not only less cumulative L2 experience, but also little recent L2 experience, and was probably undergoing L2 attrition after not having used the L2 for several months. Interestingly, Flege's results showed that these L2 learners did not differ from L1 English monolinguals with respect to L1 VOT, suggesting that any phonetic drift in VOT that might have occurred while they were abroad had subsided by the time of the study. In other words, phonetic drift in this group would have been a strictly short-term effect that did not persevere after L2 use diminished.

Unlike the least experienced L2 group, the intermediate L2 group in Flege (1987b) was frequently engaged with the L2 for professional reasons and, thus, was more likely to show signs of long-term phonetic drift. However, Flege's results showed that although the intermediate L2 group was slightly below English monolinguals with respect to English VOT, this group did not differ significantly from English monolinguals, either. This result suggests that phonetic drift is heavily influenced by the language environment, which has ramifications for both the amount and the continuity of L1 vs. L2 experience. Thus, while the most experienced L2 group (whose time in the L2 environment was lengthy, continuous, and ongoing) showed clear signs of phonetic drift, the intermediate L2 group (whose time in the L2 environment spanned a sizable period, but was interspersed with periods of time spent in an L1 environment) did not. In the current study, by comparison, it was the IL group whose time in the L2 environment was continuous, as this was their first significant stay in Korea and they never left between the start and the end of the language program; in the EL group, on the other hand, nearly everyone had spent significant time in Korea before, and this time was interspersed with periods of L1 immersion back in the U.S. Consistent with this difference between the two groups, more phonetic drift was found in the IL group than in the EL group. Of course, the overlap between time spent in an L2 environment and L2 experience *per se* is far from perfect. Nevertheless, taken together, the findings of Flege (1987b) and the findings of the current study suggest that alternations between periods of L1 and L2 experience tend to reduce the magnitude of L1 phonetic drift by way of allowing the L1 system to recover from the influence of recent L2 experience. Over time, such toggling between the L1 and the L2 is expected to result in progressively smaller effects of recent L2 experience (i.e., "diminishing returns") because the L2 becomes less and less novel.[14]

The progression of L2 learning, however, is associated not only with a decline in L2 novelty, but also with the development of distinct language modes for L1, L2, and mixed L1–L2 processing (Grosjean, 2001). If the "ideal" endpoint of late-onset L2 learning is assumed to be a state of balanced bilingualism in which there is minimal interaction between the L1 and L2, then it stands to reason that part of approaching this state is the development of separate processing modes for the L1 and L2, which would minimize the potential for phonetic drift. Presumably, accessing the L1 and L2 separately becomes easier for L2 learners to accomplish as they gain more experience with both languages. Therefore, it follows that this aspect of L2 development could provide an explanation in and of itself for the disparity in phonetic drift between experienced and inexperienced L2 learners. Note, however, that this explanation is not only compatible with, but not effectively different from, an account in terms of declining L2 novelty, because the ability to access the L1 separately from the L2 is probably dependent upon a decline in L2 novelty. That is to say, the L1 is unlikely to be accessed without influence from the L2 as long as L2 experience continues to receive a cognitive boost due to a novelty effect.[15]

[14] An anonymous reviewer wondered whether there were any studies documenting cross-linguistic influence at higher levels (e.g., the lexical level) that provide converging evidence of decreased L2-to-L1 influence at later stages of L2 learning. There are no known studies that provide this kind of data (e.g., less L2-influenced change in an L1 word's meaning in advanced L2 learners compared to novice L2 learners). The lack of such studies is not surprising, however, since the prediction of L2-to-L1 influence at the lexical level, for example, is not clearly supported by theories of bilingual lexical representation (e.g., Weinreich, 1953). In contrast, the theory driving the prediction of L2-to-L1 influence at the phonetic level (the Speech Learning Model; Flege, 1995) states specifically that L1 and L2 sounds are perceptually related to each other (equivalence classification), and that sounds equated in this way under one category come to mutually influence each other in production. A similar theory of the bilingual lexicon positing that L2 lexical items being acquired are promptly related to analogous L1 lexical items (and that lexical items linked in this way influence each other's meanings) seems reasonable, but the issue of what mutual influence between lexical items—or between morphemes, syntactic patterns, etc.—would look like (much less, how to measure it appropriately) is a non-trivial matter.

[15] An anonymous reviewer proposed an alternative account of the disparity between ILs and ELs based on (within-language) speech accommodation of ILs to their language teachers: in short, unlike ELs, ILs may lack an L2 system and, therefore, be forced to process the L2 with their L1 system, allowing for accommodation of the L1 to L2 input (which would essentially be treated as L1 input). This argument is problematic for several reasons, of which two are mentioned here. First, the idea that ILs were without a linguistic system for the L2 during the time period of the study (and, consequently, just used the L1 system to perceive and produce the L2) is not consistent with their observed behavior in the L2; rather than showing total L1 transfer, ILs' perception and production of L2 contrasts evinces an "interlanguage" (Selinker, 1972) system for the L2 that, although influenced by the L1, is distinct from the L1 system (see, e.g., Chang, 2010b). Second, positing the absence of an L2 system for ILs makes it difficult to account for their ability to comprehend and construct grammatical utterances in the L2 (a language that, in this case, is typologically very different from the L1) well before the end of their language program. In sum, independent evidence suggests it was not the case that ILs lacked an L2 system; rather, they may have lacked a distinct L2 mode.

In a way, then, the intermediate L2 group in Flege (1987b) represents one possible endpoint of the developmental trajectory evident in the comparison between inexperienced and experienced learners in the current study. If these learners continued to be engaged with the L2 after moving back to an L1 environment, the current findings suggest that further periods of L2 experience would result in progressively less influence on the L1, such that these learners might eventually pattern like Flege's intermediate L2 group in showing little trace of recent L2 experience in their L1 production despite high L2 proficiency. It should be emphasized, however, that this is only one of many possible developmental pathways, which obviously differ in terms of several other factors (e.g., quality of input, affective variables; see Flege, 1987a). The L2 speech literature is currently unable to directly address the question of how deviance from L1 norms in adult L2 learners changes over the lifespan because there are, unfortunately, no published studies that track the L1 production of adult L2 learners in the long term—a gap in the literature that highlights the need for careful longitudinal research designed to tease apart the effects of recent and cumulative L2 experience on L1 performance.

5. Conclusion

This paper examined the relationship between L1 phonetic drift and L2 experience, focusing on the role of L2 novelty in modulating the degree of L1 change observed during L2 learning. The results of two acoustic studies of speech production were consistent in showing that phonetic drift was greater for inexperienced L2 learners than for experienced L2 learners, supporting the hypothesis that L2 novelty enhances the influence that recent L2 experience exerts on the L1. Crucially, these findings contradict the notion that L2 effects on the L1 should be greater at later stages of L2 learning, but are consistent with the existence of a novelty bias in aspects of general cognition.

From the perspective of L2 learning, the novelty effect in L1 phonetic drift is intrinsically important because it shows that the L1 (which plays a central role in much of the L2 literature) does not—as is often assumed—remain static during L2 learning, at least at the beginning stages of L2 learning one might think should hardly influence the L1. On the contrary, the novelty effect in phonetic drift argues in favor of viewing the L1 and the L2 both as dynamic systems undergoing continuous change, in early- and late-onset L2 learners alike. This view is consistent with the dynamic systems theory approach to speech production, language acquisition, and other human development (de Bot, 2007; de Bot, Lowie, & Verspoor, 2007; Kelso, Saltzman, & Tuller, 1986; Thelen & Smith, 1994, 2006), although no claims are made here regarding the co-organization of the L1 and the L2 in dynamic systems terms. The main insight offered by the current findings is that change in a dynamic L1 system due to recent L2 experience is related negatively to the degree of prior L2 experience, such that short-term perturbations of the L1 system are seen to decrease, rather than increase, over the course of L2 learning.

Although the central finding in this paper was that experienced L2 learners showed less phonetic drift than inexperienced L2 learners, it is important to emphasize that experienced learners were also found to manifest phonetic drift. This result is in accordance with the findings of Sancier and Fowler (1997) and suggests that there is a strong tendency for even learners of a known L2 (i.e., individuals who have already had significant exposure to the target language) to be influenced by recent L2 experience in production of their L1; they are simply less influenced than learners exposed to an L2 for the first time. As discussed above, much is still unknown about how the L1 and L2 interact over the course of L2 acquisition and attrition, including the role of learning as distinct from exposure, the effect of intensive learning compared to regular instruction, and the influence of day-to-day living in the L2 environment. These are topics that it is hoped will be addressed by future L2 researchers supplementing cross-sectional perspectives with longitudinal analyses in new and creative ways.

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