Effects of Multiple Inputs with an Accent Cue in Speech Segmentation Facilitated by Language Experiences

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Abstract

Past studies using artificial language speech streams showed that adults use statistics to correctly segment words. However, these studies mostly used only a single stream input and monolingual populations. Given the number of bilinguals and the prevalence of exposures to multiple languages, how do monolinguals and bilinguals compare in speech segmentation task given multiple inputs? Speech segmentation becomes challenging with multiple inputs when learners combine input across languages. The statistics of particular units that overlap different languages may change and hinder correct segmentation. Current study addresses this question by using two interleaved artificial language streams and an indexical accent cue. In the study, participants were asked to segment two artificial language streams with or without an accent cue. Our results indicated that in the absent of the accent cue, bilinguals and monolinguals performed similar, while monolinguals' performance was weakened compared to those of bilinguals in the presence of the accent cue. Weakened performance can be due to two accounts: switching of accents and difficulty of languages. This study, expanding Weiss et al. (2009) and bilingualism research, informs us that the level of difficulty of languages and cues can play a role in segmenting multiple language streams.

Introduction

Statistical learning refers to people's ability to adapt to the statistical regularities that occur in their environment (Saffran, Aslin & Newport, 1996). This type of learning can be seen in a wide range of stimuli including visual and auditory input (Kirkham, Slemmer & Johnson, 2002). In recent years, researchers have theorized that statistical learning plays a central role in early language acquisition (e.g., Saffran et al., 1996a; Maye, Werker, & Gerken, 2002; Thiessen & Saffran, 2003). Through statistical learning, learners discover structural properties of language such as words and phrases by discovering what elements of the speech stream predict other elements. When elements of the input are highly likely to predict each other, people use the statistical relation between them to group them into coherent units. This allows us to segment speech properly. Such ability is demonstrated in infancy as early as 8-month-old. For example, in the English stream 'pretty baby', the syllable 'pre' is followed by a limited set of syllables, thus the probability of 'ty' appearing after 'pre' is high. However, after the syllable 'ty' in 'pretty' any English syllables can be followed, resulting low probability of appearing "ba" after "ty" (Saffran, 2003). Therefore, sounds occurring together with high probability are more likely to represent words, whereas sounds co-occurring with low probability signal word boundaries (Saffran et al., 1996a,b; Johnson & Jusczyk, 2001;Saffran, 2003).

While statistical learning is a powerful tool in language acquisition, much of research assessing it has focused on analyzing only a single speech stream. However, considering that learners hear multiple sounds or even several languages every day, how statistical learning is performed with multiple language input remains largely unexplored. Today, much of world's population is multilingual. For example, in Papua New Guinea, most children learn a local language and Tok Pisin, the standard vernacular, before they enter the school where they are instructed in English at school (Bialystok, 2001:3). In the Philippines, children may learn one of seventy languages in the home before English and Filipino instructions at school. These situations present much of population around the world to have a proficiency in at least two languages (Bialystok, 2001:3). Multilingual environment can present a challenge for learners because not all languages have a similar structure. Thus, rules in one language may behave differently in another language, which leads to increased difficulty in analyzing the statistical information.

While the "pretty baby" example describes statistical learning elegantly, the assumption is that the statistical information is only derived from a single language input and is monolingual (no other language exposure or learned). However, this may be different if the input is multiple languages. To correctly discover the structure of two separate languages, learners must be able to separate them. If learners treat two separate languages as one larger linguistic system, the statistical regularities within the languages will be harder to detect. For example, if a child is exposed to one language in which the dominant sentence order is Subject-Verb-Object, and another where the dominant order is Subject-Object-Verb, word order is less predictable when the learner considers all sentences (in which roughly 50% of the time Objects follow Verbs and roughly 50% of the time Verbs follow Objects) than when they consider the sentences only within a single language. Separating languages is thought to be necessary for successful language acquisition in natural bilingual learning settings (Bosch & Sebastian-Galles, 1997a).

One factor that may influence the ease with which learners are able to segment multiple linguistic systems may be their prior experience with multi-lingual environments. People who are exposed to multiple languages everyday may be better adapted to complex input than those who are only exposed to a single language. Bilinguals are exposed to more than one language everyday, thus their statistical learning ability may be better adapted and able to parse multiple input better. Bilinguals are loosely defined as having a mastery of two languages. However, there are variations in what degree of mastery qualifies as fluent. For the purpose of this paper, bilinguals are defined as exposure to another language before the critical period (before the age 15). In the language acquisition literature, the critical period hypothesis holds that language acquisition must occur during a critical period which ends at about the age of puberty with the establishment of cerebral lateralization of function (Lenneberg, 1967). A strong implication of this hypothesis is that the processes involved in any language acquisition, which takes place after the age of puberty, will be qualitatively different from those involved in first language acquisition. This is demonstrated in Johnson (1992) and Johnson & Newport (1989) studies, where the English proficiency of immigrants in the States highly correlated with the age of arrival rather than the length of exposure. The data suggests that after 15 years old, participants' fluency greatly declined whereas participants who arrived before 15 years old demonstrated almost native-fluency.

There are at least two reasons why bilinguals may be more successful in separating two linguistic systems, and taking advantage of the differentiable statistical structures within those systems, than are monolinguals. One is that bilinguals, by definition, have more experience learning from separate linguistic systems than monolinguals. They may, for example, have more facility in representing conflicting linguistic patterns. An alternative (and potentially complementary) possibility is that bilinguals may be more sensitive to the acoustic cues that differentiate languages, as they have presumably been at least somewhat reliant on these cues to help differentiate their own languages. When learners hear multiple languages, there are several potential cues that help with discrimination. There may be several cues including: accents, tone, stress cues. For example, a study with English-learning infants indicated that they were able to use prosodic information to segment fluent speech into sequence of syllables that begin with a strong syllable (Jusczyk, Houston, & Newsome, 1999b). They segment trochaic (strong–weak) nouns (*candle*) by 7.5 months of age, but missegment iambic (weak–strong) nouns (*guitar*) at that age (Nazzi et al, 2006). Another study showed that Catalan and Spanish infants use rhythmic information to tell these two languages apart. It was argued that the existence of vowel reduction in Catalan but not in Spanish could be responsible for rhythmic differences that make these two languages distinguishable (Bosch & Sebastián-Gallés, 1997a & Dauer, 1983). Thus learners are able to take advantages of these cues from early on. What's crucial is that participants' ability potentially available cues and use the cue that most helps with discrimination with multiple input.

Distinguishing different languages is key to perform separate computations across each language to correctly extract regularities for each individual language (Bosch & Sebastián-Gallés, 2001). In addition, previous experience with multiple languages may facilitate statistical learning. Bilinguals who already have achieved ability to discriminate two languages may have an advantage in identifying two different languages better than monolinguals. Thus this allows to segment two speech streams correctly. The goal of the experiment is compare how monolinguals and bilinguals compare in speech segmentation task when confronted with two artificial speech streams. Since bilinguals have more experience of multiple language exposures, we predict that they will be more adapt at separating the two languages using the available cues such as accents and tones. Better discrimination between the two languages leads to a better speech segmentation since it decreases chance of combining statistics across two languages, which reduces incorrect statistics in the data.

In order to test effects of multiple inputs and cues, Weiss (2009) devised series of experiments presenting two artificial languages with or without the voice cue. They used two streams of speech composed of trisyllabic nonsense words that alternated repeatedly every 2 minutes. The gender of the talker differed between the two alternating speech streams, thereby providing a strong contextual cue for the change in structure. What is crucial about this experiment is statistical properties of two interleaved artificial languages. In one condition, the interleaved languages are statistically compatible such that the word boundaries remain stable regardless of whether the statistics are combined across both languages. In the other condition, two of the interleaved languages have incongruent statistics. Thus, if participants attempted to combine statistics across two languages will result in ambiguity and present difficulty in segmentation. Thus, the second condition requires participants to first identify two separate languages and perform segmentation in each language. When the structures of the two streams were incongruent, participants were able to successfully segment both languages only when there was a contextual voice cue. Thus, adult monolinguals can correctly segment two speech streams simultaneously with a sufficient indexical voice cue.

The current study attempts to investigate effects of the level of language experience (monolinguals vs. bilinguals) and accents (English and Korean) as an indexical cue. With more exposure to multiple languages, bilinguals may identify two different languages in the interleaved language better than monolinguals regardless of indexical cue, which will lead to better performance in speech segmentation.

The outline of this study consists of four experiments. We use two artificial languages that contain four words each, which were modified from Weiss et al. (2009). For Experiment I, we compare how bilinguals and monolinguals' segmentation performance is influenced by interweaving two incongruent languages with the accent cue. Experiment II is identical with Experiment I but the accent cue was removed. For Experiment IIIa and Experiment IIIb, we tested whether learner were correctly able to segment each artificial languages in isolation. The last two experiments were conducted if participants were able to learn two languages separately.

Experiment I

Experiment 1 adapted the methods used in previous research (Weiss et al., 2009), which interleaved two artificial languages. As mentioned above, when the input streams contained incongruent statistical relationships, participants were only successful in segmenting both streams in the presence of an indexical cue. In Experiment 1, we presented participants with interleaved two incongruent artificial languages with an accent cue (Korean). Both languages were presented in the same voice, and thus only the accent provided an indexical cue to language.

Method

Participants

20 monolingual and 20 bilingual undergraduates at Carnegie Mellon University (ages 18–23) were included in this study from Psychology subject pool and received class credit for participation. Criteria for bilingual classification included anyone with 5 or more years studying a second language starting before the age of 15 or who self-classified as being bilingual.

Stimuli

Each language consisted of 4 artificial trisyllabic (CV.CV.CV) words. Language 1 (L1) was recorded with an English accent and Language 2 (L2) was recorded in a Korean accent (see figure 1). Each word was presented an equal number of times, and no words were repeated twice in a row. There were no pauses in between the syllables and no other acoustic word boundary cues to signal boundaries. Within each word, syllable-to-syllable transitional probabilities were perfect (1.0) but dropped to .33 at the word boundary. This pattern was consistent across all words in the languages (See Figure 2).

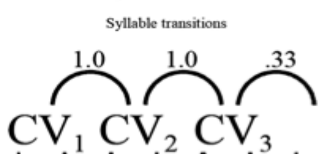
Test items consisted of four words from L1 paired with four part-words from L1. Part-words are trisyllabic sequences that spanned a word boundary in L1 Each word/part-word combination occurred during the test phase. If participants are sensitive to statistical information, they should be able to differentiate between words (which have high conditional probabilities) from part-words (which contain a transition with a low conditional probability).

Participants were exposed to an input consisting of an interleaving of L1 and L2 in two blocks of 2’04’’ each. Within each block, the two languages were presented in alternating 1’08’’ strings. Notice that this potentially alters the statistical information that participants extract from the linguistic input. If participants fail to differentiate between the two languages, the differentiation between words and part-words becomes less robust. The syllable-to-syllable transitional probabilities within words drop from 100% to between 50% and 100% (see Figure 3). By contrast, the transitional probabilities of the part-words do not drop as much, so the difference in conditional probabilities between words and part-words is much less distinct if participants fail to separate the two languages.

Figure I. Displays the design of L1 and L2

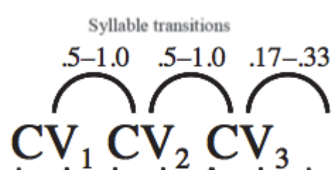
	Word	Partword
Language I (L1)	Beh-Tih-Goo	Sah-Two-Guh
	Shi-Cheh-Vee	Goo-Vuh-Bow
	Vuh-Bow-Sah	Chawh-Sih-Cheh
	Tow-Guh-Chawh	Vee-Beh-Tih
Language II (L2)	Guh-Pah-The	Bow-Gee-Gah
	Gee-Gah-Puh	Sih-Guh-Pah
	Sah-Ju-Bow	Puh-Ta-Bee
	Ta-Bee-Sih	The-Sah-Ju

Figure 2. Statistical of L1 and L2



(Weiss et al, 2009)

Figure 3. Combined statistics of L1 and L2



(Weiss et al, 2009)

Procedure

The test was presented on E-Prime Software. Participants were instructed to listen to a speech stream and told that there would be a test following the session. They were given no explicit directions about the task and had no information about the length or structure of the words or about how many words each language contained. During the exposure phase, participants listened to the interleaved language for 4'08''. Two languages were interleaved in two blocks of 2'04'' each. Within each block, the two languages were presented in alternating 1'08'' strings. After the exposure phase, participants proceed to the test trial. Each test trial consisted of 2 trisyllabic strings, separated by one second of silence. One string was a word from L1, whereas the other was a partword. Tests always compared a word with a partword from the same language (spoken in the same voice and accent). Each word from L1 was paired with 4 other part-words from L1 in randomized order, rendering 16 test items. Stimuli from only L1 was used because if participants able to perform word segmentation with L1, this would indicate that they were indeed able to separate L1 and L2 and perform the segmentation respectively. Participants indicated which of the two strings sounded more like a word from the language by pressing either "1" or "2" on the keyboard.

Following the test, participants filled out a questionnaire on language background (how many languages, at what age they started to learn, number of years studied, and whether they would label themselves as being bilingual), demographic information and comments about the experiment (see Appendix).

Results

In order to test whether participants in each group (Monolinguals and Bilinguals) learned above chance, one sample t-test was performed. Monolinguals performed at chance ($t(19),=1.39$, $p=.203$) and on average answered 9 correct ($SD= 3.39$) out of 16. Bilinguals performed above chance ($t(19)=6.26$, $p <.0001$) and on average answered 11 correctly ($SD = 2.3$) out of 16. Two-samples T-Test was performed to compare two groups. There was a statistically significant difference between two groups ($t(38)=2.29$, $p=0.027$)

The results of this experiment demonstrate that bilinguals were better than monolinguals at speech segmentation task with interleaved language with an accent cue. This is consistent with our hypothesis that bilinguals will be superior at taking advantage of the accent cue to differentiate languages. This account predicts that bilinguals are *facilitated* in their learning by their ability to take advantage of an accent cue.

However, there is alternative explanation. It may be that monolinguals are performing worse because of the accent cue. The next experiment investigates which of the explanations is plausible.

Experiment II

Experiment I indicated that bilinguals were better at parsing incongruent speech stream with an indexical accent cue. There are two alternative explanations for this result. One possibility is that bilinguals are facilitated by the presence of an accent cue. Another possibility is that monolinguals are impaired by the presence of an accent cue. Thus Experiment II investigates these two accounts by presenting the same stimuli as Experiment I without the accent cue.

Method

Participants

20 monolingual and 20 bilingual undergraduates at Carnegie Mellon University (ages 18–23) were included in this study from Psychology subject pool and received class credit for participation. Criteria for bilingual classification included anyone with 5 or more years studying a second language starting before the age of 15 or who self-classified as being bilingual.

Stimuli and procedure

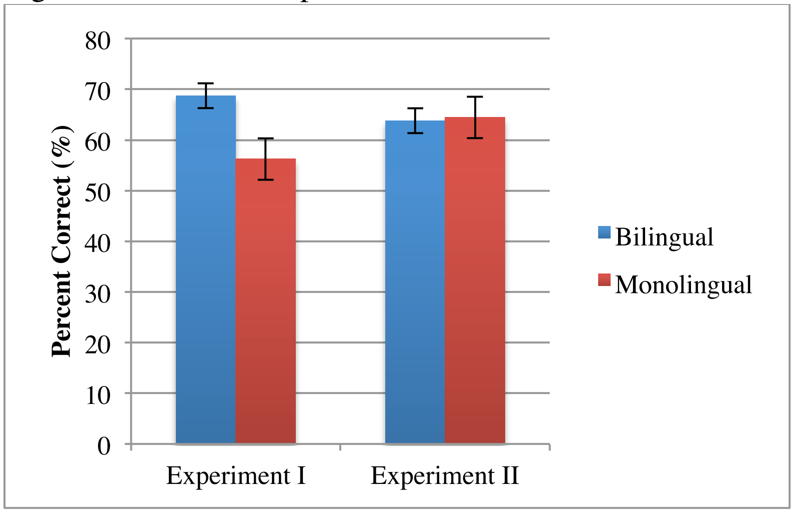
The stimuli were structurally identical to those used in Experiment I. In Experiment II, however, both languages were presented in an English accent rather than in Korean and English. In this experiment, participants listened to the interleaved language for 4'08'' and completed 16 test questions, comparing word and partword in L1.

Results

In order to test whether participants in each group (Monolinguals and Bilinguals) learned above chance, one sample T-Test was performed. Monolinguals performed above chance ($t(19)= 5.19$, $p< 0.0001$) and on average answered 10.32 correct ($SD= 1.95$). Bilinguals performed above chance ($t(19)= 3.69$, $p= 0.0018$) and on average answered 10.21 correctly ($SD = 2.4$). Two-samples T-Test was performed to compare two groups. There was no statistically significant difference between two groups ($t(38)=.149$, $p=0.88$).

With the indexical accent cue removed, both monolinguals and bilinguals performed similar in the speech segmentation task. The fact that the presence of two accents appears to impair monolinguals (as opposed to facilitate bilinguals) is unexpected. One possibility is that the switch between accents is simply distracting for monolinguals. An alternative possibility is that Language 2 (especially when presented in a Korean accent) is much more difficult to learn than Language 1, and this difficulty causes monolinguals more difficulty than it presents to bilinguals. To begin to investigate these possibilities, the next two experiments assess the difficulties of L1 and L2 when they are presented in isolation.

Figure 4. Results of Experiment I & II



Experiment IIIa

This experiment tested whether monolinguals and bilinguals were able to parse L1 speech stream. The purpose of experiment IIIa was to assess the difficulty of L1 when presented in isolation.

Method

Participants

20 monolingual and 20 bilingual undergraduates at Carnegie Mellon University (ages 18–23) were included in this study from Psychology subject pool and received class credit for participation. Criteria for bilingual classification included anyone with 5 or more years studying a second language starting before the age of 15 or who self-classified as being bilingual.

Stimuli and Procedure

The same L1 with English accent was used in the experiment. However, this time, participants were exposed to two blocks of L1 with 1’08’’ per block. In total, participants listened to 2’16’’ of L1. This was to match the time of exposure of L1 in experiment I. During the test phase, participants were asked 16 questions comparing a word and a partword in L1.

Result

In order to test whether participants in each group (Monolinguals and Bilinguals) learned above chance, one sample t-test was performed. Monolinguals performed above chance (t(19),= 4.57, p= 0.0002) and on average answered 10.32 correct (SD= 1.95). Bilinguals performed above chance (t(19)= 3.36, p= 0.0033) and on average answered 9.24 correctly (SD = 1.54) out of 16. Two-samples T-Test was performed to compare two groups. There was no statistically significant difference between two groups (t(38)=1.39, p=0.172).

Experiment IIIb

This experiment tested whether both monolinguals and bilinguals were able to parse L2 speech stream. The purpose of experiment IIIb was to assess the difficulty of L2 when presented in isolation.

Methods

Participants
20 monolingual and 20 bilingual undergraduates at Carnegie Mellon University (ages 18–23) were included in this study from Psychology subject pool and received class credit for participation. Criteria for bilingual classification included anyone with 5 or more years studying a second language starting before the age of 15 or who self-classified as being bilingual.

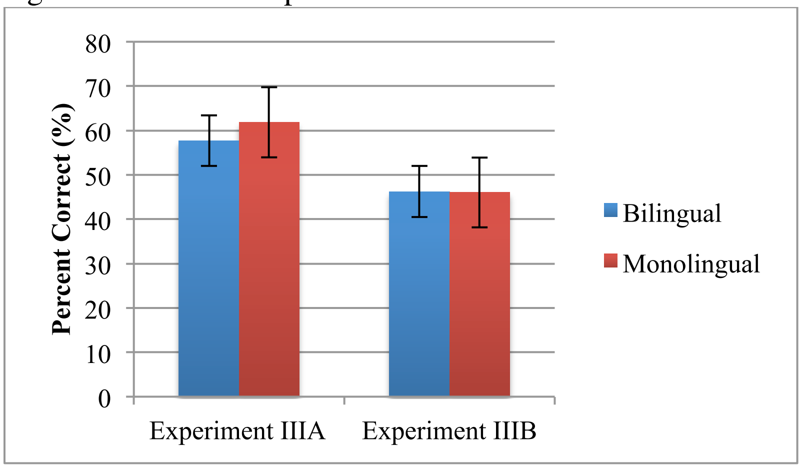
Stimuli and Procedure
The same L2 with Korean accent was used in the experiment. However, this time, participants were exposed two blocks of L2 with 1'08'' per block. In total, participants listened to 2'16'' of L2. This was to match the time of exposure of L2 in Experiment I. During the test phase, participants were asked 16 questions comparing a word and a partword in L2.

Result

In order to test whether participants in each group (Monolinguals and Bilinguals) learned at chance, one sample t-test was performed. Monolinguals performed at chance (t(19)= 2.05, p= 0.055) and on average answered 7.36 correctly (SD= 1.34). Bilinguals performed at chance (t(19)= 1.79, p= 0.089) and on average answered 7.4 correctly (SD = 1.51) out of 16. Two-samples T-Test was performed to compare two groups. There was no statistically significant difference between two groups (t(38)= 0.2276, p= 0.821).

The result indicated that both groups failed to parse L2; they are unable to differentiate words and part-words at a rate above chance. This suggests that L2 is harder to learn than L1, as both groups were able to parse L1 above chance.

Figure 5. Result of Experiment IIIa and IIIb



General Discussion

The findings from this series of experiments extend Weiss et al (2009). The statistical learning literature has typically focused on segmentation of a single input stream and monolinguals. In our study, we compare monolinguals and bilinguals' performance on speech segmentation with two artificial languages. We predicted that bilinguals, who have richer experience with multiple language inputs, will be better at separating two different languages and thus able to perform better in speech segmentation. In Experiment I, our result demonstrated that bilinguals are indeed better at parsing interleaved two incongruent artificial languages with the indexical accent cue than monolinguals. This result seemed to be consistent with our hypothesis. However, Experiment II indicated that without the accent cue, both monolinguals and bilinguals performed similar in parsing the interleaved language. Moreover, they were performing as well as bilinguals did in Experiment I.

Thus, Experiment II suggested that bilinguals are not necessarily better than monolinguals at taking advantage an accent cue. Rather, monolinguals are impaired by the presence of the accent cue in interleaved languages, while bilinguals are unaffected by the presence or absence of accentual differences between the two languages. As such, the explanation for the bilingual advantage in Experiment 1 is more nuanced than our original hypothesis. The fact that the presence of two accents appears to impair monolinguals (as opposed to facilitate bilinguals) suggests two possible accounts. One account is that the switch between accents is distracting for monolinguals. An alternative account is that L2 (especially when presented in a Korean accent) is much more difficult to learn than L1, and this difficulty causes monolinguals more difficulty than it presents to bilinguals.

Experiment IIIa and IIIb, which tested L1 and L2 in isolation, indicated that L2 in Korean accent was harder to learn compared to L1. While both monolinguals and bilinguals were able to learn L1 in English accent successfully, they both failed to learn L2 in Korean accent. There were no significant differences between two groups in both conditions. If the difficulty of L2 is causing the impaired performance of monolinguals in Experiment 1, previous language exposures can explain such impairment. Compared to bilinguals, monolinguals are not exposed to different kinds of languages with various accents. Less experience with different languages creates greater difficulty on monolinguals than on bilinguals because it distracts them to separate two languages and correctly perform speech segmentation. On the other hand, bilinguals are less prone to this distraction because they have more experience with multiple languages including various accents. Therefore, they are able to separate the languages despite L2 being difficult. This indicates that bilinguals are able to pay selective attention to one language. Nevertheless, we still cannot rule out the other account that the switch between accents is distracting for monolinguals based on our data alone. It is still unclear which account contributes to impaired performance of monolinguals in Experiment I. It may be the case that both factors contribute to impaired performance in monolinguals. Further studies need to be conducted in order to parse out these two accounts.

While our experiments provide some insights into how monolinguals and bilinguals are different, there are several limitations to our experiments. We are still in the process of replicating our experiments in order to confirm our data. Moreover, these experiments only used English and Korean accent. Given that there are many languages around world, different language pairs may yield different results. Along with different languages, different cues such as tones may have different effects.

Taking these limitations into account, there are many future studies to be done. As it was mentioned earlier, follow up studies can help to parse out two accounts of why monolinguals were impaired in Experiment I. In order to see if the accent is distracting monolinguals, we can manipulate accents in the languages. Experiments using varying accents (Spanish, German, Chinese, Japanese etc) with the same language can tell us whether the switching accents plays a role in learning languages. In addition, familiarity of accents may facilitate how switching impacts speech segmentation. While the first account predicts that switching accents is causing more difficulty for monolinguals, the second account predicts that complexities of languages impair monolinguals greatly. Building upon our experiments, studies with different levels of complexity can inform us how difficulty of languages can impact monolinguals and bilinguals differently.

Finally, our study is a starting point to understand what cues can help to facilitate separating multiple inputs and how they interact with previous language experiences. Here we used accent as a cue. Our results indicated that accents actually distract monolinguals. However, there are other cues in the speech streams that learner can use. Further research can help to find various cues that can help both bilinguals and monolinguals to separate multiple inputs and learn the languages successfully.

Appendix

Questionnaire

1. What languages do you speak? (please list all including anything from home and formal instructions)

2. For each language listed, at what year did you start learning the languages and how many years have you used the listed languages?

3. What languages do you parents speak?

4. Do you consider yourself as bilingual?

5. If yes, what language do you consider as a primary one?

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