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English only? Monolinguals in linguistically diverse contexts have an edge in language learning

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Abstract

Accumulating evidence shows how language context shapes bilingual language use and its cognitive consequences. However, few studies have considered the impact of language context for monolinguals. Although monolinguals' language processing is assumed to be relatively stable and homogeneous, some research has shown novel learning through exposure alone. Monolinguals living among linguistic diversity regularly overhear languages they do not understand, and may absorb information about those languages in ways that shape their language networks. The current study used behavioral and ERP measures to compare monolinguals living in a linguistically diverse environment and a unilingual environment in their ability to learn vowel harmony in Finnish. Monolinguals in both contexts demonstrated similar learning of studied words; however, their ERPs differed for generalization. Monolinguals in the diverse context revealed an anterior late positivity, whereas monolinguals in the unilingual context showed no effect. The results suggest that linguistic diversity promotes new language learning. Keywords: language learning, linguistic diversity, ERPs, language exposure

Accumulating evidence shows how language context shapes bilingual language use (Elston-Güttler & Gunter, 2009; Kreiner & Degani, 2015) and its consequences for broader cognition (Green & Abutalebi, 2013). In contrast, little attention has focused on the impact of language context for monolinguals. Monolinguals' language processing is assumed to be relatively stable and homogeneous. Yet an emerging body of research has cast doubt on this assumption. Some studies have demonstrated that monolinguals are less homogeneous than assumed by revealing large individual differences in electrophysiological responses during language processing (Pakulak & Neville, 2010; Tanner & Van Hell, 2014). Others studies have shown changes to the native language in late second language learning, even at early stages of learning (Bice & Kroll, 2015; Kroll, Dussias, Bice, & Perrotti, 2015). Critically, learning can occur even in the absence of attention or intention to learn, with increasing sensitivity to novel languages though exposure alone (Gullberg, Roberts, Dimroth, Veroude,

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& Indefrey, 2010; Saffran, Newport, Aslin, Tunick, & Barrueco, 1997). Monolinguals living in linguistically diverse communities regularly overhear languages that they neither understand nor speak, but may still learn something about their sounds and features. While many past studies have shown that learning can proceed under implicit conditions (Morgan-Short, Steinhauer, Sanz, & Ullman, 2012), few have addressed how the contexts from which learners are drawn may contribute to the pattern of observed results.

Here we report data on the impact of ambient linguistic diversity on the ability of monolinguals to acquire a novel language. We compared monolinguals in two different contexts: a relatively homogeneous unilingual context in which English is the predominant language (central Pennsylvania), and a linguistically diverse community in which multiple languages are spoken (southern California). The opportunity to examine the consequence of the linguistic context for learning was serendipitous, the result of a lab move across the country. Data were collected as part of a larger project in which both bilingual and monolingual speakers were recruited. In the findings that we report, we focus on participants in each context who considered themselves functionally monolingual. At the same time, the study was not designed explicitly to investigate this issue and in the results and discussion that follow we consider some of the resulting limitations.

In a strict sense, linguistic diversity refers to a plethora of different languages spoken within the same context. However, this context does not exist in a vacuum, but instead has many natural consequences for those living within the context that require the definition of linguistic diversity to be extended. For example, those living in linguistically diverse contexts may have greater exposure to non-native languages, more opportunities to learn and practice using other languages, more interactions with accented speakers of the majority language, and changes in the perceived value of knowing more languages or in what it means to be bilingual. Importantly, the ambient nature of linguistic diversity can be largely passive, and does not necessarily require community members to actively engage in learning or seek out these opportunities to be impacted by it. We therefore use the term ambient linguistic diversity in describing how these contexts are different, yet the term encompasses the many other consequences for the speakers in those contexts as well.

Monolingual Differences

The traditional view of the native language assumes very high proficiency arising from a robust and stable language network that is unperturbed by experience. While language experience and variation impact the acquisition process during development (e.g., Foulkes, Docherty, & Watt, 2018; Smith, Durham, & Fortune, 2007), monolingual children have sufficient (~100%) exposure to extrapolate and distill the language to a stable and uniform representation, such that as adults, their language network is relatively similar to other monolinguals' and relatively unmodified by continued exposure. Interestingly, much of the research on language acquisition in children suggests that greater variability and diversity facilitates acquisition (Legate & Yang, 2007). Among adults, differences in native language performance are often ascribed to constraints on cognitive resources, such as working memory (Just & Carpenter, 1992).

Here, we do not argue that the traditional view is wrong; under typical circumstances, speakers learn the native language to high levels of proficiency. However, we challenge certain assumptions within the traditional view based on recent research. Language processing in monolinguals is not uniformly homogeneous (Tanner & Van Hell, 2014), and differences in native language performance are not always a result of constraints on cognitive resources, but may reflect actual differences in proficiency/fluency (Pakulak & Neville, 2010). Native language processing is also not as stable as typically assumed, as it has been shown to change for proficient bilinguals (Ameel, Malt, Storms, & Van Assche, 2009; Dussias & Sagarra, 2007; Van Hell & Dijkstra, 2002) and for second language learners (Bice & Kroll, 2015; Chang, 2012). The findings that the native language changes in the process of learning a new language also suggests that it is open to the influence of past and new experiences. The phenomenon of language attrition is an extreme example (e.g., Schmid, 2013).

One study that exemplified many of these assumptions about monolinguals compared electrophysiological responses while monolinguals processed grammatical and ungrammatical sentences (Pakulak & Neville, 2010). Monolinguals were identified as high or low proficiency based on standardized English proficiency tests. They found that proficiency was related to socioeconomic status (SES), highlighting the effects of past and current experience on the native language. The sentences used high frequency, simple structures, and the grammatical violations were overt insertional phrases (“Timmy can ride the horse at my *his** farm”), leading to the assumption that detection and processing should be relatively automatic and uniform. Despite that, they found individual differences in both behavioral responses and event-related potentials (ERPs), such that the high proficiency monolinguals performed as expected based on the standard of “native-like” processing, whereas the low proficiency monolinguals were less accurate, with neural responses that were less robust and more varied. They concluded that there are significant individual differences in both automatic and controlled syntactic processing among monolingual native speakers, and that it is important to include participants from a wider and more diverse spectrum of society. The variation in language processing described by Pakulak and Neville can also be found in more restricted samples of college-educated adults, suggesting that the variation in monolingual language processing is typical and not simply a reflection of a single factor such as socioeconomic status (Bice & Kroll, in preparation; Tanner & Van Hell, 2014)

Under the traditional view, there should be no reason to expect differences between the monolinguals in Pennsylvania and southern California, especially given that they are all university students. It is only when we consider the possibility that the language system is open to the influence of experience as part of a typical dynamic that presents the potential for differences to emerge. Research on bilingualism has long considered the bilingual’s language system as open to the influence of exposure and usage (especially the less dominant second language), with recent studies revealing the way that different interactional contexts of language use shape both linguistic and cognitive processing (Gullifer et al., 2018; Pot, Keijzer, & De Bot, 2018). In fact, a new wave of initiatives in bilingualism research has focused on the role of interactional contexts (Green & Abutalebi, 2013) and diversity of social language use (Gullifer & Titone, 2019) in bilingual language processing and broader cognition. Ironically, as research has moved toward a focus on variation in bilingual experience (e.g., Baum & Titone, 2014; Fricke, Zirnstein, Navarro-Torres, & Kroll, 2019; Luk & Bialystok, 2013), the call to avoid comparisons of bilinguals and monolinguals has eliminated monolinguals entirely from many of these studies. While this approach has provided critical new insights into how interactional dual-language use impacts bilingual language processing and cognition, it omits the role of monolingual speakers in these communities as well as the possibility that exposure alone may play a significant role.

The current study extended this perspective to monolinguals. We contend that there is a continuum of language experiences between the traditionally dichotomized “monolingualism” and “bilingualism”. While many have argued for a continuum of bilingualism (e.g., Grosjean, 1989), based on language proficiency and the context of dual language use, we take the perspective that this continuum extends to monolingualism as well, in which proficiency is not the defining feature but rather exposure and context. While many of the bilingual initiatives have focused on the consequence for cognitive control, we examined the consequences for new language learning. It would not be too surprising to find evidence that exposure to a language improves one’s ability to learn that language; instead, the current study tested whether exposure to many different languages has the consequence of making the language system better able to learn new languages that are not present in the ambient context.

We have reason to believe that monolinguals in California have more experience with languages other than English than monolinguals in Pennsylvania, in some ways making them less “monolingual”-like. However, we argue that this is precisely the point; the monolinguals in California are nevertheless functionally monolingual with English as their native language. For our purposes, we consider functional monolinguals as speakers who report not being able to speak languages other than their native language much beyond the use of basic greetings and are not actively learning another language. Living in a linguistic context like southern California in which many languages are spoken in the surrounding environment may have the consequence of providing additional exposure or opportunities for practice in a previously studied language, increasing the perceived relevance of bilingualism and language learning, and many other things. Therefore, the role of ambient linguistic diversity necessarily involves these other experiences that are part of living in such a context.

Monolinguals in the current study were trained on vocabulary in a new language (Finnish) to which neither group had previous exposure and which is not part of the linguistic landscape in either location. Critically, Finnish adheres to vowel harmony, a phonological constraint on how words are formed in the language that prevents front vowels (ä, ö, y) from co-occurring with back vowels (a, o, u). We asked whether monolinguals living in a more linguistically diverse context would be better able to implicitly detect, extract, and generalize these novel phonological patterns to previously unencountered words. If the effect of linguistic context is specific to the language being learned, then there would be no reason to expect any differences across the two monolingual groups given that Finnish is not part of the linguistic landscape of California or Pennsylvania. But if exposure to linguistic diversity has the impact of increasing sensitivity to foreign languages in general, then we might find differences in how well the monolinguals in each location are able to learn and generalize a novel phonological pattern like vowel harmony.

Unintentional learning

Research on statistical learning, artificial grammar learning, and incidental learning converges in demonstrating that exposure alone is sufficient to produce low levels of learning in the absence of attention or the intention to learn. Given the potential influence of experience on variation in monolingual language processing, these mechanisms may play important roles in generating variation between monolinguals under different circumstances.

Statistical learning is the cognitive mechanism by which statistical regularities are extracted from the environment to aid in detecting meaningful units, such as segmenting words from the speech stream. In a seminal study by Saffran, Aslin, and Newport (1996), they demonstrated how 8-month-old infants can extract statistical information about transitional probabilities within and between words after only 2 minutes of exposure to a continuous speech stream. Since the initial study, a body of research has shown the robustness of the statistical learning mechanism across language, motor, and visual domains, and across developmental periods in children and adults (e.g., Abla & Okanoya, 2009; Hunt & Aslin, 2001; Saffran, Johnson, Aslin, & Newport, 1999; Turk-Browne, Scholl, Chun, & Johnson, 2009). The underlying idea of statistical learning is that the brain is wired to detect co-occurrences and probabilities in our environments as the first step for developing meaningful representations, and that it is constantly doing so whether we attend to the information or not.

While statistical learning studies have demonstrated how people extract chunks of information (i.e., words and word boundaries) from their environment, research on artificial grammar learning has demonstrated that people can also acquire implicit rule-based patterns between the units of the input without realizing a pattern was present (Reber, 1967). In artificial grammar studies, participants are asked to reproduce written letter strings that adhere to a consistent pattern (i.e., the grammar) under the guise of a memory task, consumer preference task, or some other distraction. After training, they are informed that the letter strings were rule-governed. When asked to select a new letter string on a 2AFC classification task, people perform above-chance at identifying letter strings that follow the grammar, even when accounting for surface similarity to the training items (i.e., chunk strength; Lieberman, Chang, Chiao, Bookheimer, & Knowlton, 2004). The implicit nature of the task is validated by studies showing that amnesiac patients, who cannot form explicit memories of the studied items, can also extract the regularities of the artificial grammar (Knowlton & Squire, 1996). Combined with statistical learning, these mechanisms help explain how people extract meaningful units and relate them to each other through repeated exposure, often without any explicit awareness of doing so.

A related body of research has taken these findings further to show how meaning is assigned to the segmented units. Studies of incidental learning, although more sparse than statistical learning, have shown that adults combine meaningful real-world information to extract the underlying semantic information. Gullberg et al. (2010) asked participants to watch an 8-

minute video of a weather forecast in a foreign language (Mandarin). In the video, certain words were repeated a different number of times, and some were paired with the forecaster's gestures to the weather map while discussing different weather conditions (e.g., sun, rain, temperature). They found that even after such a short exposure, participants were above chance in their ability to map the meaning of the weather conditions to the words. Unsurprisingly, learning was affected by the number of repetitions and gestural information, but sound-to-picture matching was above-chance after just 8 repetitions of a word accompanied by a gesture. Moreover, participants reported no awareness of learning, again demonstrating that exposure alone can produce learning in the absence of awareness or intention.

Sounds are special

While some past research has demonstrated that information about words, word meanings, and grammatical patterns can be extracted in new contexts, another body of research addresses how phonological perception and production is modified by experience over time, particularly early in life. For example, adults who consistently overhear a language as young children (childhood overhearers) and later attempt to re-learn that language, demonstrate native-like phonological perception, but are more similar to novice L2 learners in phonological production and morphosyntax (Au, Oh, Knightly, Jun, & Romo, 2008; Oh, Jun, Knightly, & Au, 2003). Research on international adoptees also shows how very early language experience with no maintenance beyond childhood continues to influence language processing much later in life and remains preserved in the neural patterns of the language network (Pallier et al., 2003; Pierce, Chen, Delcenserie, Genesee, & Klein, 2015; Pierce, Klein, Chen, Delcenserie, & Genesee, 2014). Indeed, phonological perception is tuned at a young age to narrow in on relevant phonological contrasts in the native language (e.g., Kuhl et al., 2006; Werker & Tees, 1984). Tuning occurs slightly later for infants exposed to more than one language (Bosch & Sebastián-Gallés, 1997; Werker, 2012), leaving their phonological systems open to the influence of additional languages longer. Some have proposed that early exposure to such linguistic diversity creates a "perceptual wedge" in the phonological system that has long-lasting linguistic and cognitive consequences (Petitto et al., 2012; Tees & Werker, 1984).

A recent study extended these ideas to show that adults remain sensitive to novel phonological features through passive exposure (Kurkela, Hämäläinen, Leppänen, Shu, & Astikainen, 2019). Monolingual Finnish adults watched silent movies while Mandarin speech sounds (tones) were passively played in the background for two hours at a time over the course of four days. After the exposure, their ERP responses for change detection (mismatch negativity, P3a) and attention (P3b) to novel speech sounds and non-speech sounds (sinusoidal waves) were enhanced, although their behavioral discrimination did not change. They emphasized the importance of repeated exposure with the potential for sleep consolidation as critical for successful learning. These results are among the first to demonstrate such effects in adults.

In the current study, the ability to perceive the distinction between the front and back Finnish vowels is a form of phonological perception. The California monolinguals were likely to have been exposed to linguistic diversity from a young age, but not specifically to Finnish phonological contrasts. Here we ask whether the linguistic diversity of the ambient environment has the effect of making learners’ phonological systems more flexible, such that they may be faster to tune in to the novel meaningful contrasts in a completely unfamiliar language.

Current study

The combination of research on unintentional learning with the special sensitivity of the phonological system led to a prediction that ambient linguistic diversity might promote the ability to learn novel, meaningful phonological contrasts in an unfamiliar language. The front/back vowel distinction in Finnish and its consequences for word formation and morphosyntax is a unique feature not present in the predominant languages spoken in southern California (e.g., Spanish, Mandarin, Cantonese, Vietnamese, Tagalog, Korean), nor in the languages that participants reported studying in high school (see Table 1), making it a feature that is equally novel to the monolinguals in Pennsylvania and California. Yet if ambient linguistic diversity has the effect of tuning the linguistic system of speakers in those contexts, including monolinguals, then we might expect monolinguals in diverse and homogeneous contexts to differ in their sensitivity to such a novel contrast during new learning. Therefore, if we find any differences in sensitivity to the novel Finnish vowel contrast between the monolinguals in each context, we can be confident it is not a result of previous exposure, but is more likely to be related in some way to the different contexts.

In the current study, participants knew they were explicitly learning Finnish vocabulary words, but were also told to try to learn about “what kind of words belong or don’t belong in the Finnish language”. In this way, they were required to explicitly learn vocabulary and implicitly learn the vowel harmony rule. Large individual differences often emerge under implicit conditions of learning (Batterink & Neville, 2013), making it perhaps more sensitive to any differences between these groups. In addition to making the nature of the learning task quite difficult to improve our sensitivity to detect effects, we employed electrophysiological measures of brain activity (ERPs). While most word-level manipulations in language studies typically elicit an N400 component, associated with lexico-semantic retrieval from long-term memory (for review, see Kutas & Federmeier, 2011), we may also observe other ERP effects given that the participants were asked to make a lexical decision about words for which they have no semantic mapping. Nevertheless, the expectation was that the behavioral and/or ERP measures should reveal differences between the monolinguals residing in two different linguistic contexts in their ability to detect the pattern of vowel harmony and use it to distinguish between real Finnish words and vowel harmony violations.

While the difference between the California and Pennsylvania monolinguals on which we are focused is linguistic diversity, the two contexts differ in other ways that were not possible to match closely. For example, we cannot say with certainty whether the exposure to ambient languages is the primary factor driving any observed differences, more frequent interactions with speakers who have varying degrees of accented English, sociocultural attitudes towards learning new languages, or any of the other natural consequences of linguistic diversity. Perhaps most critically, SES is a factor that differed across these different university communities. Monolinguals in Pennsylvania came from higher SES backgrounds than those in California. That difference itself might lead to a prediction that the monolinguals in Pennsylvania, like the higher proficiency and higher SES participants in Pakulak and Neville (2010), would outperform the monolinguals in California.

Methods

Participants

A total of 34 monolinguals participated (21 females). Of those, 18 were sampled from the Pennsylvania State University (PSU) community and 16 were from the University of California-Riverside (UCR) community. Inclusion criteria were to be native speakers of English between the ages of 18–35 with normal or corrected-to-normal vision, not colorblind, and no history of concussion, epilepsy, neurological, or speech disorders. Participants must have reported being functionally monolingual; that is, not being able to speak any other languages. However, most of the participants had some experience/exposure to languages other than English, whether through foreign language classes or outside the classroom.

Participants were recruited as part of a larger project that also included early and late bilinguals who spoke both English and Spanish. As part of the recruitment process, potential participants were asked screening questions, and those who reported learning Spanish in the home environment were included in the early bilingual group, preventing the inclusion of low proficiency heritage speakers of Spanish in California as being identified as monolingual. Group differences in non-native language experience can be found in Table 1.

The US Census and university demographic data provide additional evidence that these two contexts differ with respect to linguistic diversity. Pennsylvania is a predominantly unilingual English environment; the population of Centre county consists of 85.4% white (not Hispanic/Latinx) people, and only 10.3% of people in Pennsylvania live in homes with languages other than English (U.S. Census Bureau, 2015). At Penn State, approximately 16% of the student body is comprised of international students, primarily from China, India, and South Korea, although the languages spoken in those respective countries are rarely heard in daily public discourse. In contrast, only 35.4% of the population of Riverside county is white (not Hispanic/Latinx), and 44% of people in California above the age of 5 live in households with a language other than English (U.S. Census Bureau, 2015), which is among the highest level of non-English households in the continental US.

Our language history questionnaire asked the participants to report any languages they have studied or can speak (including English), such that they can produce more than basic greetings, and were asked to estimate what proportion of the time they were exposed to each reported language. In our sample, monolinguals in California reported significantly higher levels of exposure to non-English ($M = 10.44\%$) than monolinguals in Pennsylvania ($M = 0.61\%$; $t(15.33) = 2.69$, $p = .02$). This is an estimate of how much exposure they had to languages they had reported studying; although none of our questionnaires directly assessed it, the difference between contexts with respect to the amount of exposure to unknown languages is likely much larger.

While these different samples allowed us to investigate the impact of ambient linguistic exposure, it also included a confound of SES. SES was assessed by asking for mother's education of the participants, a common proxy for SES (Ensminger & Fothergill, 2003), but evidence is also found in comparing the university demographic data. The monolinguals in California came from lower SES backgrounds than monolinguals in Pennsylvania (see Table 1). This is not surprising, as UCR has one of the highest rates of first-generation college students in the country. In Centre county (PSU), 43.7% of the population has a bachelor's degree or higher levels of education, and in Riverside county (UCR), that level drops to 21.5% (U.S. Census Bureau, 2017). In 2017, 57% of UCR students were first-generation students compared to the U.S. university average of 36% and 16.8% of PSU students. Federal Pell Grant assistance is awarded to students from low-income families making less than $50,000 a year, which were awarded to 57% of the UCR students and 45% of the PSU students. Importantly, the SES differences would, if anything, bias the results such that monolinguals in Pennsylvania might be advantaged in learning. Given that the hypothesis is that the monolinguals from California might reveal a better ability to acquire the novel Finnish vowel harmony feature, any observed effects in support of the hypothesis may therefore be underestimated to some degree.

In a debriefing form at the end of the experiment, both groups reported similar experiences as part of the experiment, and similar motivations for why they remained monolingual or stopped taking foreign language classes (see Figure 1). In terms of their perception of the experiment, there were no differences in ratings for how much they enjoyed learning Finnish ($t(30) = 0.66$, $p = .51$), how difficult they found it to be ($t(30) = 0.73$, $p = .47$), and how good they are at learning languages compared to other people they know ($t(30) = 0.47$, $p = .64$). Overall, the monolinguals in each location had similar motivations for remaining monolingual, citing the time commitment and difficulty of learning a new language.

Finnish Materials—A total of 120 Finnish words were used across the training and testing paradigms. Each of the words was a concrete noun, 63 of which contained back vowels (e.g., **o**men**a**, meaning apple) and 57 had front vowels (e.g., k**ää**rme, meaning snake). A additional set of 120 Finnish words was used to create the vowel harmony violations by swapping up to half of the vowels in a real Finnish word with vowels of the opposing type (ä, ö, y were swapped with a, o, u; e.g., laiva, meaning ship, changed to läiva). The real words were split into four lists of 30 words that were matched in word length, the number of front/back vowels, and the number of neutral vowels (which essentially create noise in the signal). One list comprised the words taught to participants on the first day of training (studied words), one list comprised the words taught on the second day of training (studied words), one list was a set of words that were presented on both days of training (studied words), and the remaining list was never presented during training but reserved to test generalization of the vowel harmony rule at test (novel words). The vowel harmony violations were also split into three lists. One list of the violations contained 45 words that were presented on the first day of training (studied violations), another list of 45 words was presented on the second day of training (studied violations), and the remaining 30 violations were withheld to test for generalization during test (novel violations). The lists of violations were matched to the lists of real words in word length, the number of front/back vowels, and the number of neutral vowels, such that the only distinguishing feature between real Finnish words and violations was whether they adhered to the vowel harmony rule. All participants were presented with the same lists on the same days.

Ninety clipart images were used during training to convey the meaning of the words taught during training. Additionally, three native speakers of Finnish recorded the pronunciation of each of the real words used during training. Two of these speakers were Finnish foreign language instructors at the University of Wisconsin-Madison, and the third was an international student from Finland at the same university. These native speakers verified that the images used to depict the meaning of each of the words were valid, and that the vowel harmony violations were, indeed, nonwords that violated the pronunciation rules of the language, rendering them unpronounceable.

Design and Procedure

Finnish Training—The training paradigm was created with the goal of presenting learners with positive and negative evidence of the vowel harmony rule, without explicit instruction, while also teaching them the Finnish vocabulary words, meanings, and pronunciations. Participants were told to learn the Finnish words, but to also learn what kind of words belong or do not belong in the Finnish language. Vowel harmony violations were referred to as “fake” Finnish words.

Each training trial began with a ready screen that remained for up to four seconds, or until the participant pressed the spacebar. Upon advancement, a single word appeared in the center of the screen. Participants had to indicate whether they believed the word was a real or fake Finnish word by pressing one of two buttons. Feedback was immediately provided. Regardless of accuracy, any real Finnish word was followed by an additional screen that presented the participant with the written word, a picture of the word’s meaning in the center, and the pronunciation of the word by one of the three native Finnish speakers. Participants could take up to 5 seconds to study. Before the 5 seconds had transpired, participants were required to mimic the pronunciation of the Finnish word. Figure 2 depicts the progression of a training trial.

Training consisted of three blocks of learning followed by one block of recognition, with a break in between each block. Each block of training contained 60 real Finnish words intermixed with 15 vowel harmony violations. The 60 real words were repeated, once per block, whereas the violations were novel in each block. The imbalance of real and fake words and the lack of repetition of the fake words was included because negative evidence is rarely presented in more naturalistic learning scenarios, but also to reduce the probability of forming memory traces for the fake words that would lead to falsely thinking they were real words.

The recognition test was a lexical decision task containing all the real and fake Finnish words presented during that day’s training (60 words, 45 violations), in which participants were instructed to press one button if they knew the word was a real Finnish word, and another button if they did not know the word or knew it was a fake Finnish word. Given the imbalance between real and fake Finnish words used in each block, discrimination scores were converted to d' scores for analyses to reduce response bias.

Finnish Testing—The test occurred 1–2 days following the second day of training, and consisted of a review and the final test. The review was a variation of translation recognition that provided feedback to help the participant remember and review the words they had learned. Each trial began with a ready screen for a maximum of 4 seconds or until the space bar was pressed. One of the 90 studied pictures appeared in the center of the screen for one second, at which point a word appeared above the picture. Participants had to indicate with a button press whether the word that appeared above the picture was the correct word for the picture. NO trials consisted of other real words and previously presented vowel harmony violations. Each picture appeared twice, once as a YES trial and once as a NO trial, and participants were told this during instructions as a means to allow them to indirectly re-learn some of the words they may have forgotten.

The final test was another lexical decision task similar to the recognition test at the end of each training session, but with different instructions. The final test included: all 90 studied real words, all 90 studied vowel harmony violations that were presented throughout training, plus the additional 30 words and 30 violations reserved to test generalization. Participants were instructed to press one button if they knew the word was a real Finnish word, or if they thought it could be a real Finnish word, and another button if they knew it was a fake Finnish word or thought it could be fake. They were told that the final test would include real and fake Finnish words they had never seen before, and were warned that the fake Finnish words they encountered during training would seem more familiar than the real Finnish words that they had not studied, so that familiarity would not be a good way to determine their response. Figure 2 depicts several different types of test trials.

EEGs were recorded throughout the review and final test. Events were time-locked to the presentation of the words/violations during the final test.

Design—The participants and tasks reported here were part of a larger study examining individual differences in language processing and language learning. The tasks reported in the current study were nested within a larger experimental design, reported in full in Bice and Kroll (in prep). Of relevance for the current study, participants completed the language history questionnaire in the first session of the study, the Finnish training task during the second and third sessions, and during the fourth session they completed the Finnish testing task in addition to the operation span task and a semantic verbal fluency task in English. Other tasks that participants completed but are not reported here included a grammatical processing task performed during the first session and two domain-general category learning tasks performed during the second and third sessions.

EEG Acquisition and Preprocessing

Pennsylvania State University—EEGs at PSU were acquired from 30 Ag/AgCl scalp electrodes placed in accordance with the 10–20 system, 4 electro-oculogram (EOG) electrodes to measure vertical and horizontal eye movements, and one on-line reference electrode placed on the right mastoid plus another electrode on the left mastoid for later re-referencing. Impedances were kept below 5 kΩ. The signal was amplified using a Neuroscan SynAmps2 amplifier with a 24-bit analog to digital conversion (Compumedics NeuroScan, Inc., El Paso, TX) at a 500 Hz sampling rate and filtered with an online high-pass filter of .01 Hz.

University of California-Riverside—EEGs at UCR were acquired from 32 Ag/AgCl scalp electrodes placed in accordance with the 10–20 system and 2 bipolar electro-oculogram (EOG) electrodes to measure vertical and horizontal eye movements. An on-line reference electrode was placed on the right mastoid and another electrode placed on the left mastoid for later re-referencing. Impedances were below 10 kΩ before recording. The signal was amplified using a Brain Vision actiCHamp amplifier with a 24-bit analog to digital conversion (Brain Products, München, Germany) at a 500 Hz sampling rate and filtered with an online high-pass filter of .01 Hz.

All data were pre-processed offline using Brain Vision Analyzer 2 (Brain Products, München, Germany). Electrodes were re-referenced to the average of both mastoids and filtered using a 0.1–30 Hz IIR Butterworth filter. The data collected at UCR also had a 60 Hz notch filter applied to the EOG channels. An independent components analysis (ICA) was used to remove the components capturing eye movements (blinks, horizontal eye movements). In the uncommon case that a single component could not be determined to capture the eye movements, then no components were removed and instead the normal artifact rejection steps were used. In all cases, the first pass of artifact rejection was meant to remove any trials in which the participant was blinking or moving their eyes during the exact moment a stimulus was presented. Within 100 ms of the stimulus presentation (−100 to 100ms), we used a moving window of 150 ms with a 50 ms step to reject any trials in which the EOG electrodes deviated by +/− 200 μv. After the EOG trials were rejected, a whole-head artifact rejection moving window was applied to the other electrodes of interest with parameters adjusted to capture each participant's artifacts, but the default settings were +/− 100 μv within 200 ms, or any single step >50 μv. All artifact rejection steps were manually verified. ERPs were baseline-corrected across conditions from −200 to 0 ms, and then averaged by condition. No participants had fewer than 22 trials per condition in the novel violations condition or fewer than 26 trials in the novel words condition out of a maximum of 30. For the monolinguals in Pennsylvania, the studied words had on average 87 trials per participant out of a possible maximum of 90, the studied violations had 86.83 trials, the novel words had 28.94 trials, and the novel violations had 28.72 trials. For the monolinguals in California, the studied words had on average 88.38 trials per participant, the studied violations had 87.56 trials, the novel words had 29.44 trials, and the novel violations had 29.5 trials.

Results

Behavioral Results from Language Learning Task

To examine the behavioral results of the language learning task, we considered the trajectory and outcome of learning separately, as each may reveal differences in the learning process (trajectory) and/or the extent of knowledge acquired and retained (outcome). At the end of each training session, participants performed a lexical decision task containing all the words and vowel harmony violations that they encountered during that training session, essentially serving as a recognition test. To examine the trajectory, we compared their performance on these recognition tests at the end of the training sessions. To measure the outcome, we compared their performance on the final lexical decision task that took place 1–2 days following the second training session. The final test contained all studied Finnish words and all previously encountered vowel harmony violations from the two training sessions (hereafter: studied words and studied violations), in addition to novel Finnish words and violations that they had never before encountered (hereafter: novel words and novel violations). Performance on the trajectory and outcome lexical decision tasks was transformed to d` scores to be submitted to further analyses.

To evaluate the trajectory of learning, we submitted the d` scores to a 2 (within-subjects: Session) × 2 (between subjects: Group) mixed-effects ANOVA. A main effect of Session ($F(1, 33) = 45.25$, $p < .01$) revealed that participants had better performance in the second training session ($M = 2.03$, $SD = 0.67$) than in the first training session ($M = 1.46$, $SD = 0.49$). There was not a main effect of Group ($F(1, 33) = 0.70$, $p = .41$), nor was the interaction significant ($F(1, 33) = 0.85$, $p = .36$), suggesting that the two groups learned at a similar rate during training.

To evaluate the outcome of learning, we submitted the d` scores from the final lexical decision test to a 2 (within-subjects: Studied vs. Novel) × 2 (between-subjects: Group) mixed-effects ANOVA. As expected, a main effect of item type ($F(1, 32) = 244.49$, $p < .01$) revealed that performance was much higher for studied items ($M = 1.52$, $SD = 0.58$) than novel items ($M = -0.13$, $SD = 0.53$). There was not a main effect of Group ($F(1, 32) = 0.46$, $p = .5$), nor was the interaction significant ($F(1, 32) < .01$, $p = .87$). The lack of a significant difference at test suggests monolinguals in both locations had not learned different amounts (studied items) or different types (generalization) of information (see Figure 3).

Although none of the differences in performance between the two groups was statistically reliable, the pattern of behavioral results was contrary to what we predicted. Overall, the monolinguals in Pennsylvania had consistently slightly higher performance during learning and at test. Neither group demonstrated any ability to generalize the vowel harmony pattern from the studied words to novel words, as shown by chance-level performance for the novel words at test. This was perhaps unsurprising given the difficulty of the learning task and the subtlety of the vowel harmony distinction for speakers whose native language does not contain such a meaningful contrast.

ERP Results from Language Learning Task

Studied Items—In order to conduct a whole-head ANOVA for the ERP effects at test for studied items, we first had to select a time window of interest. If the Finnish words were represented lexically or semantically, an N400 might be expected. However, upon visual inspection of the waveforms, the component was clearly not an N400. Instead, previously studied words revealed a large, positive deflection in posterior electrodes in the 400–800 ms time window as compared to previously encountered violations. The ERP effects appeared more similar to the late positive component (LPC) effects often reported in studies of memory recall and recognition (Bakker, Takashima, Van Hell, Janzen, & McQueen, 2015; Wolk et al., 2006). In those studies, previously studied items presented at test that elicited a "recall" response (as opposed to a "recognize" response or "novel" response to indicate that they had never seen the item before) reveal a large, positive deflection in the 500–700 ms time window that was slightly left-lateralized in the posterior electrodes.

We submitted the ERP mean amplitude values for studied words and studied vowel harmony violations in the 500–700 ms time window to a whole-head ANOVA. We included a 3-level anterior/posterior factor (Anterior: F3/4, F7/8, FC3/4, FT7/8, Fz; Central: C3/4, CP3/4, T7/8, Cz; Posterior: P3/4/7/8, O1/2, TP7/8, Pz, Oz) and a 3-level laterality factor (Left: all odd-numbered electrodes, Midline: all midline electrodes ending in -z, Right: all even-numbered electrodes) as within-subjects factors along with the item type (studied word, studied vowel harmony violation). The between-subjects variable was group (California, Pennsylvania). Greenhouse-Geisser sphericity corrections were applied to any effects with two or more degrees of freedom in the numerator. Here, we only report main effects involving item type and interactions that involve the variables of interest (item type, group), and report the corrected p-values from the GG correction when necessary.

A main effect of Type ($F(1, 33) = 20.72$, $p < .01$) revealed that studied words ($M = 3.05$, $SD = 3.62$) were significantly more positive than the studied violations ($M = 2.05$, $SD = 3.06$). Item type significantly interacted with the anterior/posterior factor ($F(2, 66) = 21.33$, $p < .01$) and with the laterality factor ($F(2, 66) = 5.2$, $p = .01$), which were qualified by a higher-order interaction between type, anterior/posterior, and laterality ($F(4, 132) = 14.26$, $p < .01$). Follow-up analyses revealed that the distribution of the effect was maximal over posterior electrodes, left-lateralized, and was also present in central electrodes. Finally, a marginal Group x Type x Anterior/Posterior interaction was found ($F(2, 66) = 2.31$, $p = .06$). Follow-up analyses revealed that in the posterior electrodes, the effect was equally present for both groups, but the effect reached into anterior electrodes for the Pennsylvania monolinguals and not the California monolinguals. See Figure 4 for waveforms and topographies.

Novel Items—The behavioral results revealed d` scores no different than chance performance, suggesting that neither group of participants were able to detect the vowel harmony violations and generalize the pattern to novel items. However, neurophysiological measures of learning have been shown to outpace behavior (McLaughlin, Osterhout, & Kim, 2004), leaving the possibility that the ERP results may reveal sensitivity to the distinction between Finnish words and vowel harmony violations despite the lack of behavioral performance.

The approach to conducting analyses on the ERPs for the novel items was slightly different from the approach for the studied items. Unlike the studied items, for which an N400 component or LPC were probable candidates to appear among the results, we were not expecting to find any specific ERP component for the novel items. Instead, we sought to find any differences between the waveforms that would suggest that monolinguals were processing the two types of stimuli as distinguishably different. A visual inspection of the waveforms revealed different potential effects in each group. To remain agnostic, we conducted cluster-based permutation tests for each group separately. Cluster-based permutation tests are a special kind of permutation test that helps to detect patterns of data, such as effects that last longer in time or are present in adjacent electrodes. Permutation tests are non-parametric, and instead create hypothetical distributions of the observed data by shuffling the condition labels; if the H0 is true and there is really no difference between the distribution of observed data between two conditions, then the condition label itself should not matter, whereas if the condition does create a difference, then the observed pattern of data should be unlikely to be reproduced when the condition labels are shuffled. For our cluster-based permutation tests, we reshuffled the condition labels (word vs. nonword) and recalculated the difference wave for each reshuffling. Each difference wave was used to create a t-wave by calculating the t-value at each time point in the ERP (t = mean(diff wave)/(st.dev.(diff wave)/(sqrt(n subjects))). Clusters were identified as time points in the t-wave within 50ms of each other and within the same region (left anterior, medial anterior, right anterior, etc.) that were all above the critical t-value, which is derived from t-statistics based on the degrees of freedom. We then permutated the data 1000 times, taking the largest cluster mass from each permutation to add to the distribution, for a minimum possible p-value of .001. The results of the cluster-based permutation tests revealed two marginally significant clusters in the California monolinguals and no significant or marginally significant clusters in the Pennsylvania monolinguals. Figure 5 shows the permutated distribution of cluster masses for each group and where the observed cluster masses fall within each distribution.

The two clusters in the California monolinguals were found in left anterior electrodes from 476–766 ms (p = .055) and in left central electrodes from 482–766 ms (p = .073). For the California monolinguals, the words were marginally more positive than the violations in these clusters. The magnitude of the effect was quite large; it reached about 3.3 μv at its maximum. See Figure 6 for waveforms and topographies.

Unlike the studied items, for which the behavioral data led to the expectation of differences in brain activity given the higher than chance performance, it was much less clear as to whether either group would demonstrate neural sensitivity to the distinction between previously unseen Finnish words and vowel harmony violations. The ERP results, however, revealed two marginal effects that suggest the California monolinguals’ brains were reliably distinguishing between the novel words and nonwords. Indeed, the observation that we found any potential differences in the ERPs within the difficult context of the task and the lack of behavioral results was notable and warrants future investigation.

Discussion

In the current study, we asked whether linguistic diversity in the ambient environment significantly impacts a person’s ability to learn a novel language *not* present in that environment. We compared monolingual speakers in central Pennsylvania with those in southern California, locations with different populations and linguistic profiles. The main finding was that the monolinguals in California became sensitive to a subtle, non-native phonological contrast during language learning, whereas the monolinguals in Pennsylvania did not, suggesting fundamental differences in how the monolinguals in each location learned. While this finding needs to be qualified in a number of respects, the difference between the two groups itself holds important implications for language processing and language learning, bilingualism, and more generally for the impact of context on cognition.

The monolinguals were asked to learn Finnish, a language that is absent in their surroundings, and a language that, unlike English, adheres to a special phonological pattern called vowel harmony. In Finnish, front vowels (ä, ö, y) and back vowels (a, o, u) are phonemically distinct and cannot co-occur within the same word. Therefore, monolinguals in this study had to implicitly acquire the distinction between the front and back vowels, and then use that distinction to extract the vowel harmony pattern to discriminate novel words they had not previously encountered.

The behavioral results of the learning task revealed that both groups were able to learn the form-meaning mappings of studied Finnish words, but neither group was able to reliably generalize the vowel harmony pattern to novel words. However, the pattern of brain activity, measured via EEGs, revealed more sensitive information. Both groups had significant ERP effects for the studied words, although a marginal interaction suggested that the effect in the Pennsylvania monolinguals was more broadly distributed whereas the effect in the California monolinguals was more restricted to the posterior sites. These results are generally in line with the behavioral findings; both groups demonstrated the ability to distinguish between studied words and violations in behavior, and the Pennsylvania monolinguals had numerically (but not statistically) higher performance.

In contrast, the behavioral results for the novel words, which were no better than chance, might lead to the expectation that the monolinguals were not at all sensitive to the distinction between the novel words and vowel harmony violations. This was true for the Pennsylvania monolinguals, whose ERP results for novel words and nonwords revealed no significant or marginal differences in the waveforms. In contrast, the monolinguals in California revealed two marginally significant clusters in their ERP effects that reflected a larger positivity in the 480–760 ms window over left anterior and left central electrodes. While the effects have no functional connection to established ERP components, the morphology of the waveforms was actually quite similar to their waveforms for the studied words and violations, but the effect was in fact numerically larger in novel items than for the studied items. The observation that the ERP deflection was found in the real words rather than to the violations may imply that the California monolinguals learned something about what forms the real words, rather than something about what made the “fake” words different. Regardless of the functional interpretation of the component, the fact that their brain activity distinguished the two types of stimuli suggests that they were sensitive, and that the Pennsylvania monolinguals were not.

There are potential factors that it was not possible to control in the current study that could have impacted the results, including SES. However, if SES were the primary factor, then Pennsylvania monolinguals *should* have outperformed the California monolinguals. The effects of SES differences have broad and robust cognitive consequences (e.g., see Raizada & Kishiyama, 2010). Therefore, in many ways, one might expect larger differences between the monolingual groups based on SES factors alone, in favor of those living in Pennsylvania.

Although SES differences have not been directly linked to second language learning or learning more generally, particularly in college-age students, the differences in SES may have had other consequences for our participants (e.g., access to resources or opportunities) that would only have been biased in favor of the Pennsylvania students. Instead, we found that the California monolinguals became sensitive to a critical phonological distinction in Finnish.

The ERP differences between the two monolingual groups suggests that ambient linguistic diversity, and the various other factors co-involved in linguistic diversity, may have a positive impact on new language learning. As noted, there are other factors that may have contributed to these differences. Even if ambient linguistic diversity is the factor driving this effect, we cannot tell from these data alone whether it is simply overhearing foreign languages, the requirement to interact regularly with non-native speakers of English, or actual differences in past language learning experience. Living among linguistic diversity not only increases the number of interactions with accented speakers, but also may have consequences for the regional dialect. A wealth of studies have examined how the speech sounds in one’s native language or native regional dialect impact the sensitivity and perception of non-native speech sounds (e.g., Conrey, Potts, & Niedzielski, 2005; Williams & Escudero, 2014). While these studies have primarily focused on specific sounds that do or do not overlap across dialects or languages, it is possible that the linguistic diversity increases the heterogeneity of speech sounds in the environment in ways that impact the phonological inventories of those speakers.

Another important implication of these results concerns the term “monolingual”. Many studies would exclude the monolinguals from California in our sample for not being what one might consider “pure” monolinguals. However, in California and in other areas of the country (particularly urban areas), the linguistic landscape sampled from our California population is very characteristic of typical monolingual experience. By excluding these monolinguals from our samples, we often miss the cognitive, linguistic, and social consequences of living in such diverse environments. In our sample, similar proportions of the monolinguals in each location reported experience with other languages. Of the California monolinguals, 75% reported experience with another language, and 72% of the Pennsylvania monolinguals had experience with learning another language. What differed was that California monolinguals had on average earlier and more exposure to their reported languages than the Pennsylvania monolinguals, resulting in higher self-ratings in those other languages. From the data we report, we do not know whether earlier and/or continued exposure is a critical factor.

Would the California monolinguals be better able to learn a new language in a classroom setting? In the current study, we found similar results for the two groups for studied items, whereas the differences emerged in more implicit learning of unattended features. Additionally, the differences emerged in the neural measures but not behavioral measures. While it is not clear why the effect would present in brain activity but not in behavior, a growing number of studies have reported such patterns (e.g., Bice & Kroll, 2015; Kurkela et al., 2019; McLaughlin et al., 2004), suggesting that the two measures are capturing different aspects of the learning process. The research on childhood overhearers who later attempt to learn the language as an adult reveals quite specific effects, with advantages in learning phonological, but not grammatical, aspects of the language (Au, Knightly, Jun, & Oh, 2002; Au et al., 2008). Similarly, research on international adoptees found that adults who were adopted at a young age into a new language context show very distinct neural patterns of processing (Pallier et al., 2003; Pierce et al., 2014), but none have examined whether those neural patterns translate directly into a behavioral advantage for new learning. In fact, while international adoptees have been found to have special maintenance of the language they were exposed to at birth, other research has found the effects to be specific; they do not generalize to phonological perception for other languages (Choi, Broersma, & Cutler, 2018). The effects of ambient linguistic diversity may prepare individuals for some, but not all, aspects of new language learning.

The results also speak to the role of immersion in language learning, but raise questions about the nature of immersion. Past studies suggest that immersion in the second language benefits learning (e.g., Freed, Segalowitz, & Dewey, 2004; Linck, Kroll, & Sunderman, 2009). However, most studies on language immersion examine late bilinguals who are intentionally learning the language and who are moving from a relatively unilingual context into an immersion context that may itself be unilingual or linguistically diverse. To our knowledge, the past research has not examined the consequences of linguistic diversity within the immersion context. Given the serendipitous nature of the present study, we do not have systematic information about how long the monolinguals have lived in each place, although we suspect that the majority of those living in California had been immersed in a linguistically diverse context for most of their lives. In future research it will be of great interest to determine whether openness to new learning is created by immersion in a diverse environment itself or whether specific features of the context or language experience are critical.

The biggest limitation of the current study was that the opportunity to collect these data from such different locations was serendipitous. This lessened our experimental control and ability to report many variables and factors that could have been useful for disentangling the source of the effects. In retrospect, our conclusions would be stronger if we had been able to limit the California sample of monolinguals to only those who had been living in the context for most or all of their lives; while we suspect the majority of our sample fit that description, we do not have empirical measures to support such claims. Nevertheless, if our sample did include monolinguals who had only recently moved to that context, then the effect would likely be smaller, leading to greater noise in the signal or an underestimation of the effect. Likewise, we would have liked to have been able to ask more detailed questions regarding language experiences, exposure to languages other than those that the participants reported having previously studied, performance in foreign language classes, socioeconomic status, etc. However, despite the lack of empirical measures to describe how these groups may differ, we fully believe that the differences between contexts and the effects on language learning reported here are true and representative. We implore future research to further investigate how context modulates variation in monolingual speakers under more controlled conditions.

The current results support and extend the many new initiatives in bilingualism focusing on the role of interactional contexts and diversity of social language use to include monolingual speakers as well. The essence of these models is that the way we use and are exposed to language shapes cognition. We found that different language contexts potentially changed language learning for monolingual speakers. Like studies of bilingual language processing, the results suggest that language experience lies on a continuum between monolingualism and bilingualism. The results also provide a fruitful new avenue for investigations into adult language learning and has important implications for our understanding of the role of experience and immersion in native language processing. Considering the consequences of the ambient environment together with other sources of individual variation will frame an important new agenda research on language, learning, and cognition.

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- Ambient linguistic diversity impacts monolinguals’ language learning
- Living in diverse contexts facilitates sensitivity to sounds in novel language
- Differences found in EEG measures but not in behavior
- Learning a new language could be improved through exposure to other languages

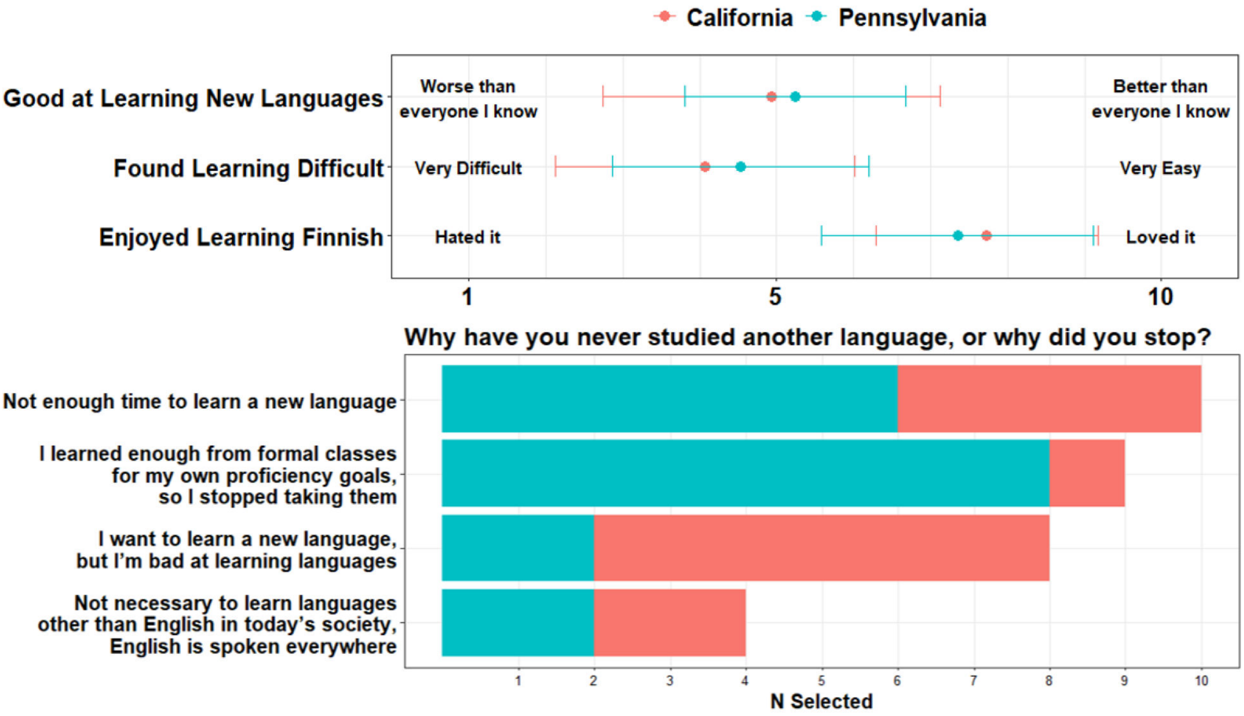

Figure 1.

Data from the debriefing survey administered at the end of the study. Points on the rating scales (top) represent the mean rating for each group and the error bars represent one standard deviation. Bottom graph shows the number of monolinguals in each location who selected a given option in response to the question posed in the title of the graph. Participants had the option to select more than one option if desired.

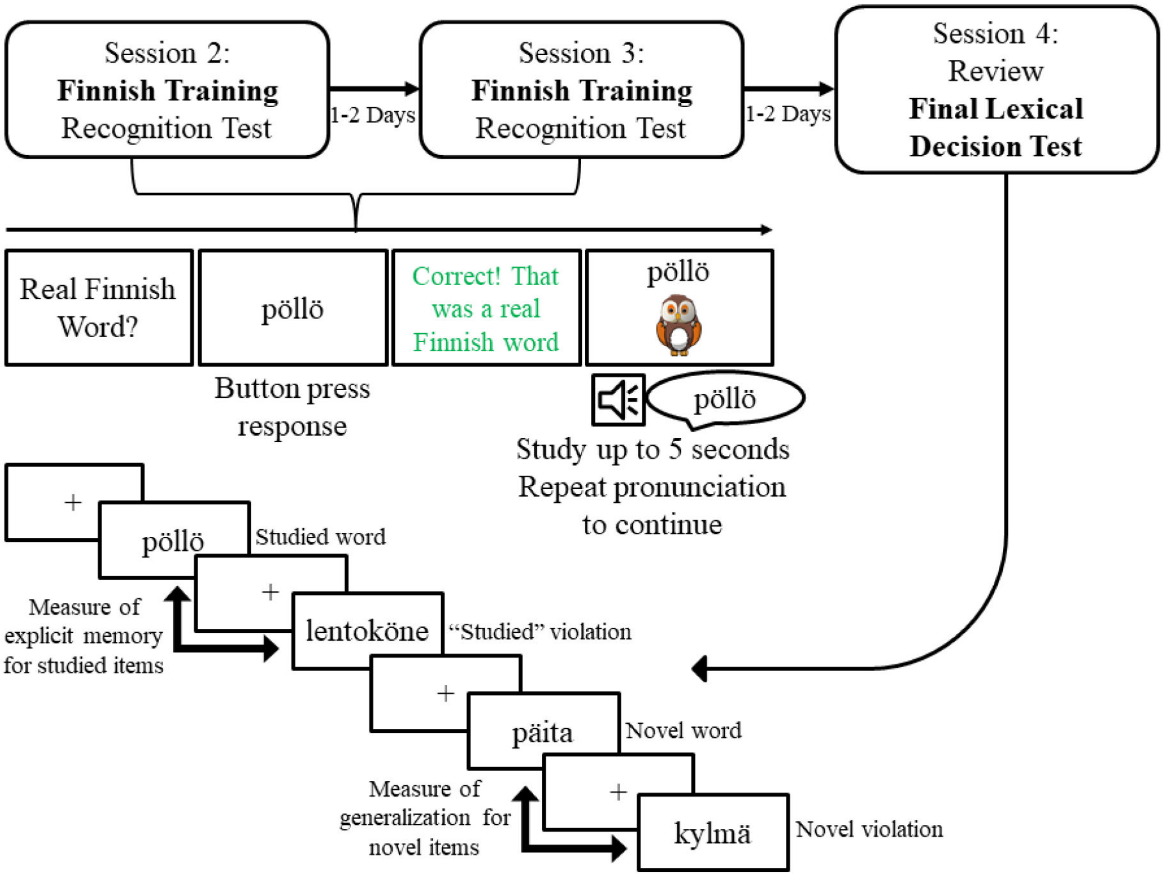

Figure 2.

Design of Finnish Training and Test across multiple sessions of the study. Top trial procedure is an example of a Finnish training trial. Participants first were asked to indicate whether they believed a word was a real Finnish word and received corrective feedback. For all real Finnish words, they were provided a study opportunity (up to 5 s) to learn the semantic and phonological mapping before attempting to reproduce the pronunciation themselves as a way to emphasize the phonological patterns of Finnish vowel harmony. Bottom multiple trial procedure is an example of the Finnish test which required a lexical decision on formerly studied real Finnish words, formerly encountered Finnish vowel harmony violations, and a set of novel real words and violations.

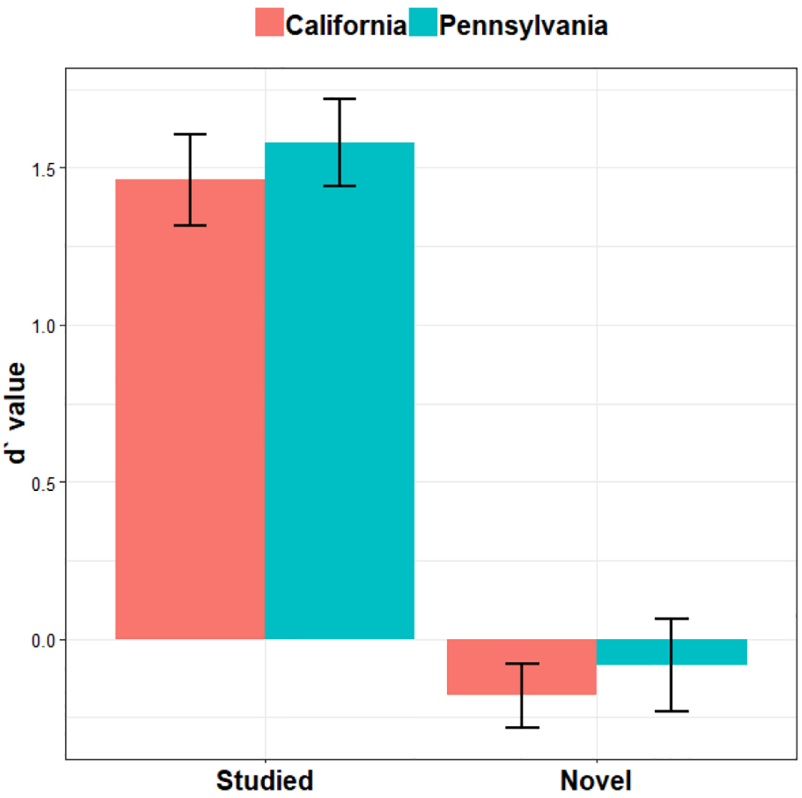

Figure 3.

Performance on the final lexical decision test at the end of the fourth session. Studied items include the comparison between the 90 real Finnish words that were studied during training sessions and the 90 vowel harmony violations that were presented during those sessions as negative evidence. Novel items include 30 novel real Finnish words and 30 novel vowel harmony violations that had never been seen before by participants. Error bars represent one standard error.

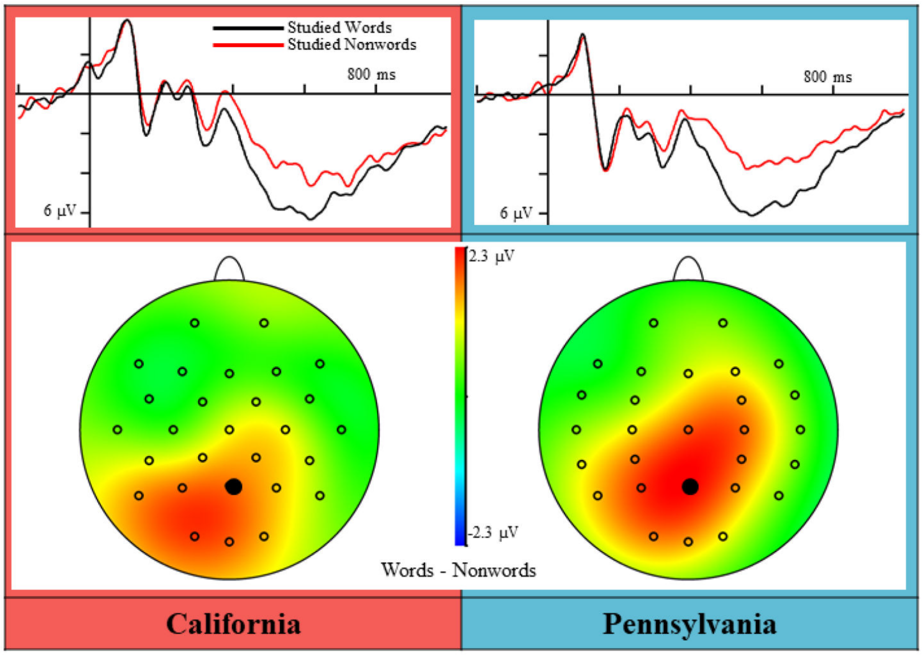

Figure 4.

Waveforms from representative electrode Pz and scalp topographies of the ERP effects for studied words and violations for the average difference in the two waveforms from 500–700 ms. Negative is plotted up.

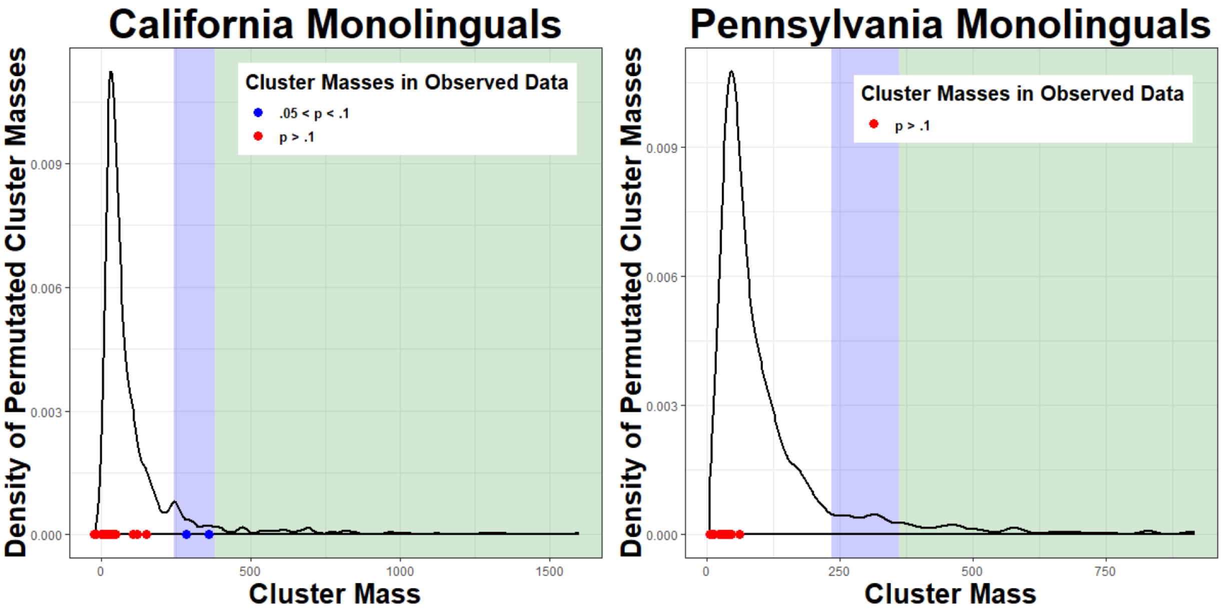

Figure 5.

Results of the cluster-based permutation tests for each group. For each permutation of the data (re-shuffling of the word and nonword labels), the maximum cluster mass was calculated and added to the distribution. After 1000 permutations, p-values were calculated for each cluster mass in the observed based on their rank order in the permutated distribution. Red dots represent observed cluster masses in each group whose p-value was > .1 and the blue dots represent observed cluster masses whose p-value was between .05 and .1 (marginally significant). Blue-shaded regions show the area of the distribution of marginal significance and green-shaded regions show the area of the distribution of significant values.

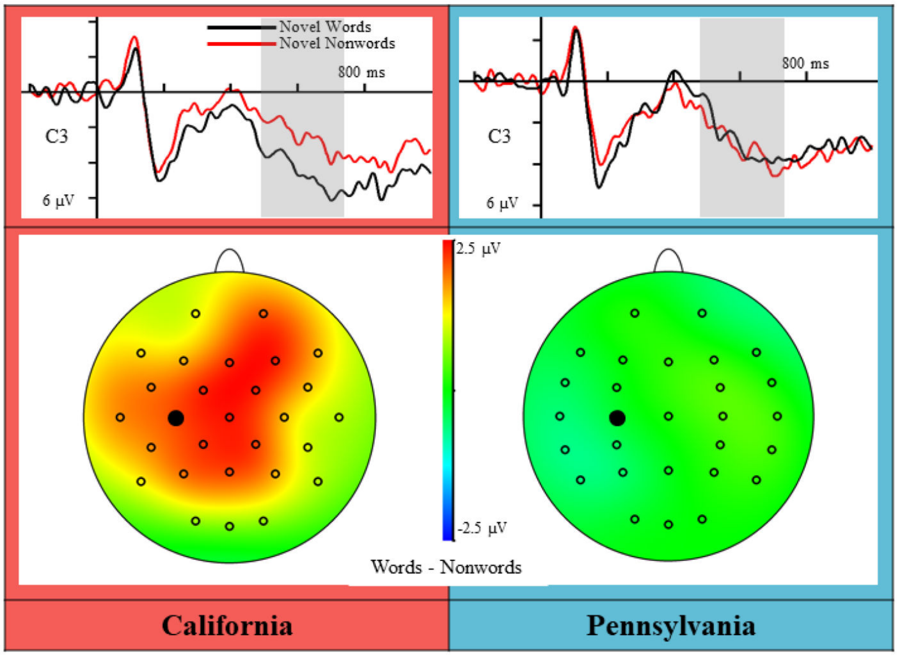

Figure 6.

Waveforms and scalp topographies showing the marginal effects found in the California monolinguals (left), in comparison to the Pennsylvania monolinguals (right). The topography shows activity from 480–760 ms, and the waveforms show electrode C3. Negative is plotted up.

Table 1:

Participant Characteristics.

	Pennsylvania (n = 18)	**California (n = 16)**	
% Female	78%	63%	X^2 = 0.36, p = .55
Age (SD)	23.78 (4.86)	20 (2.56)	t(32) = 2.78, p = .0l*
English Verbal Fluency Score (SD)	14.25 (2.36)	12.85 (3.05)	t(32) = 1.5, p = .14
English Self-Rated Proficiency (SD)	9.65 (0.62)	9.73 (0.59)	t(32) = 0.39, p = .7
Operation Span Score (SD)	48.44 (7.21)	44.67 (9.6)	t(31) = 1.29, p = .21
Mother’s Education	Up to GED: 1 Post-secondary: 17	Up to GED: 6 Post-secondary: 10	X^2 = 3.51, p = .06
Reported Experience with other language(s)	Spanish: 9 Chinese: 1 Italian: 1 French: 1 Latin: 1	Spanish: 7 Chinese: 2 Japanese: 1 Hindi: 1 German: 1	
Age of Acquisition of other language(s) (SD; range)	15.45 (4.57; 9–26)	11.92 (4.76; 5–20)	t(21) = 1.82, p = .08
Self-Rated Proficiency in other language(s) (SD)	2.18 (1.7)	3.93 (1.7)	t(21) = 2.46, p = .02*
% Exposure to reported other languages (SD)	0.61% (1.61%)	10.44% (14.54%)	t(15.33) = 2.69, p = .02*