WORD SEGMENTATION FOR JAPANESE AND ENGLISH SPEAKERS: LANGUAGE-INDEPENDENT AND LANGUAGE-DEPENDENT CUES

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ABSTRACT

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Phonotactic knowledge and experience-independent knowledge have both been argued to cue word segmentation in prior studies (e.g. Ettlinger, Finn, & Hudson Kam, 2011; McQueen, 1998). This dissertation attempts to compare the effect of two types of cues, language-independent and language-dependent knowledge, on word segmentation. The specific cues selected for each type were the Sonority Sequencing Principle (SSP) as a language-independent cue and geminates (double consonants) as a language-dependent cue. The effectiveness of the cues was determined by two groups of speakers with different language background, native Japanese and native American English speakers. The two languages were chosen particularly because they contrast in two aspects relevant to these specific cues: (1) Japanese has a simple syllable structure, no consonant clusters (except for consonant-glide sequences), while English has an extensive set of bi-consonantal clusters and limited tri-consonantal clusters. (2) Japanese has a phonemic consonant length contrast (singletons vs. geminates), while English lacks such a contrast. Details of (1) are relevant for testing the SSP, and those of (2) for testing geminates as a cue to word segmentation.

The results from three artificial language learning experiments consistently indicate, contrary to prior claims, that the (language-independent) SSP is not a reliable cue to segment speech strings for either language groups, regardless of the difference in syllable structure. On the other hand, knowledge about language-dependent geminates seems to be a good

predictor as to how speakers segment words from a string with word-internal geminates. Japanese speakers, whose language has a phonemic contrast between geminates and singleton consonants, consistently segmented the speech string so that geminates were retained within words, whereas English speakers without such a contrast in their native language tended to break up the string at geminates. Moreover, the results indicate that listeners are able to rely heavily on the transitional probability (TP) of the syllables to segment the string, primarily when the structure of the stimulus words in the target speech string is simple.

From the results of this study, language-dependent knowledge seems to be more effective than language-independent knowledge in word segmentation.

To my beloved mother and father

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CHAPTER 1 INTRODUCTION AND OVERVIEW

1.1 Introduction

One of the very first things language learners encounter is exposure to the target language speech. That exposure includes listening to a fluid stream of continuous speech strings, which do not necessarily contain definite breaks or pauses between words. Therefore, listeners must use some strategy to divide the sequence into meaningful units of reasonable length. To efficiently segment morphemes/words from the string, listeners depend on morpheme/word boundary cues that are available to them. Previous studies have shown that infants as young as 6 to 7 months old, whose native phonological system is not yet established, rely on distributional (statistical) cues e(Aslin, Saffran, & Newport, 1998; Saffran, Aslin, & Newport, 1996; Saffran, Johnson, Aslin, & Newport, 1999; Saffran, Newport, & Aslin, 1996) when perceiving target language. As infants become more exposed to their own native language, they start to rely on more language specific prosodic and phonotactic cues on top of distributional cues of that language during word segmentation (Jusczyk, Houston, & Newsome, 1999; Mattys & Jusczyk, 2001). Fast-forwarding to adulthood, it appears that adults also make use of distributional cues to word segmentation as much as children do (Saffran, Newport, Aslin, Tunick, & Barrueco, 1997). Moreover, distributional cues seem to work together in concert with other cues for adults (e.g. Ettlinger, Finn, & Hudson Kam, 2011; Finn & Hudson Kam, 2006). Nonetheless, one of the major challenges for adult listeners in word segmentation is the interference of phonological patterns of their native language when perceiving a language that is not their own. In addition, there may be other non-language specific phonological constraints, possibly universal constraints, that influence word segmentation. The present dissertation investigates two types of such constraints that adult learners possibly use to perceive target language speech, namely (a) a language-independent cue and (b) a language-dependent cue. More specifically, the cues that are examined here are the Sonority Sequencing Principle (SSP) as a language-independent cue and knowledge of geminates (or long consonants) as a language-dependent cue. It will employ the word segmentation experimental paradigm to explore the possible cues that are being used by listeners. Additionally, following prior studies, an artificial language learning paradigm will also be employed, in order to have better control with the materials that will be presented. A series of experiments will test the above two kinds of cues that differ intrinsically, and later compare their effectiveness in word segmentation.

As Endress and Hauser (2010) put it, there are two distinct literatures on *speech segmentation* studies to date. The first type of speech segmentation study that was introduced in the 1980s examined native listeners' speech segmentation strategy of their own languages (e.g. Cutler & Mehler, 1993; Cutler, Mehler, Norris, & Segui, 1986; Cutler & Norris, 1988). Endress and Hauser (2010) call this type of study *native speech segmentation*. Another type of speech segmentation literature refers to the study of the process used by infants whose native language is not yet established (e.g. Aslin et al., 1998; Brent & Cartwright, 1996; Saffran, Aslin, et al., 1996; Saffran, Newport, et al., 1996; Swingley, 2005), which Endress and Hauser coined it as *statistical word segmentation*. Furthermore, there is a growing additional literature that examines adult speakers' strategies to word segmentation in fluent speech of novel words, potentially with non-native phonotactics (e.g. Enochson, 2015; Ettlinger et al., 2011; Mersad & Nazzi, 2011; Onnis, Monaghan, Richmond, & Chater, 2005; Ren, Gao, & Morgan, 2010; Saffran et al., 1997). I will refer to this type as the *novel-word segmentation*. The experiments in this dissertation concerns this third type of speech segmentation. However, I will discuss the past work of the *statistical word segmentation* (studies on infants) as well, because the work resembles the *novel-word* *segmentation* in a way since participants (infant and adult listeners) in both types of study do not have fully established knowledge of the speech they are exposed to during word segmentation.

The current dissertation mainly focuses on adult native Japanese and English speakers' perceptual behavior to test the language-dependent and language-independent cues. Japanese and English were chosen because the languages provide useful patterns to study the cues on which this dissertation centers. Unlike English, Japanese displays a phonemic consonant length contrast (singletons vs. geminates) and very productive gemination patterns, which are suitable to test the effectiveness of language-dependent phonotactics in word segmentation. The current dissertation will show that, in contrast to speakers of English, a language that lacks phonemic consonant length contrast, speakers of Japanese consistently segment non-native fluent speech so that geminates are retained within words. Moreover, the contrast in consonant sequence patterns between Japanese and English provides a good opportunity to examine the extent to which language-independent cues impact word segmentation. In regards to syllable structure, Japanese contrasts with English as Japanese has much simpler syllable structure. No consonant clusters (except for consonant-glide sequence) are allowed in the onset position of syllables in Japanese. In contrast, English allows a more extensive combination of bi-consonantal clusters, and a much more limited combination of tri-consonantal clusters, in the onset position of syllables. As the dissertation also tests whether the Sonority Sequencing Principle (SSP), a putatively language-universal principle that constrains the sequence segments in a syllable (where the nucleus of the syllable is most sonorous and segments furthest away from the nucleus are least sonorous), the syllable structures of the two languages provide a good test-bed to probe whether the SSP has an effect on word segmentation in both type of speakers. The dissertation will show through multiple experiments that the SSP does not cue word segmentation for speakers of either language background.

A second key motivation of the inclusion of Japanese is to add to the literature on Japanese speakers' strategies to *novel-word segmentation* since it seems to be lacking. Although there are notable studies on Japanese speakers by Cutler and Otake (1999) and Warner, Otake and Arai (2010), those do not follow the word segmentation paradigm that will be exploited here concerning the examination of cues to speech string segmentation. Their focus was on *native speech segmentation* and not *novel-word segmentation.*

The following sections in the chapter will present the overview of the literature and lay out the premises of this dissertation.

1.2 Connections to previous work

To lay out the foundation of the dissertation, this section will discuss the prior work on word segmentation in both *statistical word segmentation* and *novel-word segmentation* studies. In addition, a brief account of second language acquisition studies will also be introduced since the dissertation deals with *novel-word segmentation* by adults who already have their L1 established. Participants in the following experiments are exposed to a language that is not their own; therefore, the mechanisms of second language acquisition are relevant to the current study.

1.2.1 Previous work on word segmentation

Past studies on word segmentation have tested the effectiveness of three types of cues: statistical cues, language-specific cues, and non-language-specific or intrinsic (universal) cues. The current dissertation will assume statistical and language-specific cues as 'language-dependent cues,' and consider non-language-specific cues as 'language-independent cues.' Statistical cues refer specifically to the distributional and *transitional probability* (TP) information that is available in word level, syllable level and segmental level.

Gambell and Yang (2006) explain the mechanism of TP with the equation shown in Figure 1.1. They show that if A and B are adjacent syllables, where $\Pr(AB)$ is the frequency of B following A, and $\Pr(A)$ is the total frequency of A, then $\Pr(AB)/\Pr(A)$ is the TP of B following A, as opposed to any other segment following A. It gives a measure of how often an element follows another specific element. Because syllables/segments found within words have a higher chance of co-occurring than syllables/segments that are found across word boundaries, TPs can be potentially useful in word segmentation. For the purposes of this dissertation, since such information is particular to a language, it will be considered as a language-dependent cues, along with native language-specific cues that includes phonotactics, acoustics, and allophonic information.

$$TP\ (A \rightarrow B) = \frac{\Pr(AB)}{\Pr\ (A)}$$

Figure 1.1: Formula for transitional probability (TP)

Regarding TPs, a profound number of studies have found they influence word segmentation in both adults and infants (Aslin et al., 1998; Saffran, Aslin, et al., 1996; Saffran et al., 1999, 1997; Saffran, Newport, et al., 1996). When adults and infants were exposed to a speech string of different CV-syllables, that did not contain any other cues such as pauses, stresses or acoustic cues, they used the statistical properties of syllable sequences in the continuous speech string in the input/training, i.e., TPs between syllables, to segment words. However, Gambell and Yang (2006) found, in a computational study of English words using a corpus of child-directed speech, TP information alone did not lead to achieve word segmentation. Instead, it was the primary stress information that was crucial for word segmentation. This finding was also supported in another computational study by Enochson (2015). Instead of a corpus of child-directed speech, Enochson used a corpus of English adult-directed speech, where she found that TP alone was not reliable in word segmentation. Like Gambell and Yang (2006), Enochson reported that having primary stress information improved the word segmentation. Other studies have found that TP alone is not sufficient to guide word segmentation when the language becomes more complex (Johnson & Tyler, 2010) and infants in the later stages of acquisition relied on prosodic cues more than statistical cues (Thiessen & Saffran, 2003). Therefore, it is worth investigating the role of language-dependent cues, aside from TPs, on word segmentation for adult speakers.

Language-dependent cues such as phonotactic and prosodic information have been tested for their effectiveness in word segmentation and have been observed to be useful information. It has been claimed that learners maximally use their native language phonology to enhance speech segmentation (Cutler et al., 1986). In Cutler et al.'s (1986) study, they observed that adult native French listeners, compared to adult native English listeners, showed evidence of syllabification upon segmentation. They explain that French has relatively bounded syllables compared to English, and that this phonological pattern biased French listeners to segment this way. Additionally, Jusczyk et al. (1993) saw that American and Dutch 9-month-olds show sensitivity towards their native language that they have been exposed to since birth. American infants listened longer to English rather than Dutch, while Dutch infants listened longer to Dutch rather than English. However, when infants listened to low-pass-filtered audio of the two languages, English and Dutch, that removed phonetic and phonotactic properties but only left with prosodic cues, they showed no preference of their native language over the other. Jusczyk et al. suggest that infants were responding to specific phonetic and phonotactic properties when they showed preference to their native language. Jusczyk, Houston & Newsome's (1999) word segmentation study on infants showed that learners as young as 7.5-month-old infants display their use of stress patterns in word segmentation. The infants were able to segment strong/weak words, and treated strong syllables as word onsets, while they were not able to segment weak/strong words. However, the 10.5-month-olds were able to correctly segment weak/strong words from the speech. They explain that between 7.5 to 10.5 months, infants learn to use combined informational cues about words to determine the word boundary. Mattys & Jusczyk (2001) add that in their study, 9-month-olds can depend on both prosodic and phonotactic regularities during word segmentation. They also saw that prosodic cue was the predominant cue between prosodic and phonotactic cues.

Similarly, adult speakers use prosodic and phonotactic regularities of their native language patterns to detect new words. For example, adult Finnish speakers, whose language contains vowel harmony, make use of the information to detect words; they determined word boundaries when a sequence of disharmonic vowels appeared (Suomi, McQueen, & Cutler, 1997; Vroomen, Tuomainen, & de Gelder, 1998). Additionally, prosodic cues, such as stress were used well in detecting word boundaries. Cutler & Norris (1988) propose the Metrical Segmentation Strategy (MSS) for a stress language like English that contains either strong or weak syllable. MMS predicts that native English listeners likely receive strong syllables as word onsets in the continuous speech stream. In this dissertation, I also intend to employ a language-dependent phonotactic cue, specifically geminates, to test its role in word segmentation for Japanese speakers. In Chapter 3, I will show that Japanese speakers, whose native language consists of a singleton-geminate distinction, can reliably learn words with geminates in them. English speakers too show a similar segmentation pattern as Japanese speakers, but exclusively for simple stimuli; when the stimuli are more complex, they tend to segment speech strings at geminates so that geminates are not retained. From the results, it is likely to be the case that English speakers were able to track the stimuli words in the speech string by the transitional probability (TP) rather than geminates guiding as a word edge cue in segmentation. Accordingly, it appears to be the case that the native language phonology plays a stronger role when the complexity of stimuli increases.

Furthermore, the dissertation will test a language-independent cue to contrast with the language-dependent cue to see its effectiveness in the task. Although there are a number of studies testing language-dependent information, both statistical cues and native language-specific cues, the role of language-independent cues in word segmentation is less studied. The cue that will be explored in this dissertation is the Sonority Sequencing Principle (SSP) that is claimed to be a phonological universal. Two previous studies that examined the role of SSP in word segmentation are Ettlinger, Fin, and Hudson Kam (2011) and Ren, Gao and Morgan (2010). The current dissertation will particularly follow Ettlinger et al. (2011) in Chapter 2, because Ren, Gao and Morgan (2010) is a very brief conference proceeding that does not contain full information about the experimental methodology. Ettlinger et al.'s (2011) study investigated whether the SSP would guide word segmentation for native English speakers using unattested onset clusters in English. The participants listened to a string of speech that contained CCVCV disyllabic nonsense words whose onset cluster of the first syllable differed in the SSP score ranging from 2 to -3, and then responded to questions about what they thought to be a word in the sequence they had heard. The SSP score was determined by how well the clusters conformed to the SSP. They found that the cue was a strong indicator of how listeners segmented words in the speech string. In Chapter 2, a series of experiments will test the potency of the SSP on Japanese speakers whose language has arguably no onset clusters, thereby suggesting minimal experience with the SSP because of little to no practical use of the SSP in their native language. Native English speakers will also be examined as a baseline case to see if the results from Ettlinger et al. (2011) are replicable, and to compare their performance with that of Japanese speakers. Ultimately, the present dissertation will compare the influence of language-independent SSP and language-dependent geminates cues on word segmentation and show that geminates as language-dependent cue are more reliable cue to detect novel words.

1.2.2 Second language acquisition

Since the current dissertation centers around *novel-word segmentation* and speech perception of adult speakers, it is necessary to consider the theories and existing empirical claims of second language acquisition. Adult speakers who already have established a phonological grammar for their native language will likely experience L1 interference when learning a new language (Flege, 1995). Understanding the specific mechanism in L2 learning may help predict what speakers do in *novel-word segmentation*.[1]

A word segmentation study supposes several things about word learning, such as the expectation of listeners relying on certain cues to segment strings but also more broadly and simply, it supposes that words are not learned directly from the string input unless listeners use some kind of strategy. This is because of the undeniable differences between listeners' L1 and the target L2 language. L2 learners will encounter difficulties in perception of the target language because they are not able to recognize the phonetic and phonological differences between their L1 and L2. Flege (1995) describes the mechanisms of L1 and L2 differences focusing on phoneme categorization.

Learners of an L2 may fail to discern the phonetic differences between pairs of sounds in the L2, or between L2 and Ll sounds, either because phonetically distinct sounds in the L2 are "assimilated" to a single category (see Best this volume), because the Ll phonology filters out features (or properties) of L2 sounds that are important phonetically but not phonologically, or

[1] For the rest of the dissertation, I will use the phrase "word segmentation" to mean *novel-word segmentation*, for the sake of simplicity, except in cases where further disambiguation in necessary.

both. He explains that L2 learners may not recognize the "phonetic differences between pairs of sounds in the L2, or between L2 and Ll sounds, either because phonetically distinct sounds in the L2 are "assimilated" to a single category" (Best, 1995), or because their native language filters out the important features in L2 phonology (Flege, 1995, p. 238). He proposed a learning model, named Speech Learning Model (SLM: Flege, 1995, 2003), that provides a framework to understand how learners face challenges with the non-native segments. The model ultimately aims to explain how L2 learners achieve L2 pronunciation, yet the hypotheses that it proposes are helpful in understanding the mechanisms of L2 perception as well. According to the model, the L2 sound's acoustic similarity (or the distance) to native L1 segment can determine how learners acquire those L2 sounds. One of the things he postulates is that "the mechanisms and processes used in learning the L1 sound system, including category formation, remain intact over the life span, and can be applied to L2 learning" (Flege, 1995, p.239). Thus, when L2 sounds are far enough from the closest L1 category, there is an emergence of new categories for L2 sounds. On the other hand, when L2 phones are acoustically closer and similar to the nearest L1 category, those L2 sounds are approximated to the L1 categories. Consequently, their perception of L2 sounds are similar to the L1 because their perception relies on the native sound system, which cause challenges in the L2 acquisition.

SLM also mentions that "sounds in the L1 and L2 are related perceptually to one another at a position-sensitive allophonic level, rather than at a more abstract phonemic level" and that "learners perceptually relate positional allophones in the L2 to the closest positionally (contextually) defined allophone (or "sound ") in the L1" (Flege, 1995, p.238-239). This means that context is a crucial feature in L2 learning. Flege explains using an example that native Japanese learners of English faces challenges learning the phonemic /l/ and /ɹ/. Since Japanese lacks /l/ and /ɹ/ contrast and has only one liquid, this contributes to the learning difficulties of /l/ and /ɹ/. Yet Japanese speakers also show learning discrepancies of the liquids between word-initial and word-final positions. He explains that word-final English liquids are learned more accurately (Strange, 1992 cited in Flege, 1995) because the /l~ɹ/ differences are more robust acoustically in the word-final position (Sheldon & Strange, 1982 cited in Flege, 1995). This might be relevant to word segmentation because listeners might be paying attention to such acoustic differences between the sounds in word-edge and word-medial ones. Such information about word edges may ultimately help detect the word boundary in word segmentation.

What separates word segmentation by adults from infants is that adults seem to use native segmentation strategies (Cutler, 2000). Studies suggest that L2 learners use their native language cues (prosodic, acoustic, and phonotactic cues) to segment words from non-native speech streams (e.g. Cutler & Otake, 1994; Weber, 2000).

While the current dissertation does not directly use non-native speech sounds, the stimulus words do include non-native patterns, and therefore, to that extent the process in *novel-word segmentation* will be informed by the above discussion of word segmentation of non-native speech. More specifically, I examine the influence of language-dependent phonotactics, namely geminates (long consonants) on adult word segmentation. In contrast, there are fewer clear expectations about the effectiveness of putatively language-independent (universal) cues on word segmentation for adults. In relation to this second issue, the Sonority Sequencing Principle is explored to see if it facilitates the word segmentation process for adults. They are examined separately in the following experiments, but their effectiveness is compared in Chapter 4 (Discussion).

1.3 Present dissertation

1.3.1 What is a word? – word minimality requirement

The entire dissertation is concerned with *words* and how listeners segment them from speech strings. Yet, there needs to be a discussion about what exactly are words and the minimal requirement of being a word in different languages. The two languages under investigation in this dissertation are Japanese and English, hence I will mainly focus on the discussion of words in these two languages.

McCarthy and Prince (1994) suggested that minimal word requirement of a particular language is equivalent to a minimal foot of that language:

$$\text{min(Wd)} = [\text{F}]_{\text{Wd}}.$$

Hence the smallest content word in English is the monosyllabic foot. This means that a word cannot be less than bimoraic (a heavy syllable) and it cannot be monosyllabic with a short vowel in an open syllable. Whilst a syllable with diphthongs, long vowel [+tense], or closed syllable with a coda is allowed to be a minimal word. Therefore, words such as *key* /ki/ with a long vowel, *tie* /tɑɪ/ with a diphthong, and *pass* /pæs/ with a closed syllable are attested; however, syllables such as /kɛ/, /tɪ/, and /pæ/ are not.

Likewise, there seems to be a bimoraic foot template in Japanese. To name one example, hypocoristic forms of names involves mapping the original name's segmental melody into bimoraic foot (Poser, 1990). Names such as *Hideki* can be mapped into *Hide*, and be attached to *chaN*, a hypocoristic suffix (*Hide-chaN*); or *Chiyoko* can be mapped to either *Chiyo* or *Chii* (with a long vowel), thus leaving with *Chiyo-chaN* or *Chii-chaN*. It is also possible to delete the word medial vowel in this process. For example, *Eiko* can be *Eko-chaN*, deleting the middle vowel. Loanword abbreviation is another process that requires the bimoraic foot template. For example, the word *purofesshonaru* ‘professional’ is truncated into *puro*, and *herikoputaa* ‘helicopter’ is shortened to *heri*.

Ito (1990) reveals that there is one simple problem to this since monomoraic words do exist in Japanese and they are not scarce. Table 1.1 shows some example monomoraic words that she gives in her study. She describes that these words are different from English function words such as *the* or *a* since the above examples are real content words.

su ‘vinegar’	ya ‘arrow’	*ki* ‘tree’
na ‘name’	ko ‘child’	*to* ‘door’
ta ‘rice field’	ka ‘mosquito’	*hi* ‘blood’
no ‘field’	hi ‘fire’	*e* ‘picture’
ne ‘root’	te ‘hand’	*ha* ‘tooth’

Table 1.1: Some monomoraic words in Japanese (Ito, 1990).

Despite the existence of monomoraic words, she explains that bimoraic minimality in Japanese can still be accounted for by the idea of *derivedness*. These words in Table 1.1, compared to minimally bimoraic template words, are underived forms that are excluded from the bimoraic minimality requirement. On the other hand, bimoraic templates are only applicable for a derived form of words, such as hypocoristic forms or loanword abbreviations.

In both English and Japanese, bimoraic minimality plays a role in word formation. Minimal content words in English must be bimoraic, yet there are monomoraic function words such as *the* or *a* in the language. Japanese has minimal bimoraic foot template for derived words; however, there are also underived monomoraic words as well.

1.3.2 Artificial language learning

The word segmentation paradigm in this dissertation will consist of a learning phase that allows participants to listen to a speech string consisting of a random sequence of words, and a test phase that contains questions to see how they segmented the string. The study particularly employs the artificial language learning paradigm to follow the conventions of the majority of the previous word segmentation studies, such as Saffran et al. (1996), Aslin et al. (1998), Kim, Cho, & McQueen (2012), and Kim, Broersma, & Cho (2012), to better control for the stimuli in the experiments. Artificial language learning involves training participants with artificial languages that contains nonsense words and often times with synthetic audio stimuli. With this method, the stimuli and the (artificial) languages that are presented can be controlled with particular acoustics and specific structural constraints (Christiansen, 2000; Culbertson, 2012).

The speech strings introduced in the dissertation will contain nonsense stimulus words that are created particular to the cues that are being tested. The SSP study in Chapter 2 has stimuli with complex onset clusters and the geminate study in Chapter 3 has /k/, /s/ or /z/ geminates in each stimulus. All of the stimuli were created synthetically, and the strings formed by concatenated stimuli were presented as new languages, so that participants did not associate the strings with existing languages, including their own. In order to examine the effect of language differences, speakers of two language groups, Japanese and English, were tested. These two groups were chosen because there is a good contrast between the two to test the SSP. Japanese is a language that has very limited (consonant+glide sequences) or no consonant clusters, while English allows a larger variety of consonant clusters in the language. The availability of consonant clusters in the language allows to test whether the SSP influences word segmentation in the same extent for the two types of speakers. The two languages also differ in the phonemic consonant length contrast, which gives good comparison for testing geminates as cues: singleton-geminates contrast is phonemic in Japanese, while it is not in English. Throughout the dissertation, experiments will explore the word segmentation patterns of these two language groups.

1.3.3 Language-independent and Language-dependent information

The primary focus of the dissertation is the investigation of word segmentation cues for native Japanese and English speakers, testing and comparing the effectiveness of language-independent and language-dependent cues. These cues will be tested separately but will be examined using the same experimental methodology in order to compare the usefulness of the two cues at the end. For the language-independent information, the SSP, which is argued to be a phonological universal, will be examined. For the language-dependent information, geminates that is will be tested. Here, the two types are discussed their probability of detecting word boundary in speech strings.

1.3.3.1 Language-independent SSP

The SSP governs syllable structure patterns: languages generally have a rise in sonority as one moves towards the nucleus in an onset, and a fall in sonority as one moves away from the nucleus in a coda (Clements, 1990; Jespersen, 1904; Kiparsky, 1979; Elizabeth Selkirk, 1984). Vowels are considered most sonorous, followed by glides, liquids, nasals and obstruents in the sonority hierarchy (Figure 1.2) in that order and languages generally prefer sonority rising into the nucleus rather than falling, as well as the preferential tendencies for larger sonority distances over smaller sonority distances between segments which is termed the Minimal Sonority Distance Principle (Selkirk, 1984; Clements, 1990).

low sonority ---→ *high sonority*

Plosive **Fricative** **Nasal** **Liquid** **Glide** **Vowel**

Figure 1.2: Sonority Hierarchy (Clements, 1990)

There have been claims about the universal preference that large sonority rises (e.g. /bl/) are more favored than small sonority rises (e.g. /bn/) (Berent, Lennertz, Jun, Moreno, & Smolensky, 2008). Berent, Lennertz, Jun, Moreno & Smolensky (2008) observed that universally dispreferred onset clusters that violate the SSP are more misperceived than the SSP adhering onset clusters, even to native Korean speakers whose language does not have onset clusters apart from consonant+glide sequences. Berent, Steriade, Lennertz & Vaknin (2007) also argue that listeners show grammatical preferences for the SSP obeying structures that are unattested in languages. Therefore, the SSP does not cause bias only for speakers who have experience with consonant clusters. In word segmentation studies, Ettlinger et al. (2011) and Ren, Gao and Morgan (2010) observed that native English speakers and native Mandarin speakers, respectively, segmented speech strings according to the SSP. Given that the SSP plays a role in perception even for speakers of languages with no consonant clusters, it is reasonable to expect that the SSP would also play a role in perception and, more relevant to us, in word segmentation for Japanese speakers, whose language has no consonant clusters which implies speakers' minimal experience with the SSP.

Rather than explaining it in terms of universal bias, Daland et al. (2011) suggest that, for English, lexical statistics can explain the SSP preference for unattested sequences. They claim that a computational model of phonotactics based on lexical type statistics can be applied for listeners to decide what is good and what is bad about particular phonological sequences. Their model can generalize and show preference to syllables towards a more phonologically similar kind in the language. While this casts some doubt on the SSP as a language universal, the viewpoint does not readily explain how speakers of languages without onset consonant clusters also show similar patterns. This is an important argument to keep in mind, and the notion of the SSP as language-independent knowledge will be maintained in this dissertation.

1.3.3.2 Language-dependent phonemic consonant length

Gemination occurs when two identical consonants are adjacent to each other. It can occur word-internally or at the juncture between words. Word-internal geminates can either be phonemic or formed by concatenation (e.g. morphological processes). Japanese has a phonemic contrast between geminates and singleton consonants. For example, [kako] 'past' and [kakko] 'parenthesis' have contrastive meanings in the language. These phonemic geminates are also called *true geminates* (Hayes, 1986). Word-internal geminates can also result from morphological process and are termed *fake geminates* (Hayes, 1986). While English does not have phonemic geminates, it does have word-internal heteromorphemic geminates – *fake geminates* (e.g. *bookcase* – formed via compounding; *unnatural* – formed via affixation). There are also word-external geminates at the boundary of words resulting from identical consonant fusion (e.g. *I hi**t** **T**om*; *ope**n** **n**ow*). *True geminates* are phonetically longer than singleton, yet it might also be the case that certain *fake geminates* are consistently long as well (Ben Hedia & Plag, 2017).[2] Regardless, the language-specific phonological patterns govern where and what type of gemination occurs in a specific language.

In terms of phonological representation of geminates, there have been different arguments on how to analyze the cross-linguistic phonological patterns and capture the singleton–geminate contrast. The standard representation of geminates is as presented by Hayes (1989). In this

[2]Ben Hedia & Plag (2017) focused primarily on *in-* and *un-* prefixed geminates, but the durational geminates/singleton differences suggest the relative durational properties of other geminates as compared to singletons in English.

representation, geminates are underlying moraic or heavy. The underlying forms for [ta] and [atta] in Figure 1.3 depicts the differences between singleton and geminate. Note that the singleton /t/ in [ta] is represented as underlyingly moraless, whilst the geminated /t/ in [atta] bears a mora. Upon syllabification, geminated /t/ in [atta] is linked to a mora in the preceding syllable and to another mora that it shares with the following vowel. On the other hand, the singleton /t/ is linked to the syllable of the following vowel and is not shared with any other syllable.

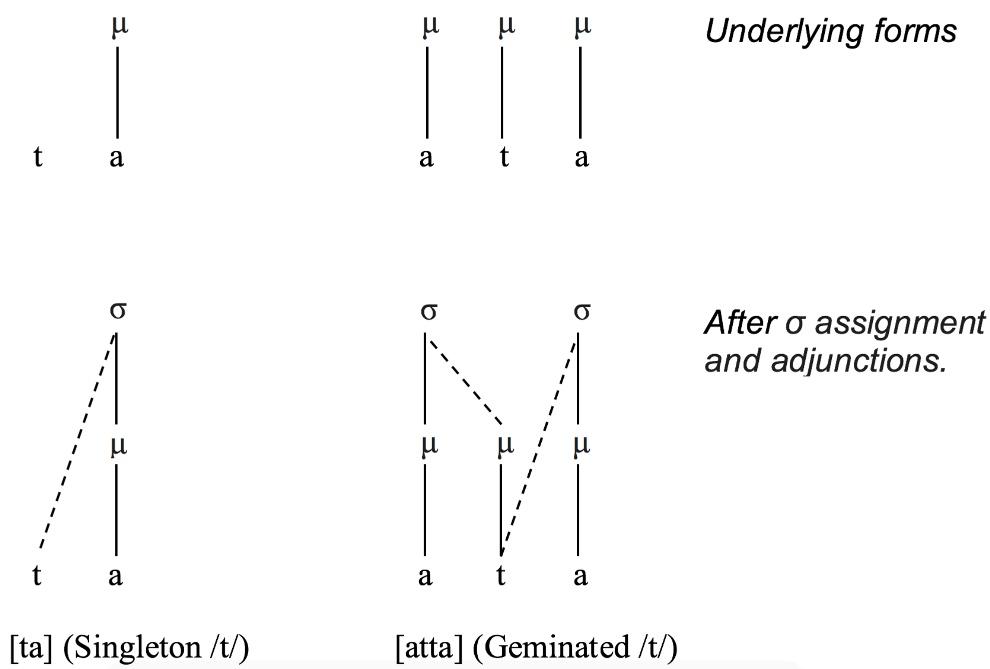

Figure 1.3: Geminates representation proposed by Hayes (1989) Left [ta] with singleton /t/ and right [atta] with geminated /t/.

This mora view of geminates contrasts with another autosegmental representation that captures the segmental length, where the singleton is linked to a slot and phonemic geminates are underlyingly double-linked to the prosodic tier (Figure 1.4; Leben, 1980; McCarthy, 1986). In case of the latter representation (Figure 1.4), Selkirk (1990) modified the relevant prosodic segmental unit to be root-nodes so that it can readily capture certain phenomena.

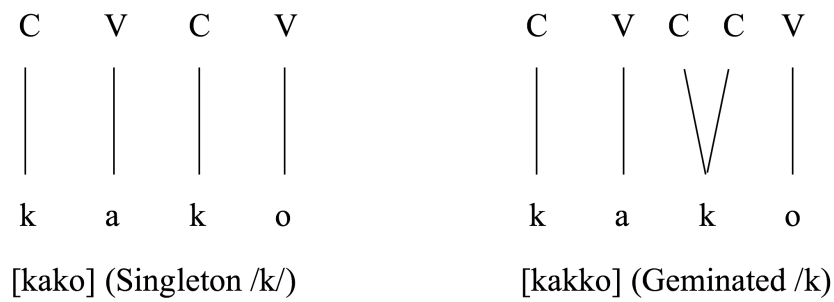

Figure 1.4: Geminates representation: where a geminate is linked to two root nodes. Left [kako] with singleton /k/ and right [kakko] with geminated /k/.

For immediately relevant for the current dissertation is the fact that *true geminates* in Japanese are phonetically longer than singleton counterparts (e.g. Kawahara, 2015). As gemination is common in native Japanese as well as in Japanese loanwords (Kubozono, Ito, & Mester, 2008), speakers are experienced with perceiving the geminates–singleton contrast. Therefore, it is highly likely that their knowledge of geminates in the language will influence perception of artificial language word segmentation during artificial language learning. They may recognize the consonant length difference better than those who are not familiar with phonemic geminates, such as English speakers, who might disprefer word-internal geminates. There are reports that the non-contrastive geminates, or *fake geminates* are also longer than their singleton counterparts (Ben Hedia & Plag, 2017).

1.4 Research Questions and Predictions

The current dissertation is interested in the word segmentation strategies for adult native Japanese and English speakers. It will center around three main questions:

(1) Will a language-independent cue, the SSP, guide word segmentation for Japanese and English speakers?

(2) Will a language-dependent cue, geminates, guide word segmentation for Japanese and English speakers?

(3) Between language-independent and language-dependent cues, which one is more effective in word segmentation for Japanese and English speakers?

The hypothesis for question (1) is that, considering the previous studies by Ettlinger et al. (2011) and Ren et al. (2010), it is probable that Japanese speakers will employ the SSP in word segmentation. However, if it does not guide segmentation, it may suggest that language-independent information is not sufficient as cues. In regards to (2), it is highly likely that geminates will guide Japanese speakers to retain geminates within words because their phonology allows such patterns in their language. In contrast, English speakers that do not have consonant length contrast in their native language will be more inclined to actually use those geminates as word edge segmentation cue and break up the double consonants in to two separate words. In regards to (3), I hypothesize the language-dependent cue rather than the language-independent cue will show more effectiveness in the specific case of geminates (language-dependent cue) than the SSP (language-independent cues) because word segmentation relies more on language-dependent knowledge than a language-independent one. On the other hand, geminate patterns reflect the phonotactics of individual languages, hence listener's knowledge of where and how geminates occur in words in their language may affect their perception and bias word segmentation.

1.5 Organization of the Dissertation

This dissertation is organized as following. Chapter 2 will examine the SSP and Chapter 3 will test geminates on word segmentation. Both chapters will focus on native Japanese and English speakers. Chapter 4 will discuss the findings from the series of experiments in Chapter 2 and 3. Finally, the paper will complete with the conclusion in Chapter 5.

CHAPTER 2 THE SONORITY SEQUENCING PRINCIPLE

2.1 Introduction

Some phonological knowledge of sound structures is observed to be universal (Berent & Lennertz, 2010). Such knowledge has been argued to be accessible to listeners with any language background and its knowledge is not particularly language-dependent (e.g. Berent et al., 2008, 2007). Accordingly, it is reasonable to assume that such constraints can be used strategically to perceive and learn languages the listeners are not familiar with. The current experiment investigated the language-independent Sonority Sequencing Principle (SSP), a presumed phonological universal, and its role in word segmentation.

Essentially, the SSP is a principle that concerns syllable structure. It proposes that typologically, syllables are formed with a rising sonority to the nucleus peak in the onset and descending sonority in the coda (Clements, 1990; Jespersen, 1904; Kiparsky, 1979; Elizabeth Selkirk, 1984). The syllable nucleus is the most sonorous and the segments at both ends of the syllable are least sonorous. For example, the syllable *bni* would be considered as an SSP adhering syllable because the plosive /b/ that is considered less sonorous than the nasal /n/ is further away from the nucleus /i/. In contrast, *nbi* would be violating the SSP. (This is described in more details in 2.2).

Given that the SSP is about syllables, the role in word segmentation is questionable, and is *at best* quite an indirect one. Regardless, there are claims that assert its usefulness in the process. Previously, two studies have investigated the SSP's role on word segmentation: Ettlinger, Finn, & Hudson Kam (2011) and Ren, Gao, & Morgan (2010). These studies found that the SSP biases the way native English speakers (Ettlinger et al., 2011) and native Mandarin speakers (Ren et al., 2010) segment words in a string of speech. In these studies, when listeners were presented with a continuous string of speech with no pauses between nonsense word stimuli, they separated the string into memorable units, or words, so that the word edges obey the SSP. Although they suggest that the SSP is a universal constraint, or a universal bias if not an immutable constraint (Ettlinger et al., 2011), that is available to listeners of different language background because the effect is evident in certain consonant cluster sequences that do not occur in English and in Mandarin, each study appears to have problems with their claim. Ettlinger et al. (2011) seemed to have problematic audio stimuli. They employed synthetic C_1C_2VCV stimuli in their experiment, where the word-initial C_1C_2 was a consonant cluster that either complied with or violated the SSP. However, some of their C_1 had noticeably vocalic releases upon closer inspection.[3] Perhaps the vocalic element between the C_1 and C_2 were due to synthetic stimulus artifact, yet it would be difficult to claim the SSP's role in word segmentation if the stimuli used did not contain consonant clusters to see if listeners' use of the SSP. In Ren et al.'s (2010) study, they employed monosyllabic stimuli throughout their experiment to test on Mandarin speakers. However, it is unknown if the segmentation results of monosyllabic stimuli apply to multisyllabic word level segmentation. The experiments in this chapter will introduce disyllabic stimuli words to test whether the SSP cues segmentation for monosyllabic words as well.

To address these issues and explore the role of the SSP, the current study focused on reexamining the effect of the SSP on word segmentation by testing two groups of speakers with different language backgrounds, native Japanese and native (American) English speakers. The main purpose of having two types of speakers was because the role of language-dependent factors in perception was also assumed. Even if the SSP is presumably a universal constraint, the degree of its effectiveness in word segmentation may be affected by the listeners' language experience.

[3] Marc Ettlinger generously shared his stimuli with me. The stimuli were heard by me and several other linguists and determined that the C_1C_2 had vocalic element between the segments.

Thus, the listeners who do not have experience with complex consonant clusters (namely, Japanese speakers) were compared with those who have experience with complex consonant clusters (namely, native English speakers) with respect to how much the SSP influenced their word segmentation. The speakers of languages that allow complex onsets may be more experienced with and sensitive to the SSP than speakers of languages that do not have complex onsets.

This chapter will reveal that upon reexamining the role of the SSP, there is no observable evidence that it is used to cue word segmentation by listeners of different language backgrounds, both native Japanese speakers and native English speakers. It is likely that the SSP, a principle about syllables, does not apply to word-boundary detection. As Clements (1990) states, the SSP governs "the preferred order of segments within the syllable" and it does not predict the preferred order of segments within words. Therefore, the SSP does not help detect word edges in fluid speech.

The following research questions guided the study in this chapter:

(i) does the SSP have an effect on word segmentation?

(ii) does language experience have an effect on the extent to which the SSP plays a role in word segmentation?

2.2 Background and previous studies

The SSP, which governs the sequences of consonants within a syllable, is generally accepted to be a language universal (Clements, 1990; Kiparsky, 1979; Elizabeth Selkirk, 1984). The SSP is a general tendency for syllables across languages to have a rise in sonority as one moves towards the nucleus in an onset, and a fall in sonority as one moves away from the nucleus in a coda (Clements, 1990; Elizabeth Selkirk, 1984). According to the sonority hierarchy, vowels are considered the most sonorous type. Glides, liquids, nasals and obstruents follow the vowels in sonority, in that order as it is demonstrated in Figure 1.2[4].

For example, the segment sequence in the word /slæp/ in English abides by this principle. The onset cluster /sl/ starts with a less sonorous obstruent /s/ then rises to a more sonorous liquid, which is followed by the nucleus /æ/. On the other hand, there are sequences that violates the SSP as the word /stɑp/. The onset cluster /st/ has a less sonorous plosive /t/ closer to the nucleus than the fricative /s/. Nevertheless, past studies have demonstrated that languages typically favor sonority rising into the nucleus rather than falling (Clements, 1990; Steriade, 1982; Zec, 2007). The more common rising sonority sequences are considered to be unmarked in onsets, while those with falling sonority are uncommon in onsets, thereby marked. Moreover, there tends to be a universal preference for larger sonority distances over smaller sonority distances between segments. This phenomenon is called the Minimal Sonority Distance Principle (Selkirk, 1984; Clements, 1990). Berent, Lennertz, Jun, Moreno & Smolensky (2008) discuss the universal preference whereby, in onsets, *large sonority rises* (e.g. /bl/) are more preferred than *small sonority rises* (e.g. /bz/), *small sonority rises* are more preferred than *sonority plateaus* (e.g. /bd/), and *sonority plateaus* are in turn preferred over *sonority falls* (e.g. /lb/).

This raises the question, "what about languages that do not allow complex consonant clusters in a syllable?" Languages such as Japanese, Korean, and Mandarin do not have complex syllabic structure, apart from consonant-glide sequences; hence, it is debatable whether the knowledge of SSP is actually present in speakers of such languages. It is important to note that whether these languages have complex consonant clusters (namely, consonant-glide sequences) is debatable as well. Although languages such as Japanese, Korean, and Mandarin have simpler

[4] Due to formatting restrictions, this figure cannot be presented again on this page. Please refer back to Figure 1.2 in the previous chapter.

syllabic structure than English because, for example, it does not allow the second member of CC onset cluster to be anything other than glides. Yet it is also not clear if the pre-nuclear glide in /Cj/ consonant-glide sequences are actually part of the vowel nucleus or actual consonants forming a cluster. Some studies claim that the pre-nuclear glides are part of the nucleus, in Korean (Sohn, 1987; Kim, 1998) and in Mandarin (Cheng, 1973), while some suggest that they form an onset cluster with the preceding consonant, in Korean (Lee, 1994; Cheon, 2002) and in Mandarin (Bao, 1990; Duanmu, 1990; Lin, 1989). Duanmu (2002, 2009) proposes a single-slot analysis for languages with both simple onsets (e.g. Mandarin) and complex onsets (e.g. English). His analysis proposes a single complex sound to encompass a traditionally assumed consonant cluster. More over some claim that the glides can be either part of the onset or nucleus in Mandarin, determined by the place of articulation of the consonant which they precede (Wan, 1997). Therefore, whether these languages have consonant clusters at all is unclear.

In Japanese, the focus language of this dissertation, the most complex consonantal sequence found in syllables is the /Cj-/ sequence in the onset, where a glide intervenes between a consonant and a vowel nucleus. There are three possible analysis of the pre-nucleus glide of /Cj-/ sequence in Japanese. One possibility is that it is a distinct segment, giving rise to a complex consonant cluster. Concluding from duration measurements of [CjV] and [CV] comparison, Nogita (2016) claims that the [Cj]s are consonant clusters since [CjV] were longer than [CV] counterparts. Another possible analysis is that the pre-nuclear glide is the secondary palatalization on an obstruent. The third possibility is that the pre-nucleus glide is part of the vowel nucleus /iV/ as Hashimoto (1984) claims. Nasukawa (2015) also supports that the palatal glide in /Cj-/ is not a consonant but forms part of the vowel nucleus in Japanese because /j/ behaves more correlated with the vowel than the /C/. Nevertheless, Japanese has a much simpler syllabic structure compared to English; therefore, employing the two in the experiment will allow a stark language comparison of the speakers' behaviors with different language experience and see whether Japanese speakers are also equipped with the SSP.[5]

There seems to be independent evidence that has been argued to show that speakers without relevant linguistic experience (of complex onsets) have knowledge of the SSP. Previously, Berent, Lennertz, Jun, Moreno & Smolensky (2008) examined Korean speakers' knowledge of SSP by presenting CCVC stimuli that have sonority varying onset consonant clusters (e.g. /blif/ and /lbif/) along with CeCVC disyllabic counterparts (e.g. /bəif/ and /ləbif/). They demonstrated that universally dispreferred onset clusters that do not adhere to SSP are more confusable with the disyllabic counterparts than the onset clusters that adhere to SSP, even to speakers whose language prohibits both /bl/ and /lb/ sequences. Arguably, the knowledge of the SSP in Korean speakers biased them to misperceive universally dispreferred /lbif/ as /ləbif/, more so than more preferred sequences /blif/ as /bəlif/.[6]

Other experimental studies support the claim that the SSP is obeyed for structures that are unattested in certain languages. Berent, Steriade, Lennertz & Vaknin (2007) and Ettlinger et al. (2011) observed native English speakers' perception behavior by employing unattested sequences in English as stimuli. The two studies utilized different experimental methods, syllable counting (Berent et al., 2007) and word segmentation (Ettlinger et al., 2011); however, their results both suggest that the SSP plays a role in perception and suggest its universality.

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[5]Ideally, employing languages, such as Hawaiian, that has no consonant cluster or coda would allow much more stark contrast against languages (e.g. English) that allow consonant clusters and coda; however, the author was unable to recruit such speakers in the dissertation.

[6]Berent, Lennertz, Jun, Moreno & Smolensky (2008) explain that the vowels transcribed as schwas /ə/ in /ləbif/ and /bəlif/ are short 'schwa-like' vowels, which are not precisely schwas.

There is also an alternative claim that the SSP is based on linguistic knowledge. One study that is worth mentioning here is Daland, Hayes, White, Garellek, Davis & Norrmann (2011). Rather than explaining it in terms of universal bias, Daland et al. (2011) suggest that a computational model of English phonotactics based on lexical type statistics can account for sonority distinctions speakers make about unattested sequences. Their model can generalize from observed sequences and shows a preference to nonce syllables that are of a "similar" kind to the ones observed in the language. Hence, they argue that the claim that SSP is based on language-independent knowledge may not be needed at all for speakers to decide what is good and what is bad about phonological sequences; if lexical statistics is responsible for sonority well-formedness, then there may be no pre-existing universal bias for sonority. While this casts some doubt on the SSP as a language universal, as pointed out in the Chapter 1 (Introduction), the viewpoint does not explain how speakers of languages without consonant clusters, apart from consonant+glide sequences, also show similar patterns. This is an important argument to keep in mind, and therefore, the notion of the SSP as language-independent knowledge will be maintained in this study.

The current dissertation extends the question on the SSP, based on Ettlinger et al. (2011). Ettlinger et al.'s (2011) study which investigated native English speakers' knowledge of the SSP using unattested onset clusters in English. Their experiment employed a word segmentation task that involved learning an artificial language. The participants listened to a string of speech, which consisted of a concatenation of stimuli that created an artificial "language", and then responded to questions about what they thought to be a word in the sequence they had heard. All of the stimuli consisted of CCVCV disyllabic nonsense words whose onset cluster of the first syllable differed in an "SSP score" ranging from 2 to -3. The SSP score was determined by how well the clusters conformed to the SSP. Given that the sonority scale is on a continuum as shown in Figure 1.2[7], the scores were calculated by the number of tiers between the two consonants in the cluster. For example, the /dn/ onset cluster was given a score of 2 since /d/, an obstruent, is two tiers away from /n/, a nasal. In another example, the /rd/ onset cluster was given a score of -3. Since /r/ is a liquid that is three tiers away from /d/, a plosive, it was given an absolute score of 3. Moreover, the score was negative because it violated the SSP. In addition to the SSP score, they also introduced varying transitional probabilities (TP) to their stimuli in segmental-level and syllable-level. In their experiment, the TP was determined by the sequence of segments that made up the onset cluster (segmental-level TP) and by the sequence of syllables that occurred in the string (syllable-level TP). For example, when determining the segmental TP, they looked at the rate of different segments occurring across stimuli. Some of the stimuli used are shown in Table 2.1. For instance, the stimuli /lzʌfɑ/ has a 0.5 TP. This is because /l/ occurs before /z/ in /lzʌfɑ/ and *n* in /lnʊpo/, which means that there is a 50% chance that /l/ will be followed by /z/ and a 50% chance that it will be followed by /n/. Other segments like /z/, /ʌ/, /f/, and /ɑ/ only occur once in the entire stimuli inventory; hence the TP is 1.0. If we multiply the TP of /l/ 0.5 by the TP of the segments in the rest of the word, 1.0, then we have 0.5 for within-word segmental TP for /lzʌfɑ/.

[7] Due to formatting restrictions, this figure cannot be presented again on this page. Please refer back to Figure 1.2 in the previous chapter.

	Language 1	*Language 2*
SSP score		
2	**dn**ɛku	**bm**ɪfei
1	**mr**ɪtei	**ml**æpi
0	**gb**ævi	**dg**ʊsa
-1	**ln**ʊpo	**rn**ɛko
-2	**lz**ʌfɑ	**rv**ʌtu
-3	**rd**əsai	**lb**ɪzo

Table 2.1: Some stimuli used in Ettlinger, Finn & Hudson Kam's study (2011). Adapted from "The Effect of Sonority on Word Segmentation: Evidence for the Use of a Phonological Universal", by M. Ettlinger, A. Finn, and C. L. Hudson Kam, 2011, Cognitive Science, 36, p. 5, 2011 by "Cognitive Science Society".

During the experiment, participants passively listened to a long string of concatenated words, which contained a total of six words in pseudorandom order, for approximately 18 minutes. This session was the learning part of the novel language and the participants were encouraged to draw during the listening session to avoid overt analysis of the language. Following this session, the participants were asked about the words they heard in the string to examine how they segmented the continuous speech. Ettlinger et al. (2011) employed a forced choice task where each test item played two tokens, one full stimulus and one part-word stimulus, and asked a question that forced the participants to choose one between the two: "Which was a word in this language?" The part-words contained simplex onsets that lacked the first segment of the complex onset cluster in the original stimuli (e.g. *lnʊpo* (Language 1) vs. *nʊpo*). The part-words also contained codas that were taken from the inventory of word-initial consonants of all stimuli in the list. For example, a part-word for *lnʊpo* were *nʊpod*, *nʊpom*, *nʊpog*, *nʊpol*, and *nʊpor*.

Upon running a forced choice task following the listening of the stimuli string, Ettlinger et al. (2011) found that the SSP biased the way native English speakers segmented words. When the SSP score of the stimuli was negative, the participants had a low accuracy. This suggests that clusters like [rdə] were not learned as a part of the same word. Instead, the segments were perhaps separated to form part of two different words. On the other hand, clusters with good SSP scores such as [dnɛ] were learned as clusters belonging in the same chunk. This is shown in Figure 2. The percent correctness steadily goes up as the SSP score increases.

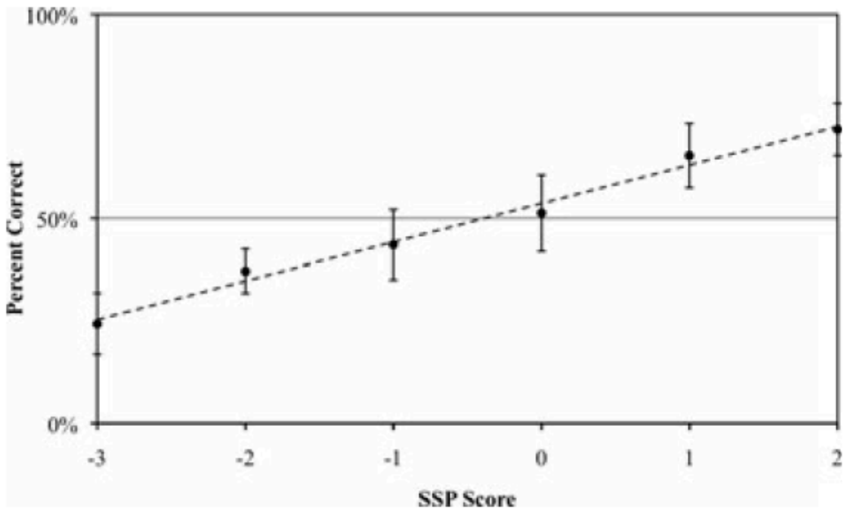

Figure 2.1: Results to Ettlinger et al.'s study (2011). Mean percent correctness for stimuli with SSP score ranging from -3 to 2.

Ettlinger et al. (2011) claim that the phonological universal worked in concert with a language-dependent factor, the transitional probability, during word segmentation. The result of their study indicated that along with the sensitivity to TPs, the SSP played an important role as a word segmentation cue. When an onset cluster of the stimulus abided by the SSP (SSP score > 0), it was segmented according to the TPs. However, when an onset cluster violated the SSP (SSP score ≤ 0), the TP was ignored and the cluster was segmented in a way that adheres to the SSP. If a word did not adhere to the SSP and there were alternate ways to segment the speech that was SSP-adhering, participants chose the SSP-adhering clusters over those that violate it. This was evident even though such SSP-adhering clusters occurred less than the actual stimuli in the language training phase.

Despite their claim that the SSP was used in word segmentation, there are a couple of concerns with their study that should be addressed here. One concern is their audio stimuli. As mentioned earlier, their audio stimuli seemed to contain a vocalic element between the clusters, especially with the ones that were assigned 0 or negative sonority scores. For example, the /r/ in the stimuli ***rd**əsai* with -3 sonority score was vocalic in that the onset /rd/ did not sound like a consonant cluster. The vocalic element may be a synthetic stimuli artifact; but, they are a confound in interpreting their results. Another concern is the lack of control group in the experiment. Although their focus was English speakers' word segmentation, they should have had another language group with which to compare the results.

Another study that explored whether the SSP biased speech segmentation was Ren et al. (2010).[8] They examined native Mandarin speakers' knowledge on the SSP for onsets and codas. Some of the things that differed from Ettlinger et al. (2011) were that the stimuli were monosyllabic CVC nonce words and that each syllable contained simple onsets and codas. The concatenation of their syllables (…CVCCVCCVC…) yielded consonant sequences as consonants were put adjacent to each other. After the exposure to the concatenated string, participants answered questions about which CVC words they heard in the training. Their results were in accordance with Ettlinger et al. (2011). The SSP appeared to cue word segmentation. Moreover, in their case, the results suggested that the knowledge of SSP was evident for Mandarin speakers for both coda and onset clusters.

Ettlinger et al. (2011) and Ren et al.'s (2010) results suggest that the SSP is perhaps a universal bias which is independent from language-specific experience. Ettlinger et al. (2011) asserted that their stimuli did not resemble attested English clusters and Ren et al. (2010) focused

[8]This study was presented at a conference and the available report is a short two-page article. Therefore, I was not able to obtain their stimuli list but only minimal information about the experiment.

on monolingual Mandarin participants who had minimal experience with complex clusters. However, it is possible that English speakers' former experience with onset clusters in their language might have had an effect on the task. Ettlinger et al. (2011) themselves mention that there might be "something about English that makes the SSP particularly salient" (p.14). Language-specific knowledge of consonant clusters may have prompted the segmentation process. Daland et al. (2011) point out that instead of being a language universal, the SSP could just be a generalization on the basis of the speakers' linguistic experience that is driven by phonetics, the "implicit knowledge of articulatory and perceptual relations" (p.229). If this is the case, it would be worthwhile to examine and compare the differences between speakers of languages with consonant clusters and speakers of languages that prohibit onset/coda clusters all together, because Ettlinger et al. (2011) and Ren et al. (2010) tested one group of language speaker in each study. Ettlinger et al. (2011) solely examined English speakers and Ren et al. (2010) examined Mandarin speakers only (Ren et al. (2010) is not an experiment that has been presented elaborately, so it is necessary to evaluate it with caution.); hence, this chapter will test two language groups and directly compare them their performance on the same stimuli.

In this chapter, we will look at the issue of SSP and word segmentation using Japanese and English. Japanese prohibits consonant clusters in onset and coda positions.[9] Therefore, if SSP is a product of a generalization from observable phonotactic patterns, then it is reasonable to assume that the generalization for Japanese speakers would be quite different from that of English speakers. Furthermore, it is not possible to imagine inferring something like the SSP purely from experience with consonant-glide sequences. The experiments in this study were designed to see the differences between how native Japanese monolinguals with no experience with consonant clusters and

[9]As mentioned earlier, the one exception is the obstruent-glide combination in the onset. However, it is still debatable whether the glide is a separate segment or a secondary articulation.

English speakers with such experience would employ SSP to segment a string of speech with consonant clusters.

Past word segmentation studies have dealt greatly with TPs and it has been shown that TPs influence word segmentation for both adults and infants (Saffran, Aslin & Newport, 1996; Saffran, Johnson, Aslin & Newport, 1999; Saffran, Newport & Aslin, 1996). Therefore, the present study attempted to control the TPs to be as similar as possible, so that they were not as pronounced as the SSP cue, the main focus of the study. The segmental TP was controlled by utilizing the maximal variety of segment types possible in order to keep steady TP for all segments. The most prominent TP variability lies at the syllable-level as it was inevitable to get around the word units in the strings that is composed of specific syllables. For instance, if the speech string contains nonsense words like /bnife/, the chances for /bni/ syllable following /fe/ is higher than /bni/ following any other syllables. Thus, the existence of TPs, especially syllable TP, should be noted as an additional cue in the experiments. However, the TPs are the same for all the test words and therefore do not bias the main experimental question: do listeners use SSP during word segmentation?

2.3 Purpose of this study and hypotheses

The two research questions that will be addressed in this study are as follows.

(i) Does the SSP have an effect on word segmentation?

(ii) Does language experience have an effect on the extent to which the SSP plays a role in word segmentation?

The study in this chapter aimed to investigate whether the SSP affects word segmentation and replicate Ettlinger et al. (2011) and Ren et al.'s (2010) findings. The study also examined whether having a different language experience has an effect on the extent to which the SSP plays a role in artificial language learning. Participants with different language backgrounds, Japanese and English, were recruited to test this.

Previous studies such as Berent et al. (2007) and Ettlinger et al. (2011) showed that the phonological universal has an impact on structures that were not attested in the languages of their participants. Berent et al. (2008) and Berent et al. (2007) claim that listeners exhibit the knowledge of universal restrictions in perception by looking at native Korean speakers whose language lacks the actual patterns that could allow one to learn such restrictions. The current study extended the investigation by looking at how the SSP contributes in word-learning rather than perceptual syllable-counting tasks. It followed Ettlinger et al. (2011) and employed a word segmentation task to language learning for Japanese speakers. If language experience does play a part along with the SSP, then it may be the case that Japanese speakers will rely less on the SSP than English speakers because they have less experience with complex consonant clusters that requires the extensive knowledge of the SSP and the language does not overtly exhibit the SSP because of their simple syllable structure. Instead, Japanese speakers will rely on alternate phonotactic or prosodic cues such as pitch patterns and duration instead of the SSP. Although, there are not many studies on the interaction of language experience and phonological universals in word learning tasks, the influence of the native language experience on perception of speech sounds for adult speakers has been well established in the literature (Best, 1995; Boomershine, Hall, Hume, & Johnson, 2008; Flege, 1995). Hence, it is plausible to anticipate that language experience will impact (or modulate) the SSP's role in word segmentation. On the contrary, if experience does not impact the effectiveness of the SSP, then the outcome of the word segmentation task for Japanese and English speakers should be identical.

Based on such claims in the literature, one might be inclined to hypothesize that the SSP will impact word segmentation for all speakers. However, it is questionable if a principle specifically about syllables (Clements, 1988) will extend to constrain the detection of words in a speech string. Although the SSP is argued to be a universal constraint that influences listeners' perception, regardless of the language background of the listener, it is only a restriction on syllables and not words. While it might perhaps guide segmentation for languages that have a high number of monosyllabic words (such as Ren et al. 2010), where principles about syllables can perhaps be transferred probabilistically to principles about wordhood, it is questionable if the principle can be applied generally to word level representations, especially in languages which do not contain a high proportion of monosyllabic words. A series of experiments below will indeed demonstrate that the SSP does not guide word segmentation for both native Japanese and English speakers.

2.4 Experiment 1

A word segmentation task was employed in this experiment. This task was comprised of a learning phase during which participants listened to an auditory stream of nonsense word stimuli; followed by a test phase that examined how participants chunked the sequence they heard. Through this experiment, it was examined whether the SSP is as strong of a cue for Japanese speakers (who only have language experience primarily with simple syllabic structure) as for English speakers (who have experience with complex onset clusters).

In the learning phase, participants were exposed to a string of novel words with complex onsets (CC) that varied in SSP scores. In the test phase, after exposure, participants were asked about their knowledge of the words they just heard. TPs at the segmental-level and syllable-level was controlled to be minimal so that they did confound the SSP cue. The segmental TPs were kept steady for all segments by controlling the appearance of each type of consonant to be as equal as possible. On the other hand, the introduction of syllable TP was inevitable as the specific syllables had to be present to create stimulus words in the string. As explained earlier, for nonsense words like [bnife] in the string, the chance of the syllable [bni] following [fe] is higher than [bni] following any other syllables. Hence, the existence of syllabic TPs is unavoidable and must exist supplementary cues. However, crucially, these syllabic TPs don't confound the main question about SSP, as all the constructed words have the same syllabic TPs.

To have even better control over the experiment, all of the stimuli in the string were nonsense words and synthetically recorded, creating novel *languages*. The concatenated string of such recordings was heard by the participants. An artificial language learning paradigm (ALL) was employed, as it has been discussed in the literature to be a useful method for a controlled language learning environment (Culbertson, 2012). Synthetic stimuli may not sound like natural speech; they are, however, necessary to control what cues are being introduced in the speech strings.

2.4.1 Methods

2.4.1.1 Participants

The participants of this experiment were 22 native Japanese speakers (7 females and 15 males) and 30 native American English speakers (22 females and 8 males). They were all college aged, between 18 to 23. The Japanese speakers were monolinguals living in Tokyo, Japan, with limited knowledge of other languages. The English speakers were also monolinguals with limited knowledge of languages other than their own. The participants all claimed to have lived in their home countries (Japan or the U.S., respectively) all their lives and to have spent no longer than 30 days abroad. Both participant groups had normal hearing and received the same experiment in a controlled setting.

2.4.1.2 Stimuli

The stimuli consisted of nonsense disyllabic words with varying onset clusters on the left-edge of the word as is shown in Table 2.2, below. The two lists of stimuli are such that they are counterparts of each other; the segments in the onset clusters in the first list are reversed in sequence to create the second list. This was done to control for any effect purely due to the acoustics of the specific segments in the tokens. The two lists of the *language types* were named *Language 1* and *Language 2*. The two "mirror-image" *languages* were introduced in order to avoid looking at only the results of specific segment combination of the stimuli (e.g. only ***bn****ife* for SSP score 2); therefore, the two languages allow us to control for segment-specific responses in the experiment . The results and the analysis of the results should represent the effect of SSP on word segmentation and not the particular stimuli effect on word segmentation. The following experiments in the entire dissertation (Experiment 1, 2, 3, 4 and 5) applied this method of introducing two *language types* that are counterparts of each other.

The onset clusters in each *language type* had stimuli with SSP scores[10] {2, 1, 0, -1, -2}. Hence the reversal of a sequence will change the polarity of the scores. For example, ***bn****ife* in *Language 1* with a score of 2 is a counterpart to ***nb****ife* in *Language 2* with a score of -2. Ettlinger et al. (2011) had limited their consonants in the stimuli to be voiced in their study; however, the current study introduced both voiced and voiceless consonants in order to test if the SSP applies to both voiced and voiceless consonants.

Upon creating the stimuli, I attempted to control the TPs to be less varied and less prominent as possible for all segments by not repeating the same consonant twice in the onset. Therefore, [b] in ***bn****ife* did not appear in other clusters in *Language 1* or [b] in ***nb****ife* did not appear

[10]The SSP score were determined using the same method as Ettlinger et al. (2011) where the tiers between two consonants in the sonority hierarchy were counted.

in any other clusters in *Language 2*. Varying syllable TP, however, was inevitable because of the formation of syllables to create specific stimulus words. For words like [bnife], the chances for [bni] syllable following [fe] is higher than [bni] following any other syllables like [fek], for example.

All of the stimuli were recorded using a male voice on MacinTalk (Speech Synthesis Programming Guide, 2006), a software available to Macintosh computers that produces synthetic speech sounds. Rather than recording each stimulus word at once, each syllable was recorded separately because MacinTalk was imposing stress and producing words that were not quite controlled when stimuli words were recorded at once. It appears to be the case that MacinTalk utilizes sound pattern of the language to which the computer device is set, and it tries to mimic the sounds of that language. In my case, my MacBook Pro was set in American English; therefore, the output was somewhat English-like. Hence, words were created by first recording each syllable first, then those relevant syllables were put together to form disyllabic words. After the creation of stimuli sounds, those stimuli in each *language type*, *Language 1* and *Language 2*, were concatenated into separate strings to last 15 minutes each. The order of stimuli in the string was pseudo-random such that the same stimulus never appeared consecutively. The order in which the stimuli appeared was determined by hand and not automated. Each stimulus was controlled to appear roughly the same number of times in the string to avoid creating any kind of bias. I also made sure that there were no pauses in between the stimuli so that there were no obvious cues for spotting the stimulus words in the string.

I created two strings in total; hence, the two *language types* (Table 2.2). Each participant was exposed to only one *language type*.

Language 1		***Language 2***	
SSP score		SSP score	
2	**bn**ife	-2	**nb**ife
1	**kf**ɑmi	-1	**fk**ɑmi
0	**dg**usɑ	0	**gd**usɑ
-1	**vt**eko	1	**tv**eko
-2	**lz**otʃu	2	**zl**otʃu

Table 2.2: Stimuli lists with varying degrees of SSP in onset clusters according to *language type*: *Language 1* and *2*.

The test tokens in the test phase were also recorded using MacinTalk. These tokens were recorded using a female voice to contrast with the male voice used in the stimuli speech string. This was done to verify if participants learned the words they learned in the string, regardless of the voice. To examine the degree to which the SSP affected the participants' word segmentation, yes-no questions were prepared for the test. Each test trial presented either (1) an actual complex onset stimulus (e.g. ***bn****ife*), (2) a simple onset part-word (e.g. ***n****ife*) or (3) a filler in the *language type* and asked a yes-no question if it was a word in the language participants just heard. There were 5 tokens for each type of test item (1, 2, and 3), and there were 15 total of tokens per *language type*. The list of tokens is presented in Table 2.3, below. Similar to the creation of the training task stimuli, all test stimuli and filler items were recorded as separate syllables, then the syllables were concatenated to create disyllabic words. To create part-word audio, the first segment of the onset cluster was spliced out using Praat (Boersma & Weenink, 2015).

Language 1		***Language 2***	
Test item type		*Test item type*	
Stimuli	**bn**ife	Stimuli	**nb**ife
	kfɑmi		**fk**ɑmi
	dgusɑ		**gd**usɑ
	vteko		**tv**eko
	lzotʃu		**zl**otʃu
Part-word	nife	Part-word	bife
	fɑmi		kɑmi
	gusɑ		dusɑ
	teko		veko
	zotʃu		lotʃu
Fillers	bimano	Fillers	bimano
	tʃetʃe		tʃetʃe
	demtom		demtom
	shanpa		shanpa
	tudal		tudal

Table 2.3: Test tokens (stimuli, part-word and fillers) used in Experiment 1 for *Language 1* and *Language 2*.

The purpose of part-word questions was to see if the SSP score on the onset cluster influences segmentation. In the results, it was examined whether stimuli with a high SSP score such as ***bn**ife* were segmented into a part-word (***n**ife*) as much as stimuli with low SSP score such as ***lz**otʃu* were segmented into a part-word (***z**otʃu*). As mentioned in the hypothesis, it was anticipated that more universally accepted onset clusters would be accepted more by the participants as word-initial clusters than less universally accepted onset clusters being accepted as word-initial clusters.

The test items were presented with a simple yes-no question format. Only one token (either a stimulus, a part-word, or a filler) was played in each test item. After hearing the item, the participants who heard *Language 1* answered questions like "Was ***bn**ife* a word in this language?". On the other hand, participants exposed to *Language 2* were asked, "Was ***nb**ife* a word in this language?”. Another question was related to the part-word counterpart of the relevant stimulus item they heard, e.g. “Was ***nife*** a word in this language?”. Japanese participants heard the equivalent questions in Japanese, e.g. “***bnife***はこの言語の言葉ですか? (***bnife*** wa kono gengo no kotoba desu ka?)”. It was made sure that the questions specifically asked for words in order to prompt participants to answer for words, and not for any other possible type of units in the string (e.g. phrases, morphemic units).

2.4.2 Procedure

There were two parts to this experiment and the entire session was performed in a quiet room. The first part was the learning phase where participants listened to a language string. This was followed by the test phase where participants were tested on their inferred knowledge of the words they have heard during learning phase. In the instructions right before the learning phase, participants were told that they will be listening to a new language and that they will be asked about the words they heard in the language after the listening. This was to motivate participants to listen for words, and no other possible units in the string. During the learning task, the string of stimuli was presented through a headset (Koss R-80 Over ear headphones) for 15 minutes while watching a silent cartoon (Popeye[11]). The original sound of the cartoon was removed to accommodate the stimuli speech string, hence the only audio they heard was the stimuli and not the voices in the cartoon. The purpose of the video was to have the participants not concentrate too much on the audio. Half of the participants of each native language (English or Japanese) were exposed to *Language 1* and the other half were trained with *Language 2*. None of the participants heard both *language type*s. For the second part of the experiment, participants were asked a series

[11]This particular cartoon was chosen because its original copyright has expired and it is free to obtain.

of questions through a headset (Koss R-80 Over ear headphones) that tests their knowledge of the words they heard. The instructions and questions in this test phase were in their native language and the participants responded by clicking on answers, either “Yes” or “No,” that are presented through PsychoPy (Peirce, 2007).

2.4.3 Experiment 1 Results

Similar to Ettlinger et al.’s (2011) procedure, the primary analysis employed to examine the role of SSP in word segmentation in this study is to compare the participants’ responses to stimuli with different sonority scores. If the SSP plays an important role in word segmentation, their results should be replicated in Experiment 1. Moreover, if the SSP is a phonological universal that is available to all language speakers, then their results should be replicated for both English and Japanese speakers. In fact, Experiment 1 did not show similar results as Ettlinger et al. (2011). It appears that the SSP score did not predict how participants learned the words in the *language type* they heard.

For the results, the “Yes” responses given by each participant were analyzed to the questions that asked whether each of the three types of tokens (Table 2.3) were words. By selecting “Yes,” participants presumably considered the token that they heard was a word in the *language type* that they trained with. All the statistical analysis and plots presented here were done in R (R-Core-Team, 2013).

2.4.3.1 Results for English speakers

First of all, the low rate of “Yes” responses for fillers in the middle plot in Figure 2.2 indicates that participants were able to correctly tell apart the fillers from the content of the string. It shows that they were not completely guessing in the test phase of the experiment. Hence the results shown here are not the outcome of pure guesses or random responses, but they are the outcome of what participants claimed to have learned in the word segmentation experiment.

The results for English speakers do not show a consistent increment in “Yes” responses as the SSP score increases. Instead there seems to be an unpredictable variation across the SSP score for the responses for both complex onset cluster tokens and simple onset tokens. Taking a look at the results for complex onsets in Figure 2.2, it can be observed that the stimuli with the SSP score -1 and 1 received the highest “Yes” response for complex stimuli. These stimuli were learned more likely as words by the English speakers, whereas the rest of the stimuli were learned less likely as words.

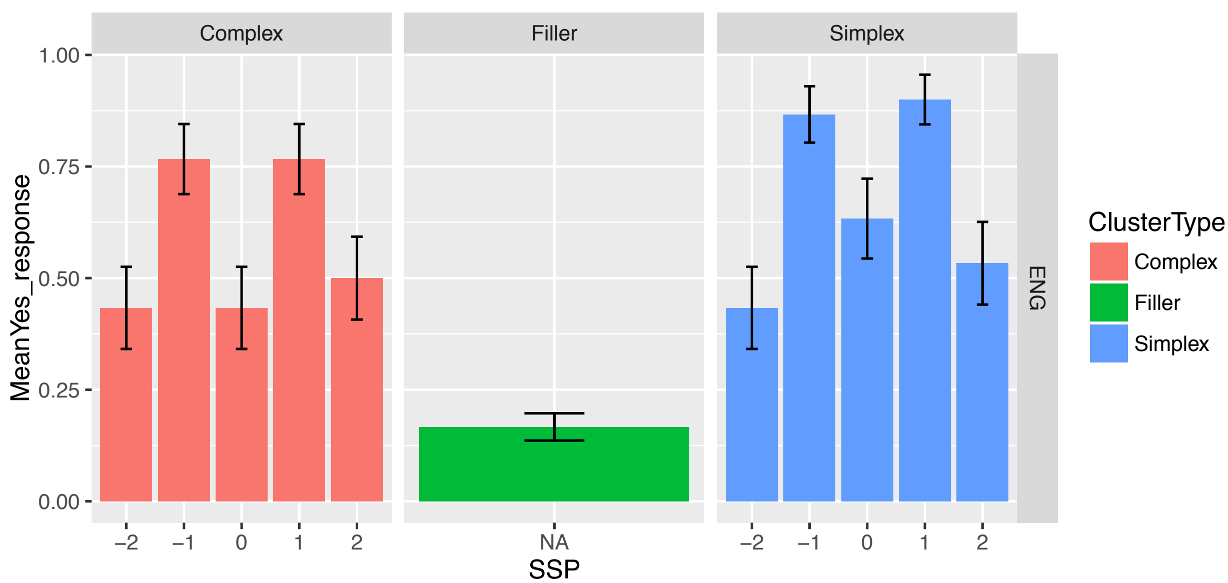

Figure 2.2: Mean Yes response by SSP score for English speakers. Left (Red): Mean “Yes” for complex onsets. Middle (Green): Mean “Yes” for fillers. Right (Blue): Mean “Yes” for simplex onsets.

A one-way ANOVA was run using ez package (Lawrence, 2015). It showed that the difference of the responses between the SSP scores is significant for both complex [$F(4,116) = 4.24$, $p<.005$] and simplex [$F(4,116) = 6.03$, $p<.005$] tokens. This indicates that there are likely differences in the "Yes" responses for different SSP scores. Furthermore, the mean "Yes" response for SSP score 1 and -1 was both around 77% (Figure 2.2). This was higher than the mean "Yes" response for SSP score 2, at 50%. A paired *t*-test was run to compare the differences between the mean "Yes" response for SSP score 1 with the results of SSP score 2. There was a significant difference in the two responses [$t(29) = 2.11$, $p = 0.043$]. Another paired *t*-test was run to compare the differences between the mean "Yes" response for SSP score -1 with the results of SSP score 0. There was a significant difference in the two responses [$t(29) = 3.34$, $p= 0.0023$]. These results support the inference that there is likely a drop of mean "Yes" response from SSP score 1 to SSP score 2 and from SSP score -1 to SSP score 0, and that the two pairs are going in the opposite trend that the SSP-based word-segmentation account predicts. A paired *t*-test was run to compare the mean "Yes" response for SSP score 1 and SSP score 0. There was a significant difference in the two responses [$t(29) = -2.76$, $p= 0.0098$]. Another paired *t*-test was run to compare the mean "Yes" response for SSP score -1 and SSP score -2. There was a significant difference in the two responses [$t(29) = -3.01$, $p= 0.0054$]. Although these results show the trend that the SSP predicts, the significant drop of mean "Yes" responses between SSP score -1 and 0, and between SSP score 1 and 2 do not support that the SSP guided word segmentation.

Furthermore, if the SSP was able to guide segmentation of definite word edges, there should have been a tradeoff between complex and simplex mean "Yes" responses. It was observed that the results for simplex onsets seem to show a variation similar to the complex results. The "Yes" response rates of SSP score -1 and 1 were high in both complex and simplex cases. It appears that participants accepted both complex and simplex tokens with SSP scores of -1 and 1 as single words. The stimulus ***kf****ami* (SSP score 1, Table 2.2), for example, was accepted as a single word but the part-word *fami* was also accepted. If the participants used the SSP to segment words, then there should be a trade-off between complex and simplex "Yes" responses: when stimuli with a low SSP score are not accepted as words, their part-word should have been accepted instead; and when stimuli with high SSP score are accepted as words, their part-word should not have been accepted. However, the results did not exhibit such a pattern.

The above results would not be anticipated if the SSP is expected to be a good word-edge indicator for English participants, based on the prior research discussed earlier in the paper. The results showed that even the most SSP adhering stimuli, SSP score 2, were not learned as individual words.

2.4.3.2 Results for Japanese speakers

The pattern seen in English speakers was evident for Japanese speakers as well. First of all, the low mean "Yes" response for fillers indicates that they were not completely guessing in the test phase (Figure 2.3). In addition, the complex stimuli with SSP scores of -1 and 1 seem to be associated with higher "Yes" responses than the rest, similar to the English speakers' results. There was no consistent increment in "Yes" responses as the SSP score increases. A one-way ANOVA revealed that the difference of the responses between the SSP scores is significant for both complex [$F(4,84) = 4.37$, $p<.005$] and simplex [$F(4,84) = 2.58$, $p<.005$] tokens. Complex stimuli that received the highest "Yes" response was SSP score 1, whose mean "Yes" response was over 95.5% (Figure 2.3). This was higher than the mean "Yes" response SSP score 2 received, at 50%. To compare the differences between the mean "Yes" response for SSP score 1 with the results of SSP score 2, a paired t-test was run. There was a significant difference in the two responses [$t(21) = 3.58$, $p= 0.0017$]. This indicates that the drop of mean "Yes" response from SSP score 1 to SSP score 2 is significant, and that the two are going in the opposite trend that the SSP assumes. A paired *t*-test was run to compare the mean "Yes" response for SSP score 1 and SSP score 0. There was a significant difference in the two responses [$t(21) = -4.18$, $p = 0.0004$]. This points that there was a rise in mean "Yes" response from SSP score 0 to SSP score 1, as the SSP assumes. However, it is incorrect to conclude that this was the effect of the SSP because of the significant opposite trend that was observed between SSP score 1 to SSP score 2.

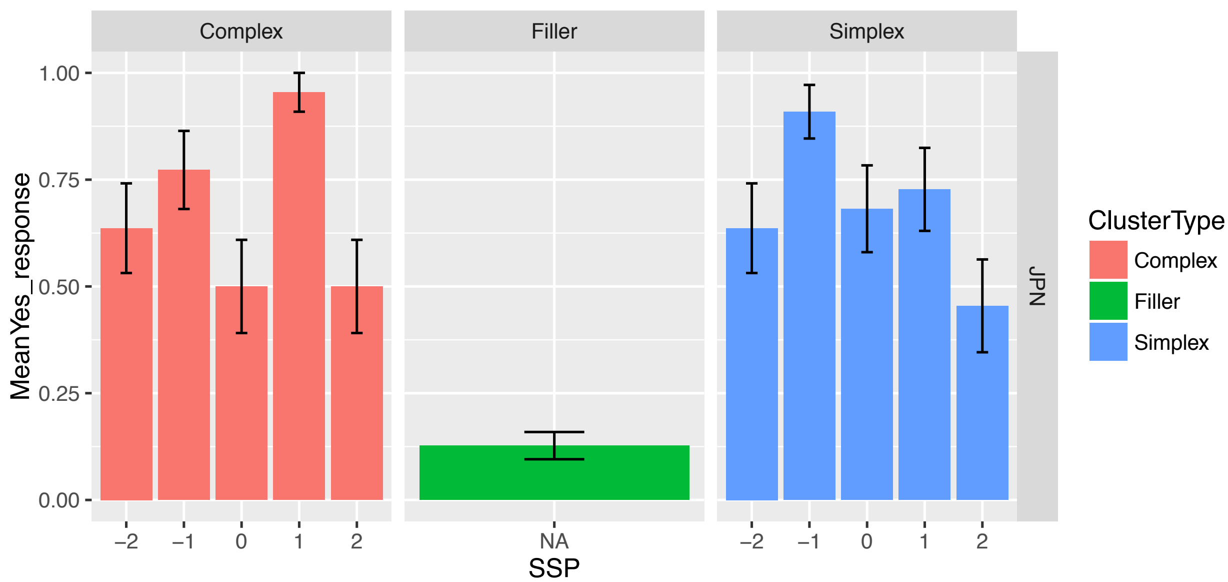

Figure 2.3: Mean Yes response by SSP score for Japanese speakers. Left (Red): Mean "Yes" for complex onsets. Middle (Green): Mean "Yes" for fillers. Right (Blue): Mean "Yes" for simplex onsets. X-axis: SSP score; Y-axis: Mean Yes response, 0~1.

As mentioned above, if the SSP was able to guide segmentation of definite word edges, there should have been a tradeoff between complex and simplex mean "Yes" responses. That is to say, if listeners segmented the word ***k****fami* (SSP score 1, Table 2.2) and the SSP marked definite word edges, then listeners would have given "No" response to the part-word *fami*. Yet the results do not indicate such pattern. The highest mean "Yes" response for complex were SSP score 1 and -1 (Table 2.5). The simplex results also had highest mean "Yes" response for SSP core 1 and -1 as well. This means that when listeners responded “Yes” for ***kf**ami* (SSP score 1), they also said “Yes” to ***f**ami*, similar to English speakers’ results.

2.4.3.3 Results by *language type*

To seek any interpretable pattern from the results, I decided to examine by separating the data by the *language type* participants were trained with for both English and Japanese speakers. Taking a look at the English speaker’s results by *language type* (Figure 2.4), one can notice a different trend for *Language 1* and *Language 2*. While the participants that were trained with *Language 1* appeared to have considered complex onset stimuli with an SSP score of 1 and 2 to be words at 75%, those who were trained with *Language 2* had the lowest “Yes” response for the stimuli with score of 2. The ANOVA shows that the complex onset results “Yes” responses are significantly different by SSP scores for both *Language 1* [$F(4,60) = 3.41$, $p<.05$] and *Language 2* [$F(4,52) = 6.81$, $p<.005$].

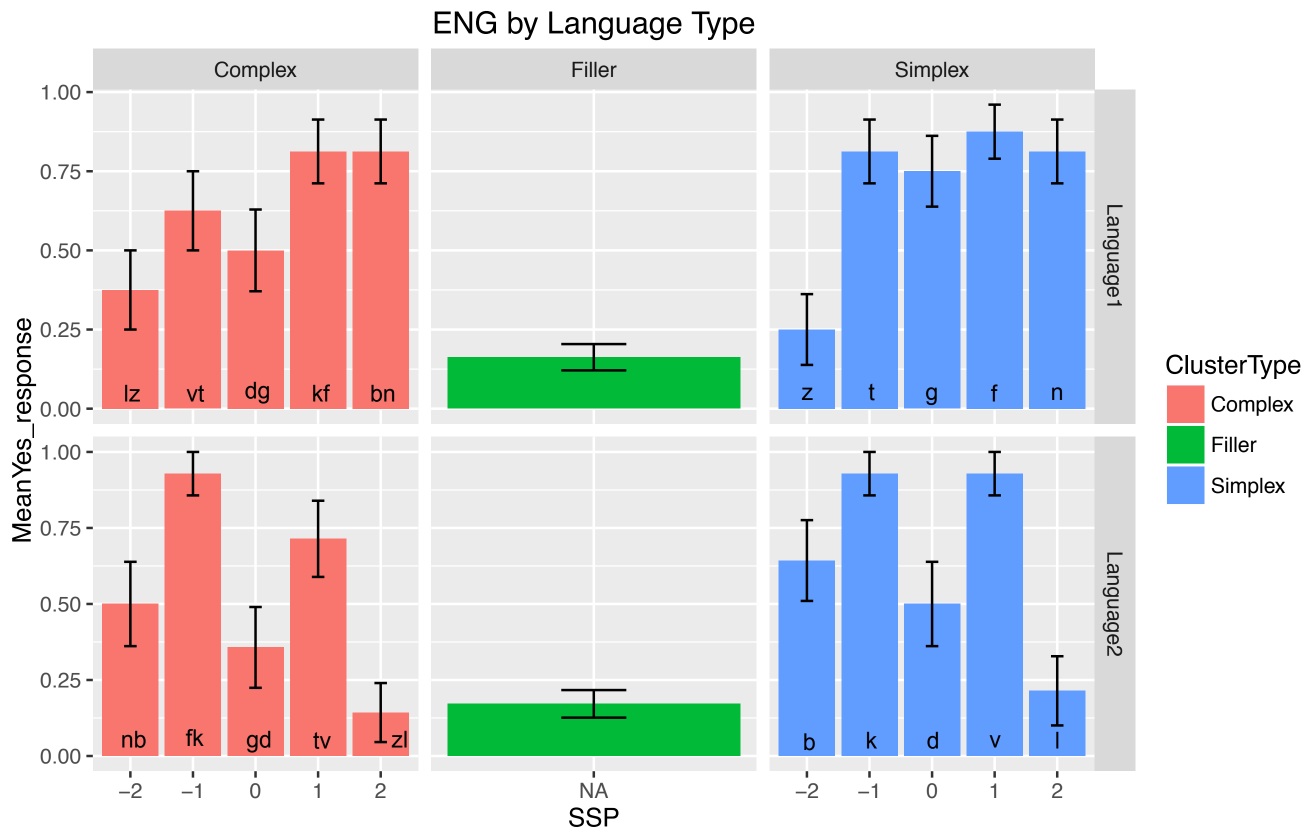

Figure 2.4: Mean Yes response by SSP score for ENG speakers by *language type.* Each bar for complex and simplex items is labeled with the word initial consonant/s of that item. Top row: *Language 1*. Bottom row: *Language 2*.

Although it is unclear, there seems to be a vague increase in "Yes" responses by the SSP scores for *Language 1*. The stimuli, ***lz****otfu* with the lowest -2 SSP score had the lowest rate of mean "Yes" (about 37%) and the ***bn****ife* with the highest 2 SSP score had the highest rate (about 78%), despite its tie with ***kf****ami* (SSP score 1). The SSP scores -1 and 0 results show a reversal of predictions; however, *t*-test demonstrates that there is no significant difference here. A paired *t*-test was run to compare the mean "Yes" response for SSP score -1 and SSP score 0, but there was no significant difference between the two [$t(15)=1$, $p=.333$]. On the contrary, *Language 2* reveals a rough trend in the opposite direction, where the SSP score of -1 received the highest "Yes" responses and the SSP score of 2 received the lowest "Yes" responses. Interestingly, in both *language types*, no matter what the SSP score was, the stimuli with voiceless onset clusters, ***kf****ami* and ***fk****ami* were learned well.

Moreover, in addition to the fact that ***fk****ami* was well accepted despite its non-adherence to the SSP, interestingly, its simplex part-word ***k****ami* was also accepted well. If we take a look at Figure 2.4 the complex response rates for each SSP scores are relatively similar to those of simplex response rates. Again, there is no tradeoff between complex and simplex onsets nor do we see a replication of Ettlinger et al.'s (2011) results.

Likewise, the results of Japanese speakers did not reveal a pattern that was expected either. By looking at the data by *language type* (Figure 2.5), we can see that there is no tradeoff for the "Yes" responses between complex and simplex onsets. For both *language types* there is no inverse relationship of the rate of "Yes" response between the complex and simplex onsets. Moreover, the ANOVA shows that the complex onset results for different SSP scores are significantly different for *Language 1* [$F(4,40) = 3.61$, $p<.05$] but not significant for *Language 2* [$F(4,40) = 1.5$, $p=.22$]. The lack of statistical significance in *Language 2* could imply that Japanese participants who were trained with *Language 2* had a distinct perceptual experience during the language exposure phase from those who were trained with *Language 1.* In addition, this dissimilarity between *language type* may indicate that the SSP scores was not a good predictor for how words were segmented and learned by the participants.

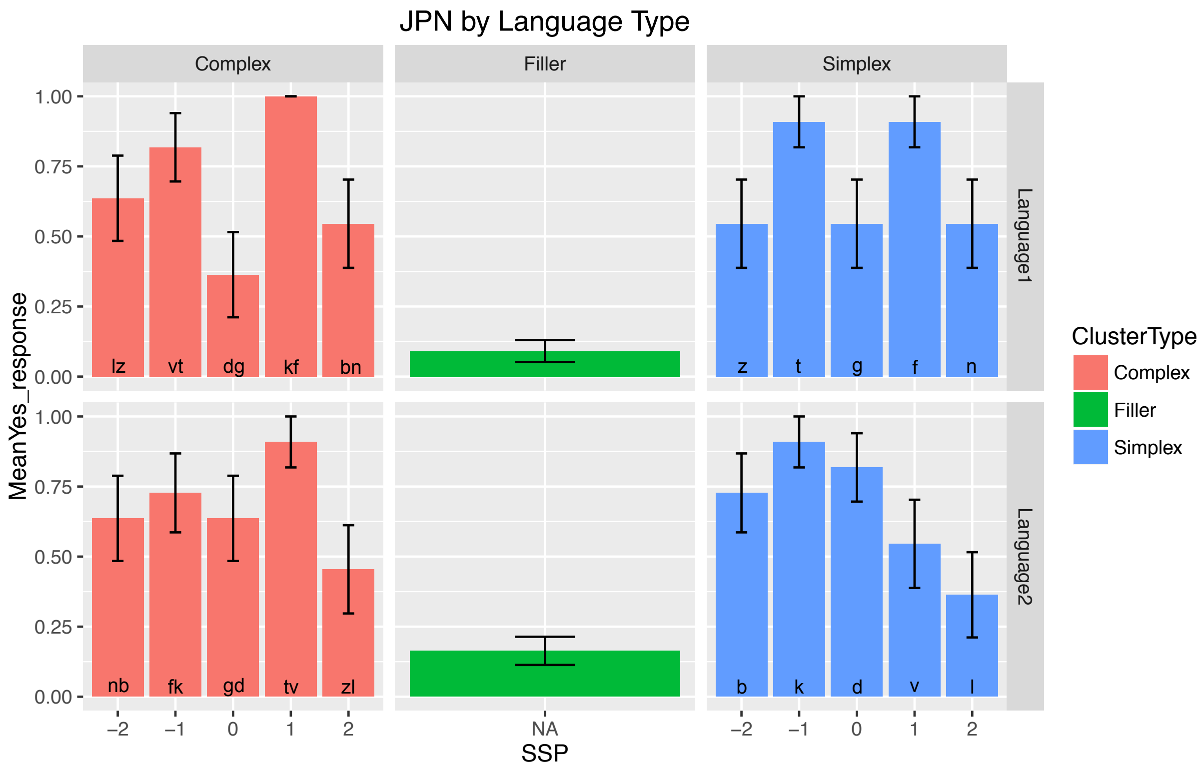

Figure 2.5: Mean Yes response by SSP score for JPN speakers by *language type*. Each bar for complex and simplex items is labeled with the word initial consonant/s of that item. Top row: *Language 1*. Bottom row: *Language 2*.

2.4.3.4 Positive correlation between complex and simplex test items

The results from Experiment 1 did not show that the SSP cued word segmentation for English and Japanese speakers. Initially, I had expected a positive correlation between the "Yes" responses to the complex test items and the SSP score, and a negative correlation between the "Yes" responses to the simplex test items and the SSP score. Nonetheless, the outcome was not what was expected. Furthermore, rather than having an inverse relationship, complex and simplex results seemed to both be positively correlated with each other. The "Yes" response rate for complex is strongly correlated to that of simplex for English speakers [r=.813, p<.001] and marginally significant for Japanese speakers [r=.375, *p*=.059]. A plot in Figure 2.6 summarizes the results.

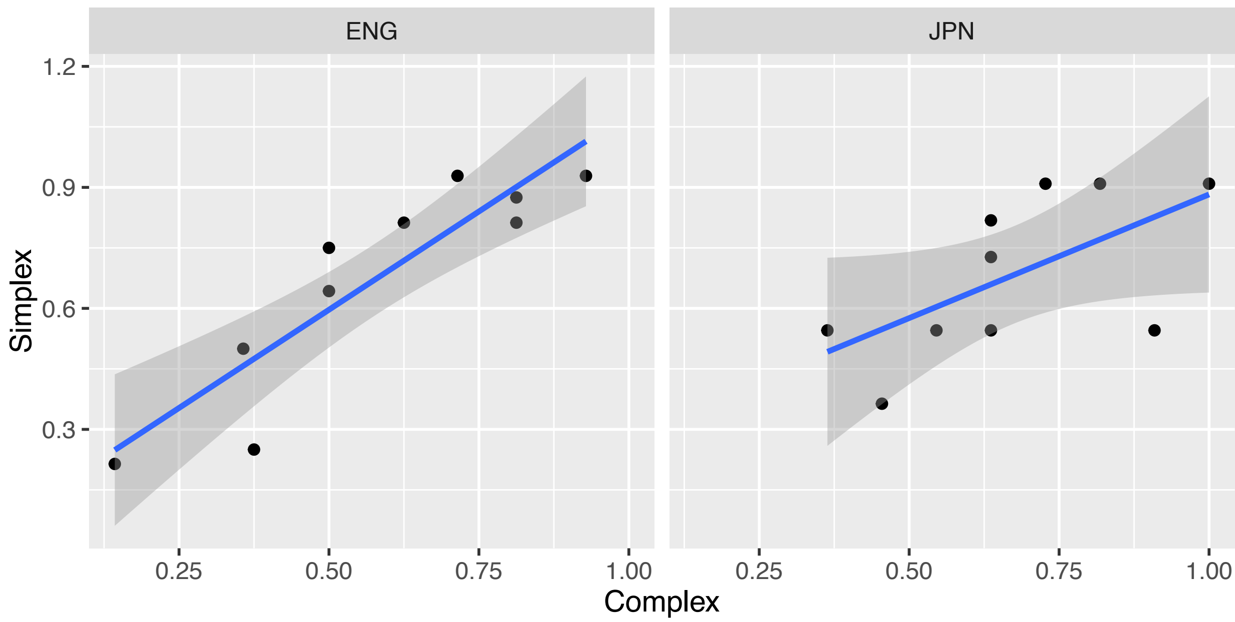

Figure 2.6: Correlation between the "Yes" response rates for Complex and Simplex test items for English and Japanese participants. Each data point indicates one test item; total 10 test items.

Since the results for English speaker did not replicate Ettlinger et al.'s (2011) study, even for the English speakers, it is not possible to draw any conclusions about how language experience affects the role of the SSP on word segmentation for Japanese speakers. The difference in experimental methodology may have possibly caused the differences in these results (McGuire, 2010). The following experiment tested the initial hypotheses with an experiment design that is more comparable to Ettlinger et al. (2011).

2.5 Experiment 2

To test whether the experimental method for Experiment 1 negatively affected the results of the current study a second experiment with a more faithful design to Ettlinger et al.'s (2011) study was conducted. If Ettlinger et al.'s (2011) claim is correct, Experiment 2 should yield similar results, where the SSP biases word segmentation. However, if the results of Experiment 2 are also not consistent with theirs, then it might be an indication that SSP does not cue word segmentation. Nevertheless, this experiment will again demonstrate that the SSP was not used in word segmentation for Japanese and English speakers. The slight difference in the experiment design was not in fact the cause of the divergence in results from Ettlinger et al. (2010), but the results in Experiment 2 gives a stronger support for the ineffectiveness of the SSP as a cue in word segmentation.

2.5.1 Methods

2.5.1.1 Participants

Participants were 16 (7 females, 9 males) native American English speakers, aged 18 to 23, attending Michigan State University. The number of total participants recruited was the same as the number of participants reported in Ettlinger et al. (2010). They were all monolingual speakers with limited experience with other languages. In this experiment, I did not test any Japanese speakers because I gave priority to test whether the new experimental design affected the results and to see if I was able to replicate prior study's results.

2.5.1.2 Stimuli

The stimuli used in this experiment were identical to the first experiment (Table 2.4). Like Experiment 1, each *language type* string lasted 15 minutes. The audio stimuli had the same male voice; however, the stimuli were altered to have a steady pitch in each vowel.[12] The stimuli in

[12] Although it is not indicated in Ettlinger, Finn, & Hudson Kam's (2011), their stimuli had a steady pitch as well. I was able to check this since I acquired the audio files of their stimuli from Marc Ettlinger.

Experiment 1 had a varying pitch pattern resulting as the by-product of MacinTalk synthesizer, thus the pitch difference was removed for Experiment 2.

Language 1		***Language 2***	
SSP score		SSP score	
2	**bn**ife	-2	**nb**ife
1	**kf**ɑmi	-1	**fk**ɑmi
0	**dg**usɑ	0	**gd**usɑ
-1	**vt**eko	1	**tv**eko
-2	**lz**otʃu	2	**zl**otʃu

Table 2.4: Stimuli used in Experiment 2. This is identical to the stimuli in Experiment 1.

2.5.2 Procedure

In the learning phase, participants were exposed to either *Language 1* or *Language 2* for 15 minutes. They were encouraged to draw anything they like on a piece of paper so that the task would be a passive listening one. After the learning phase, there was a test phase. Instead of "Yes" or "No" questions, Experiment 2 employed a forced choice task similar to Ettlinger et al.'s (2011) study. Each test item played two tokens, one stimulus and one part-word, and asked "Which was a word in this language?", where the participants had to choose between the two. This method allowed a direct comparison between the stimuli and part-words, which "Yes" or "No" type questions were not able to do. Another change that was made was with the part-word tokens. All of the part-words had codas that were taken from the inventory of word-initial consonants of all stimuli in the sample. Crucially, part-words had codas with segments taken from the original full word stimuli (e.g. training word = bnife, part word = nife + b), even though this was not a possible sequence heard in the training since no two identical stimuli were adjacent to each other. There was a total of 25 test items as there were 6 part-words for the 5 stimuli, and these test items were given in randomized order. No fillers were presented in Experiment 2. The list in Table 2.5 shows the stimuli and part-word counterparts used in the test items in *Language 1* and *Language 2*.

Language 1		*Language 2*	
Stimuli	Part-word	Stimuli	Part-word
	nifek		**b**ifef
	nifed		**b**ifeg
bnife	**n**ifev	**nb**ife	**b**ifet
	nifel		**b**ifez
	nifeb		**b**ifen
	famib		**k**amin
	famik		**k**amif
kfami	**f**amid	**fk**ami	**k**amig
	famiv		**k**amit
	famil		**k**amiz
	gusɑb		**d**usɑb
	gusɑk		**d**usɑf
dgusɑ	**g**usɑd	**gd**usɑ	**d**usɑg
	gusɑv		**d**usɑt
	gusɑl		**d**usɑz
	tekob		**v**ekon
	tekok		**v**ekof
vteko	**t**ekod	**tv**eko	**v**ekog
	tekov		**v**ekot
	tekol		**v**ekoz
	zotʃub		**l**otʃun
	zotʃuk		**l**otʃuf
lzotʃu	**z**otʃud	**zl**otʃu	**l**otʃug
	zotʃuv		**l**otʃut
	zotʃul		**l**otʃuz

Table 2.5: List of stimuli and part-word test items for *Language 1* and *Language 2* in Experiment 2.

2.5.3 Experiment 2 Results

Once again, the results for Experiment 2 were not consistent with Ettlinger et al. (2011). Here, I will present the data by the mean accuracy of each type of stimulus because the questions forced the participants to choose between a stimulus and a part-word. Participants were always accurate if they chose the stimulus over the part-word. If we take a look at the overall results that combines *Language 1* and *Language 2,* in Figure 2.7, none of the stimulus types reached 60% accuracy. The task may have been more challenging for the participants. In addition, there is no observable positive correlation between the SSP scores and the accuracy. A one-way ANOVA was run to compare the effect of SSP score on the mean accuracy. It did not reveal a significant difference in accuracy between the SSP scores [$F(1,15) = 0.027$, $p=0.87$]. Although the statistical test did not reveal any difference, from the plot in Figure 2.7, the SSP 0 stimuli seems to have a very low accuracy compared to the other types that are more or less around chance.

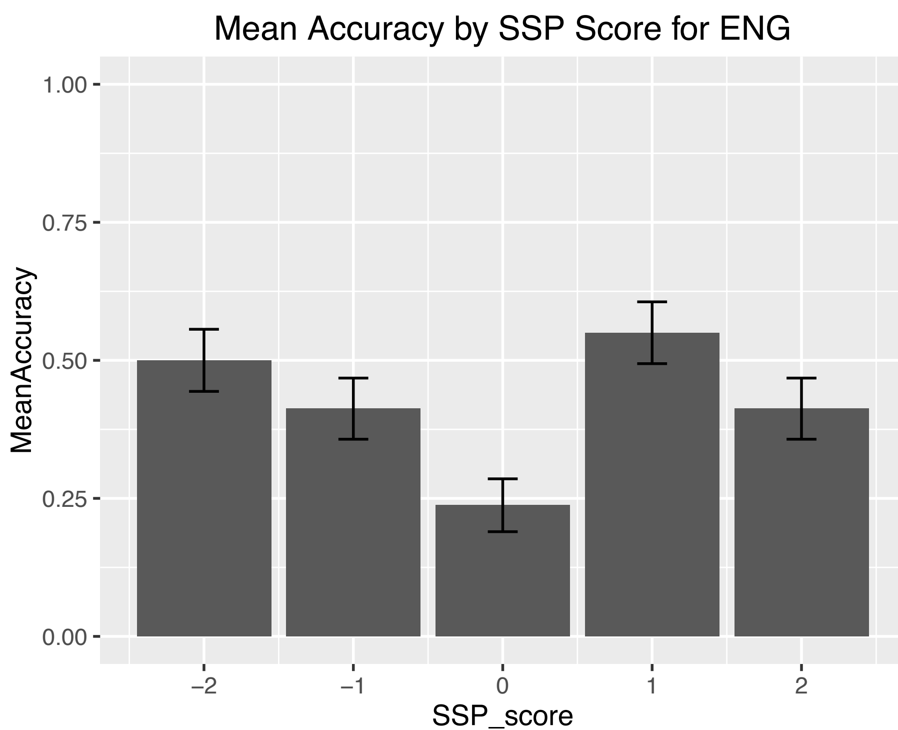

Figure 2.7: Mean percent accuracy by SSP score for Experiment 2 (*Language 1* and *Language 2* combined).

The non-systematic nature of the data is still evident if we look at the results by *language type*. As shown in Figure 2.8, there is no clear pattern that is entailed by the SSP score. A one-way

ANOVA was run to compare the effect of SSP score on the mean accuracy in *Language 1.* The test it did not show significant differences between the accuracy means for different SSP scores in *Language 1* [$F(1,7) = 0.23$, $p=0.64$]. Another one-way ANOVA was also run to compare the effect of SSP score on the mean accuracy in *Language 2,* and it did not show significant differences in mean accuracy between SSP scores [$F(1,7) = 0.83$, $p=0.39$]. Although the SSP score 1 for *Language 1* seems to have a high accuracy, above 75% and the SSP score 0 for *Language 2* seems to have a remarkably low accuracy, below 25%, these differences were not observed to be significant.

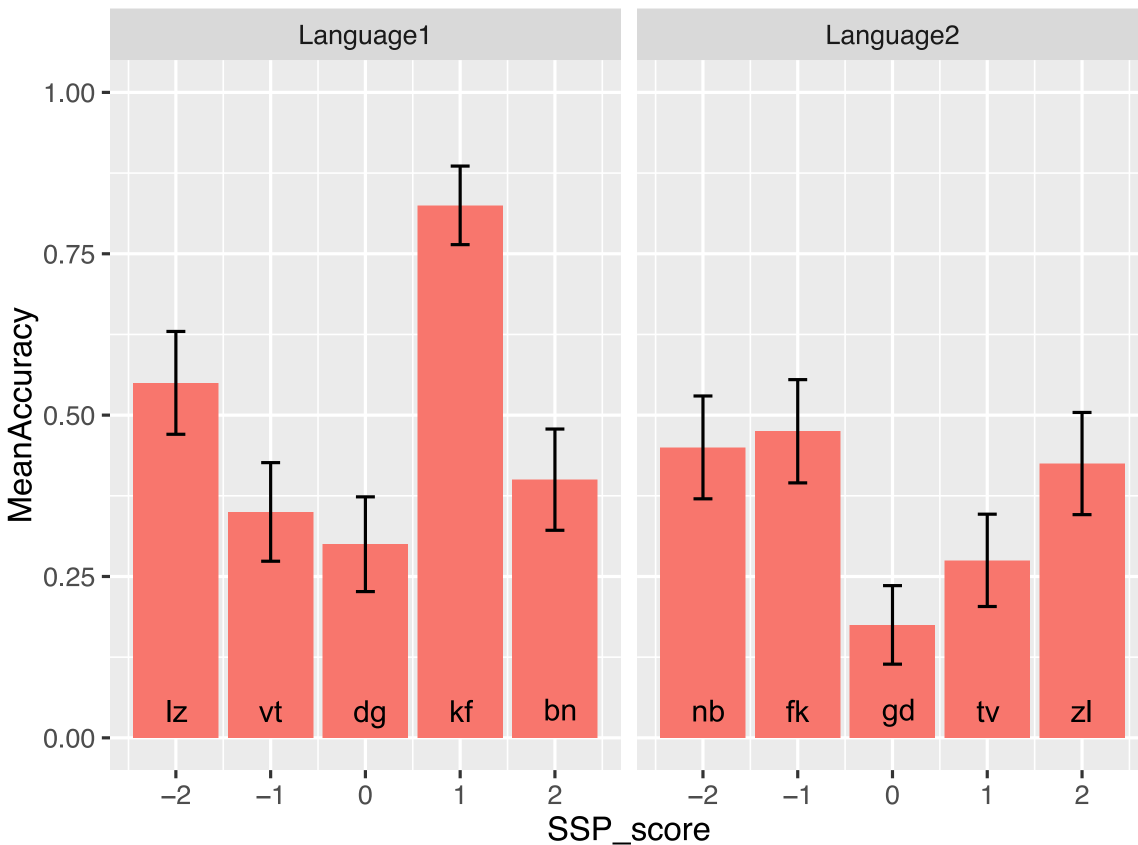

Figure 2.8: Mean percent accuracy by SSP score by *language type* for Experiment 2. Each bar is labeled with the word initial consonants of that item. Left: *Language 1*, Right: *Language 2.*

The TP of the language strings does not seem to explain the pattern of results in Figure 2.8 either. The word level TP and syllable level TP were determined for *Language 1* and *2* for Experiment 2. The entire list of TPs is shown in Appendix G, but the *Language 1* TP that I will use to discuss here will be listed below in Table 2.6. Since the stimulus string in Experiment 2 was also used in Experiment 1, the TPs for this list are the same as for Experiment 1. Notice that in Table 2.6, that the syllable TPs after *vte* + *ko* is varied. Since the speech string was constructed with randomized order of stimuli, it has created some variations of TPs.

TP Type	**Transition**		**Count**	**TP**
Syllable TP	bni	fe	228	1
	dgu	sɑ	243	1
	kfɑ	mi	214	1
	lzo	tʃu	229	1
	vte	ko	257	1
	tʃu	vte	100	0.437
	mi	bni	85	0.397
	fe	dgu	85	0.373
	sɑ	kfɑ	85	0.35
	fe	lzo	71	0.311
	ko	dgu	71	0.277
	ko	kfɑ	71	0.277
	fe	vte	57	0.25
	sɑ	vte	58	0.239
	sɑ	lzo	57	0.235
	ko	lzo	58	0.227
	ko	bni	56	0.219
	mi	dgu	44	0.206
	mi	lzo	43	0.201
	mi	vte	42	0.196
	tʃu	bni	43	0.188
	tʃu	dgu	43	0.188
	tʃu	kfɑ	43	0.188
	sɑ	bni	43	0.177
	fe	kfɑ	15	0.066

Table 2.6: Syllable level TP and word level TP for *Language 1* in Experiment 2.

Table 2.6: (cont'd)

Word TP	lzotʃu	vteko	100	0.437
	kfɑmi	bnife	85	0.397
	bnife	dgusɑ	85	0.373
	dgusɑ	kfɑmi	85	0.35
	bnife	lzotʃu	71	0.311
	vteko	dgusɑ	71	0.277
	vteko	kfɑmi	71	0.277
	bnife	vteko	57	0.25
	dgusɑ	vteko	58	0.239
	dgusɑ	lzotʃu	57	0.235
	vteko	lzotʃu	58	0.227
	vteko	bnife	56	0.219
	kfɑmi	dgusɑ	44	0.206
	kfɑmi	lzotʃu	43	0.201
	kfɑmi	vteko	42	0.196
	lzotʃu	bnife	43	0.188
	lzotʃu	dgusɑ	43	0.188
	lzotʃu	kfɑmi	43	0.188
	dgusɑ	bnife	43	0.177
	bnife	kfɑmi	15	0.066

Looking at the syllable level TP for *Language 1*, we can see that the transition from a syllable to syllable within the stimulus word, **bn**ife, **kf**ɑmi, **dg**usɑ, **vt**eko, and **lz**otʃu are TP of 1. For example, the syllable *bni* is always followed by *fe*, and nothing else; therefore, the syllable TP is 100%. On the other hand, the transition between a right-edge syllable of the stimuli and a left-edge syllable of other stimuli that occasionally appeared together in the string does not have a TP of 1. For example, the highest syllable TP 0.437 in *Language 1* is the transition between of *tʃu* (part of **lz**otʃu) and *vte* (part of **vt**eko), but it is clearly less than the TP 1 for the syllable within stimulus words. In the forced choice test items, the two options were one stimulus word and one part-word with coda that was taken from the inventory of word-initial consonants of a stimulus word (e.g. zotʃuv = (l)**zotʃu** + **v**(teko)). Essentially, the transition between the two parts in the part-word follows a pattern similar to the syllable TP. For example, if the syllable TP for *tʃu-vte* which is part of **lz**otʃu and **vt**eko is low, then the TP *zotʃuv* which is also composed of part of **lz**otʃu and **vt**eko should also be low. The *tʃu* and *vte* syllable TP 0.437 is highest among all non-stimulus word syllable TP; however, this does not explain why the -2 **lz**otʃu had the second highest mean accuracy for Experiment 2. First, this is because high TP means that the two parts is likely to be perceived as one item. The sequence *zotʃuv* would be thought as one word more so than *nifek* (TP 0.066) for instance. If this is the case, then **lz**otʃu would be less considered as a word; however, its accuracy is higher than most stimuli, despite it being the least adhering to the SSP. On the other hand, **bn**ife with the most favorable SSP score resulted in less accuracy than **lz**otʃu. Even though one of the lowest syllable TPs in this language string was 0.066 between *fe-kfa*, part **bn**ife and part **kf**ami, **bn**ife was not perceived as a word to the participants. Whether TP is interpreted alone or with the interaction with SSP scores, it does not explain the results.

The most reasonable claim that can be made from Experiment 2 is that the experimental method was not at fault in Experiment 1 for the dissimilar results from Ettlinger et al.'s (2011) study. This poses a question of what causes the skewing results. I will discuss in further detail in the following section.

2.6 Experiment 3

The results of the previous two experiments did not indicate the influence of the SSP on word segmentation for both Japanese and English speakers. However, before concluding that there is no observable bias from the SSP, it is reasonable to question again the effect of methodological differences of the current study and the previous ones. Although the two experiments were modeled on Ettlinger et al.'s (2011) methodology, the fine-grained differences of the stimuli used or the procedure followed may have triggered the stark differences in the results. However, if this is the case, then there might be problems with the general methodology of this word segmentation, or even the methodology of artificial language testing because then it would mean that the results are completely dependent on the methods (particularly, the stimuli) and that the fundamental quality of word segmentation cues are easily affected by slight differences in the task. Regardless, did a complete replication of Ettlinger et al. (2011) in Experiment 3.

2.6.1 Methods

In this study, I used the same stimuli[13] used in Ettlinger et al. (2011) and followed the same procedures as described in that study. Therefore, the following sections will explain the methods and procedures used simultaneously with Ettlinger et al.'s (2011) methods and procedures.

2.6.1.1 Participants

Since the purpose of this study is to see if the results from the previous study were replicable, participants had a similar language background as Ettlinger et al. (2011). All participants were native American English speakers with minimal background experience with another language. 14 (10 females and 4 males) college aged participants (aged 18 to 23) from the Michigan State University community were recruited for this experiment. Participants recruited in this study did not participate in Experiments 1 and/or 2.

2.6.1.2 Materials

As mentioned, the stimuli used for this experiment were identical (Table 2.7) to the ones reported in Ettlinger et al. (2011). The audio files of the stimuli were shared by Marc Ettlinger. Since the audio given were in separate files by stimulus, I concatenated the stimuli of each

[13] As mentioned before, Marc Ettlinger very kindly shared his stimuli with Karthik Durvasula and me for the purpose of a replication.

language into 18 minutes of speech strings, as in the original study. No pauses were introduced between stimuli and the order of repetition was pseudo-random, so that no identical stimuli were repeated next to each other.

Language 1		***Language 2***	
SSP score		SSP score	
2	**dn**ɛku	2	**bm**ɪfei
1	**mr**ɪtei	1	**ml**æpi
0	**gb**ævi	0	**dg**ʊsa
-1	**ln**ʊpo	-1	**rn**ɛko
-2	**lz**ʌfɑ	-2	**rv**ʌtu
-3	**rd**əsai	-3	**lb**ɪzo

Table 2.7: Stimuli by Ettlinger et al. (2011) used in Experiment 3. Adapted from “The Effect of Sonority on Word Segmentation: Evidence for the Use of a Phonological Universal”, by M. Ettlinger, A. Finn, and C. L. Hudson Kam, 2011, Cognitive Science, 36, p. 5, 2011 by "Cognitive Science Society".

According to Ettlinger et al. (2011), the stimuli were created using SoftVoice (Katz, 2005). Each stimulus was a nonsense disyllabic CCV.CV words, similar to Experiment 1 and 2 of this chapter. The onset consonant cluster introduced varying sonority scores as indicated in Table 2.7. They mention that no English or English like onset clusters were introduced, in order to examine the impact of the SSP on unattested onset clusters in English for English speakers.

2.6.1.3 Stimuli differences between Experiment 1-2 and Experiment 3

It is worth pointing out the noteworthy difference between the materials in Ettlinger et al. (2011) and in Experiment 1 and 2 of this chapter which lies in the quality of the stimuli.[14] The audio stimuli in Ettlinger et al. (2011) were created using the text-to-speech SoftVoice test-to-speech program, whereas Experiment 1 and 2 utilized MacinTalk software. The onset clusters in

[14]Other differences, such as procedure are worth mentioning as well, and this difference will be discussed under the procedure section that follows.

Ettlinger et al.’s (2010) stimuli, especially for the clusters that are assigned with negative SSP scores have intervening vocalic features between the consonants. For example, the [rd] cluster for the stimuli ***rd****əsai*, the [r] seems to have a clear vocalic portion (Figure 2.9). On the other hand, [bn] cluster of *bnife* stimuli from Experiment 1 has no vowel like element in between [b] and [n] (Figure 2.10). Comparing the two, the consonant cluster quality seems to be different. Stimuli from Ettlinger et al. (2011) seems to have some vowel quality introduced in between the segments.

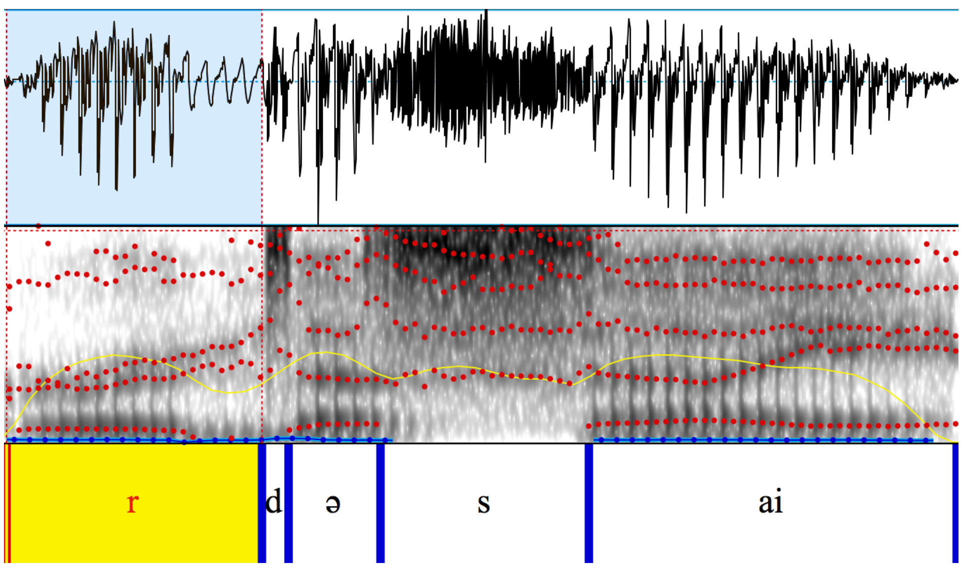

Figure 2.9: Spectrogram of stimuli audio [***rd****əsai*].

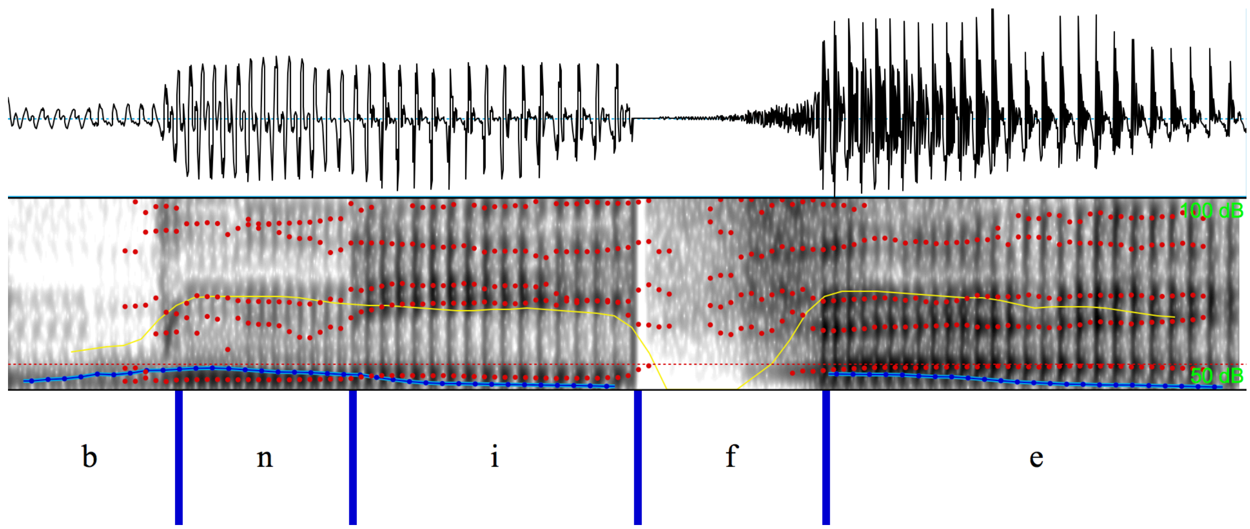

Figure 2.10: Spectrogram of stimuli audio [**bn**ife].

2.6.2 Procedure

In Ettlinger et al.'s (2011) study, the participants were asked to draw during the learning task (listening of the string). They intended a passive listening task and control the participants from paying too much attention to the speech string by introducing a drawing activity. Although Experiment 2 in this chapter took a similar approach having participants draw during the listening, Experiment 1 followed a slightly different procedure. As mentioned earlier, it showed a cartoon video (Popeye) during the learning task. The purpose of this method was to prompt a passive listening experience similar to Ettlinger et al. (2011); however, there is no absolute denial that the difference could have caused the discrepancy in the results. The procedure in Experiment 3 was as faithful as possible to Ettlinger et al. (2011).

In Experiment 3, participants were placed in a quiet chamber and were run individually. As in Experiment 1 and 2, the experiment comprised of two phases: learning phase (listening of the string) and test phase. The learning phase introduced 18 minutes of continuous speech string listening through headphones and a drawing activity during the listening. In the learning phase, participants were instructed to listen to a new language and not to overthink about the audio being played. They were also given paper and a pen to draw in order to prevent from over analyzing the speech being heard. The test phase introduced a forced choice task. Participants were instructed to listen to two tokens separated by a pause and choose the one that was more likely to be a word in the *language* they just heard during the learning phase. There was no time restriction for the response. The entire experiment lasted about 30 to 40 minutes.

Ettlinger et al. (2010) had three types of test items that tested different cues: syllabic TPs, segmental TPs, and the SSP. For the syllabic TPs, they examined whether their participants were able to track syllabic TPs. For example, in the test trial, they presented an actual stimuli ***lz**ʌfa* and a similar test item that did not exist in the string ***lz**ʌku* (***lz**ʌ* never followed *ku*). To test segmental TPs, they asked if an actual stimuli ***lz**ʌfa* or a token with position switched segment *zʌfal* was a word in the *language* they heard. For the SSP, they asked whether an actual stimuli ***lz**ʌfa* or a part-word stimulus with a word final coda *zʌfad* was a word. The coda segment was taken from the word-initial consonant of one of the stimuli in the *language* and an actual segment that followed ***lz**ʌfa* in the string.

2.7 Experiment 3 Results

Similar to Experiment 1 and 2, results to Experiment 3 did not indicate SSP bias on word segmentation. The overall result that combines two *language types* (Figure 2.11) does not show the gradual increase in accuracy corresponding with the increment in the SSP score. A one-way ANOVA was conducted to compare the effect of the SSP scores on mean accuracy. There was no significant difference in mean accuracy for different SSP scores [$F(1,13) = 0.64$, $p = 0.44$].

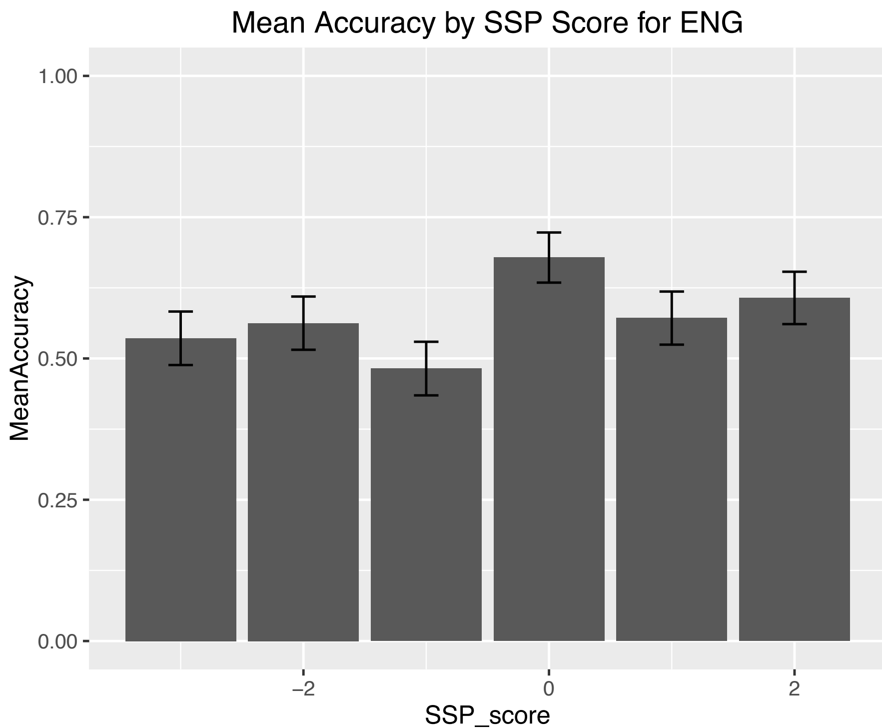

Figure 2.11: Mean percent accuracy of Experiment 3 by SSP score {-3 to 2}.

Looking at Figure 2.11, the mean accuracy across the SSP scores are relatively low throughout, only reaching 67% (SSP score 0) the highest. The mean accuracy for SSP score 2 does seem to be higher than the mean accuracy for SSP score -3. However, the results do now show a gradual increment in accuracy like Ettlinger et al.'s (2011, Figure 2.1). Moreover, when the results are examined by *language type* (Figure 2.12), the two *language types* do not reveal the same effect on accuracy. While Language 2 yields results that seem to show an increment of accuracy by SSP score (except for SSP score of 0 that has a higher accuracy than SSP score of 1), Language 1 does not reveal the same pattern. Rather, Language 1 seems to yield a lowering of mean accuracy by the wave of SSP score of three: the high mean accuracy starts at SSP score of -3 and decrease until SSP score of -1, but it starts high again at SSP score of 0 until it decreases at the SSP score of 2.

This contrast in results between the two *language types* demonstrates that the slight increment of accuracy seen in Figure 2.11 was not driven by the SSP bias.

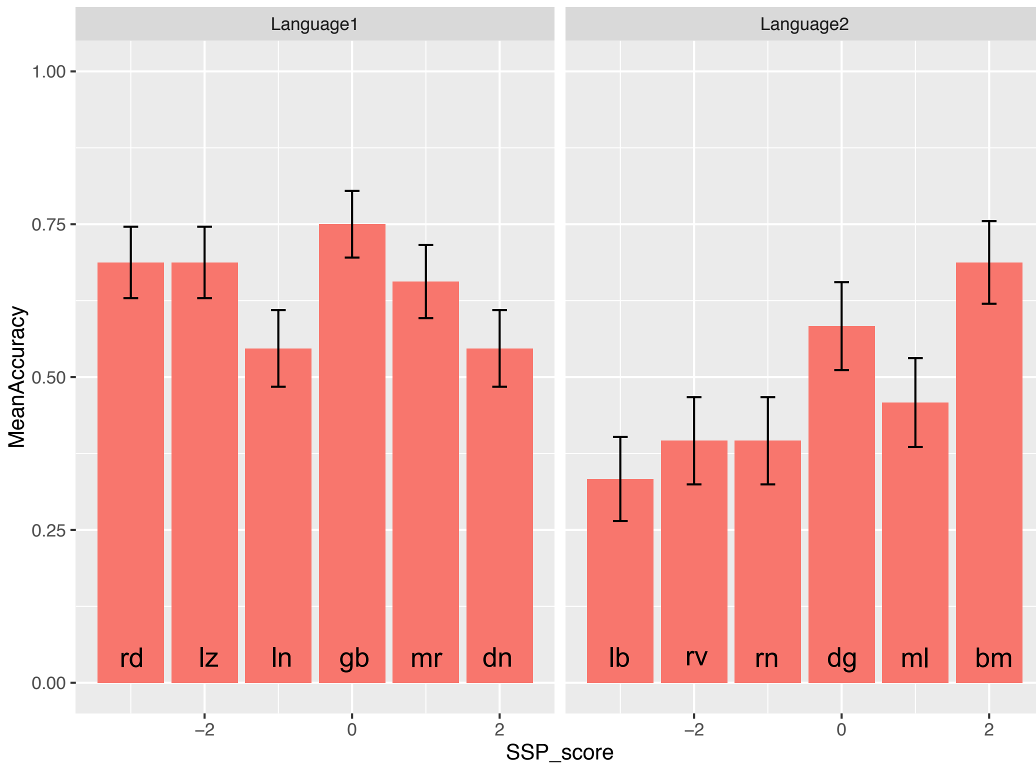

Figure 2.12: Mean percent accuracy of Experiment 3 by SSP score by *language type*. Each bar is labeled with the word initial consonants of that item. Left: *Language 1*, Right: *Language 2*.

2.8 Discussion

The three experiments in the current study did not replicate Ettlinger et al.'s (2011) results, suggesting that the SSP did not bias word segmentation for either English or Japanese speakers in the experiments. Although the results did not reveal any overt sign that the SSP plays a role in word segmentation, by no means this reveals the absence of SSP in listeners' grammar. At best, the findings here reveal that the SSP was not an effective cue to word segmentation. Furthermore, it is of course possible that there might still exist a small possibility that the SSP could bias word segmentation and that it just may have been less effective than other cues; however, the three experiments consistently revealed its ineffectiveness in the process.

Nevertheless, one might argue that there are two possibilities regarding the role of SSP. One possibility is that the SSP does not play any role in word segmentation, and another possibility is that the SSP cue is present but weak and overridden by other cues. If one is to argue for the latter position, there needs to be positive evidence for it; which is lacking as of now. Furthermore, fundamentally, the SSP is a principle concerning syllable structure (Selkirk, 1984; Clements, 1990). The sonority rises as it moves closer to the nucleus and the sonority falls as it moves away from it. The SSP does not necessarily predict anything directly about the word-edge level. So, if a syllable violates the SSP, the violation could be fixed by positing a syllable break, or by inferring an illusory vowel, or some other phonotactic repair. But, all of these repairs could still allow both consonants of the violating consonant sequence to be in the same word.

Ren et al.'s (2010) study specifically looked at monosyllabic stimuli and they were able to find that the speech was segmented according to the SSP. However, this brings up a question for future research: why were Ettlinger et al. (2011) able to manifest a flawless positive correlation between the accuracy and the SSP score with disyllabic stimuli, while the current study was not successful at replicating their results in a series of experiments.

Before moving forward, it is necessary to discuss a little more about the SSP that is assumed here. Many languages seem to exhibit a pattern that adheres to the SSP principle and speakers infer judgments about what are good syllables and bad syllables from it (Jespersen, 1904; Kiparsky, 1979; Selkirk, 1984; Clements, 1990). One study by Daland et al. (2011) claims that such a language universal is not necessarily needed to decide how good or bad a syllable is. Instead of being operated by the language universal, they assert that the sonority can be projected from the statistical patterns in the lexicon. According to their claim the knowledge of the SSP is not needed, rather, the statistical patterns available in the lexicon can yield sonority projections. Another study by Davidson (2006) claims that English speakers tried to infer information about similar sounding attested sequences to produce unattested sequences. Similarly, the participants in this study could have inferred information about their native language patterns to perceive new language, instead of relying on a universal knowledge that may or may not exist. Despite these claims, as pointed out above, there is certainly some evidence of the language-independent nature of the SSP. Berent et al. (2008, 2007) tested languages such as Korean with very impoverished onset clusters and found that there are biases that cannot be explained only from statistical patterns available in the lexicon.

Although the language-independent nature of the SSP is supported with some evidence and the selection of this particular cue is reasonable to test as a language-independent cue, the above series of experiments did not support its role in word segmentation for the two language groups. One of the strongest arguments against the SSP bias in word segmentation is the strong positive correlation demonstrated between complex and simplex results in Experiment 1. The test items were designed to separate the complex and simplex results to see whether the language training had caused the participants to store definite segments in their memory. Nevertheless, the positive correlation between the two demonstrates that the participants did not mark definite edges of words but learned the possible sequences in the string. This could be a problem with the experimental design but it could also mean that the SSP was not a good enough of a cue that defined word edges clearly.

With the same strong positive correlation results in Experiment 1, one could also speculate the possibility of listeners treating the left edge consonant as a prefix of the word stimulus (e.g. ***b*** of ***bn**ife*; or ***n*** of ***nb**ife*). If such a case were true, both ***bn**ife* and ***n**ife* (or ***nb**ife* and ***b**ife* and so forth) could have been perceived as words which in turn have led to select the same answers for the two, resulting in the positive correlation between complex and simplex results for both Japanese and English speakers (Figure 2.13 and Figure 2.14).

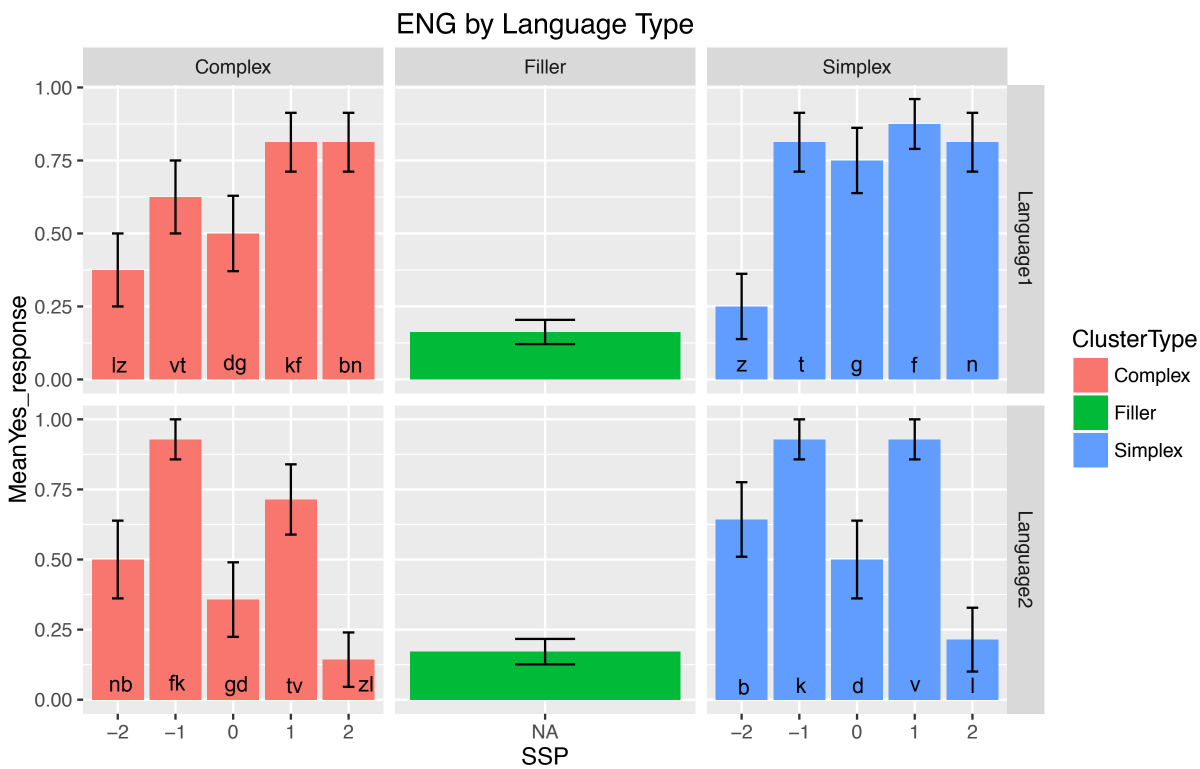

Figure 2.13: Mean Yes response by SSP score for English speakers by *language type* from Experiment 1. Each bar for complex and simplex items is labeled with the word initial consonant/s of that item.

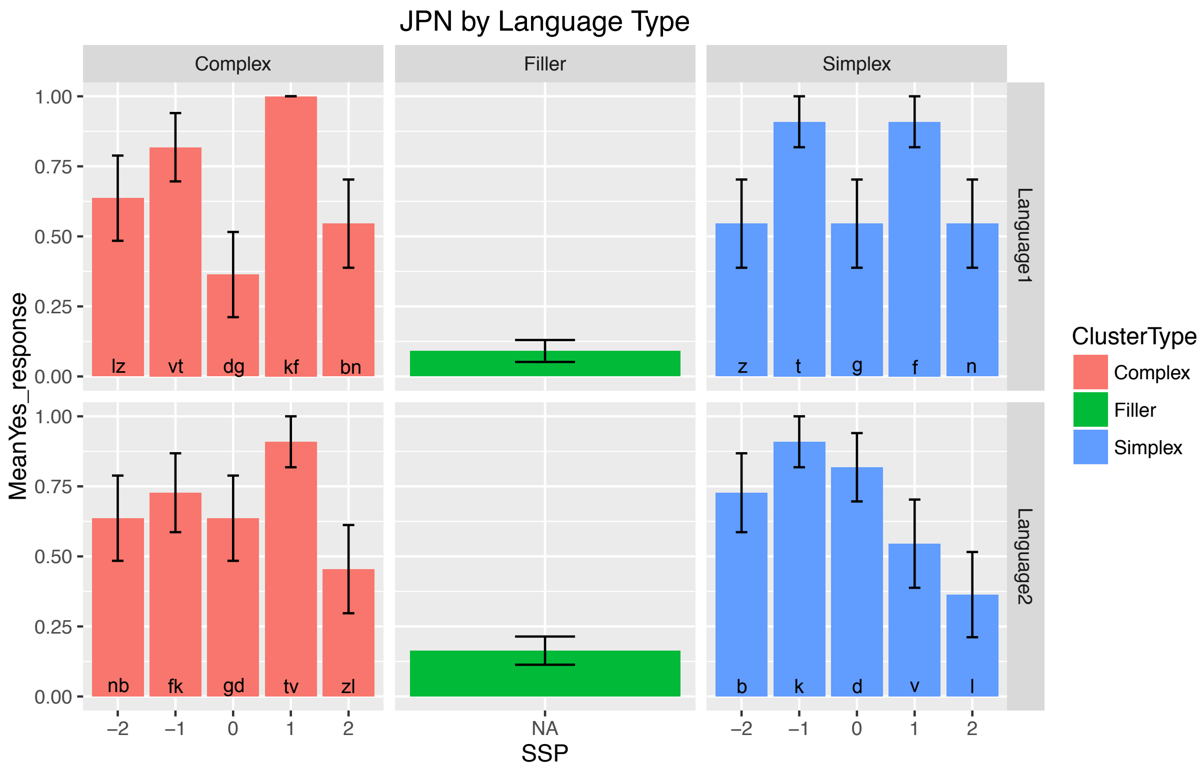

Figure 2.14: Mean Yes response by SSP score for Japanese speakers by *language type* from Experiment 1. Each bar for complex and simplex items is labeled with the word initial consonant/s of that item.

The instructions of Experiment 1 did not specify to choose either only word stem or not, as the question was: "Was [stimulus word] a word in this language?" Hence when listeners have accepted ***n****ife* as a word, they also perceived ***bn****ife* as a word, and vice versa and the trend is different according to the listeners' native language. For English participants (Figure 2.13), both complex ***bn****ife* and simplex ***n****ife* were given high *yes* responses. However, Japanese participants (Figure 2.14) only gave around 50% of *yes* responses. There was something particularly word-like about ***bn****ife* and ***n****ife* for English speakers but not for Japanese. This suggests that the word segmentation in these experiments highly depended on the segmental combination of the stimuli and the SSP score alone could not account how words were segmented.

Furthermore, adjusting the sonority scores of the stimuli does not change the analysis of the results. The three experiments in this chapter employed the sonority scale proposed by Clements (1998) in Figure 1.2[15]. In the literature, there are more elaborate sonority scale such as Zec (2007), that includes a voicing distinction as shown in Figure 2.15. Adapting Zec's (2007) sonority scale does not exactly change the dynamics of the SSP scores in favor of explaining our results.

low sonority --→ *high sonority*

Voiceless Stops	**Voiced Stops**	**Voiceless Fricatives**	**Voiced Fricatives**	**Nasals**	**Laterals**	**Rhotics**	**Glides**	**Vowels**

Figure 2.15: More detailed sonority scale with voicing distinction.

Another strong argument against the SSP's effectiveness in word segmentation is the failure of the direct replication of Ettlinger et al. (2011). Experiment 3 has demonstrated that even with all voiced stimuli, the listeners did not apply the SSP information to segment words. The series of experiments in this chapter give strong indication that the SSP has no role in word segmentation.

One may argue that the difference of distraction task between the current experiment and Ettlinger et al. (2011) may have contributed to the difference in the results. The task during the learning phase in Experiment 1 utilized a silent cartoon video (Popeye) to watch along with the stimuli string for 15 minutes. The cartoon was used in order to create a more passive listening task, rather than having participants pay attention to every detail of sound that was heard during the listening. This method was distinct from Ettlinger et al.'s (2011) study that used drawing as

[15] Due to formatting restrictions, this figure cannot be presented again on this page. Please refer back to Figure 1.2 in the previous chapter.

distraction task; however, the difference in the distraction task must not have been the reason for the differences in the results. This is because Ettlinger et al.'s (2011) results were not replicated in Experiment 2 and 3, even when same distraction task as Ettlinger et al. (2011), a drawing task, was used in the two experiments. The results of Experiment 3 are particularly strong evidence that the distractor task did not have a crucial influence on the difference of results being non-replicable. Therefore, it is highly unlikely that such a contrast in the distractor task created a discrepancy in the results.

The consistent indication of the ineffectiveness of the SSP in word segmentation for Japanese speakers and English speakers demonstrates that there must be other useful cues to word segmentation. The lack of influence the SSP has on these speakers may also indicate that the cue is not useful for speakers with other language background as well; although it is necessary to test this to confirm. Regardless, since both Japanese speakers and English speakers did not show a sensitivity to the SSP in the word segmentation task, it can be predicted that other language speakers like Korean or Hawaiian that have no consonant cluster may not experience word segmentation guided by the SSP as well.

The current study attempted to investigate the interaction of language experience with the phonological universal, sonority sequencing principle (SSP), in an artificial language learning setting. If the SSP is a language universal that is used in word segmentation, then it should have biased segmentation during language learning for both English and Japanese speakers. None of the three experiments showed this pattern of results. The participants showed no indication of employing the SSP to segment words in a string.

CHAPTER 3 GEMINATION

3.1 Introduction

Chapter 2 showed that a language-independent cue, the SSP, did not guide the word segmentation process for listeners, for both Japanese and English speakers. This chapter will focus on the possibility of geminates, a language-dependent phonotactic pattern, and investigate its role in word segmentation for Japanese speakers. The main questions are:

(1) Do geminates guide word segmentation?

(2) Will language background affect how gemination is used in word learning?

As in the previous chapter, two groups of participants, Japanese and English speakers, were tested. Because native phonology has been found to influence perception (e.g. Berent et al., 2007, 2008; Berent, Lennertz, Smolensky, & Vaknin-Nusbaum, 2009; Dupoux, Kakehi, Hirose, Pallier, & Mehler, 1999; Kiparsky, 1979; Moreton, 2002), two languages with contrasting geminate inventories were compared: Japanese has true geminates (phonemic or intra-morphemic geminates) and English has no true geminates – word-internal geminates are only derived geminates formed via compounding or affixation for example. A series of experiments in this chapter will show that unlike the SSP, speakers' knowledge of geminates function as good predictor as to how Japanese and English speakers segment a novel-word speech string. The findings show that in *novel-word segmentation*, geminates are retained in words, only for those whose native language has contrastive geminates (i.e. Japanese speakers). More specifically, if speakers' native language, like Japanese, allows consonant gemination within words, then the presence of geminates in the stimuli does not prompt segmentation at the geminates but the TP (transitional probability) signals the segmentation instead. On the other hand, if speakers' native language does not have contrastive geminates, like English, then the speakers will rely more on their phonology instead of the TP in word segmentation. Which means that such speakers are prone to divide the string at geminates and not preserve them. In the following experiments, the effect of phonology on word segmentation became more evident when presenting a more complex stimulus. The two language groups, Japanese and English speakers, showed different patterns: only speakers with *true geminates* in their native language were likely to learn words with them; but, for speakers without *true geminates* in their native language, their native phonology plays a stronger role when the task is harder for speakers, as they tended to break them up such sequences as separate words.

3.2 Overview of gemination

A geminate, or "long consonant", is the occurrence of two identical adjacent consonants. Gemination can be found word/morpheme internally or at the word/morpheme boundary – at the juncture between words/morpheme. Word- or morpheme- internal geminates can be phonemic. Some languages, like Japanese, have a phonemic contrast between long (geminates) and short (singleton) consonants. These types of geminates are also termed *true geminates* (Hayes, 1986). Word-internal geminates can also arise as a result of morphological concatenation and are termed *fake geminates* (Hayes, 1986). Unlike Japanese, English has no phonemic geminates or true geminates; however, fake geminates can appear through affixation. Fake geminates can also be found in English at the boundary of words if it creates a sequence of identical consonants. Table 3.1 lists the relevant type of geminates in Japanese and English. Keeping in mind the focus of the study is word segmentation, it is important to note that where and what type of gemination is possible in a language depends on the phonology of the language.

	Type	Example Word
Word-internal geminates	*True geminates* – Phonemic	o**nn**a “women” (Japanese)
	Fake geminates (Heteromorphemic) arise by affixation	u**nn**atural
	Fake geminates (Heteromorphemic) arise by compounding	boo**kc**ase
Word boundary geminates	*Fake geminates* (Non-phonemic)	ope**n n**ow

Table 3.1: Types of gemination observed in Japanese and English. More elaborate description of gemination in each language is shown in 3.2.1for Japanese and 3.2.2 for English.

Phonetically speaking, phonemic geminates, or *true geminates* are significantly longer than singletons. The spectrograms below give an example of consonant duration differences between singleton /k/ (Figure 3.1) and geminated /k/ (Figure 3.2) word in Japanese. The general ratio between geminates and singleton in Japanese depends on the consonant. Kawahara (2015) gives a general overview of prior studies on phonetic length of geminates and singletons in Japanese. He gives durations and ratios of different consonant types, as will be discussed later in Table 3.5. This data will be used to create the stimuli in Experiments 4 and 5. As for the *fake geminates* in English, some claim that they may be distinguished from *true geminates* by relative duration (Miller, 1987, cited in Oh and Redford 2012) as well as vowel-to-consonant duration (Ridouane, 2010, cited in Oh & Redford, 2012). On the other hand, recent studies investigate the previous claim that, in English, the *in-* prefix degeminates and the *un-* prefix geminates and find that they actually both geminate, but not with all stems (Kaye, 2005; Oh & Redford, 2012). Ben Hedia & Plag (2017) also support the claim that it is not the case that only certain kinds of prefixes geminate. They also find that locative *in-* and negative *un-* have durational differences, but both are significantly longer than singleton counterparts. Although these studies primarily focus on *in-* and *un-* geminates, they do provide evidence for relative durational properties of fake geminates (as compared to singletons) in English.

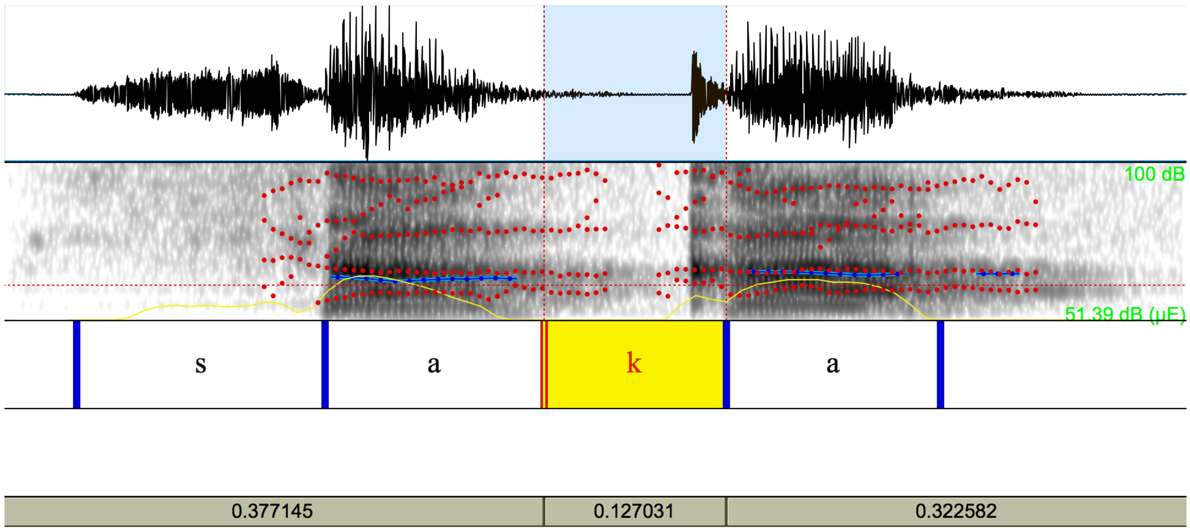

Figure 3.1: Spectrogram presentation of singleton /k/ word *saka* "hill" uttered by adult native Japanese women.

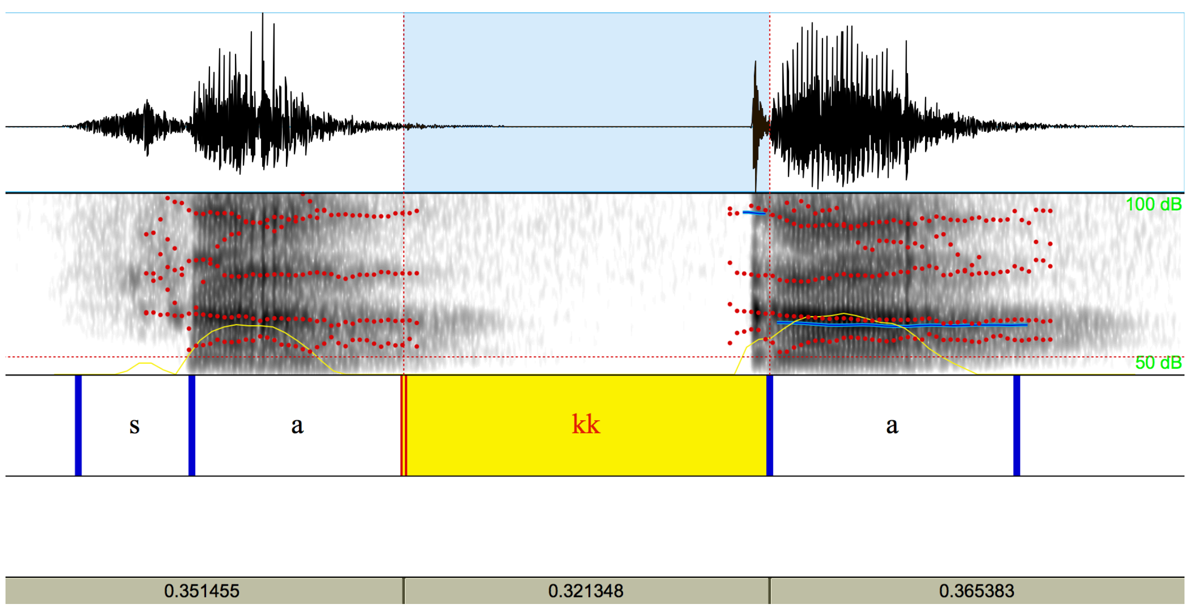

Figure 3.2: Spectrogram presentation of geminated /k/ word *sakka* "writer" uttered by adult native Japanese women.

In this chapter, a series of experiments will introduce word-internal geminates in the stimuli concatenated to create a stream for the training phase of an artificial language word segmentation task to investigate how Japanese and English listeners use the germination information to segment words. Thus, before introducing the experiments, language-specific gemination will be discussed in the following sections.

3.2.1 Gemination in Japanese

Gemination in Japanese is common[16] and the geminate–singleton contrast is phonemic in the language; therefore, it is reasonable to assume that Japanese speakers will be sensitive to the consonant length differences upon hearing novel language and are willing to internalize words containing geminated words during a word segmentation task. Japanese allows various types of consonants to geminate word-internally, and people are likely aware of such phonotactics because of the phonemic contrast between geminate and singleton. Furthermore, there is a particular orthographic mark that defines geminated consonants for non-nasal sounds in Hiragana "っ" or Katakana "ッ".[17] The only geminates at the word boundary (word-external) are nasals, as /N/ is the only consonant that is allowed in the coda position at the right edge of a word and /m, n/ can be at the onset of the left edge of a word.[18]

Although Japanese allows geminates in more contexts than English, its phonology has restrictions on where they can appear. Kubozono, Ito and Mester (2008) discuss a few key

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[16] Perhaps more so in recently emerging words as loanword corpus demonstrates in Table 1.
[17] Hiragana and Katakana are two phonetic syllabary systems in Japanese. The two systems are identical in total number of characters yet Hiragana is used mainly for native/Sino Japanese words and Katakana is used mostly to represent loanwords. Kanji (Chinese characters) is another writing system in Japanese, which is borrowed from China. This system is logographic and not phonetic.
[18] Ito (1989) suggests that /N/ behaves placeless and undergoes nasal place assimilation, wherein /N/ assimilate in place with the following segment at the surface representation. However, it is also the case that /N/ can remain placeless when it is followed by a vowel or glide that are [+cont], because it becomes a nasalized vowel or glide.

phonological constraints about geminates in Japanese: (1) the native stratum does not allow voiced consonants to be geminated. (2) the language disfavors superheavy (trimoraic) syllables, thus geminates do not occur after a long vowel. (3) the native stratum disfavors Light-Heavy (LH) sequences but favors HL and HH sequences word-finally; therefore, LH formation is avoided by gemination in loanword phonology. Kubozono et al. (2008) explains this phenomenon using *Zuzya-go*, which is a language game used by jazz musicians that involves metathesis (e.g. /ma.nee.zyaa/ → /zyaa.ma.ne/ 'manager'). Words with L (e.g. /me/ → /ee.me/ 'eye'), H (e.g. /kii/ → /ii.ki/ 'key'), LL (e.g. /me.si/ → /sii.me/ 'rice'), LH (e.g. /go.han/ → /han.go/ 'meal'), HL (e.g. /tan.go/ → /gon.ta/ 'tango'), HH (e.g. /too.kyoo/ → /kyoo.too/ 'Tokyo') prosodic forms all change to either HL or HH prosodic form. If gemination does not result in prosodic well-formedness, either HL or HH, it is avoided. (4) accent structure – one example they give is that, loanword phonology violates the voiced consonant gemination constraint for words like *flag* /fu.rág.gu/ and *frog* /fu.róg.gu/ because the of the constraint against accenting the penultimate mora in trimoraic words and disfavors /fu.rá.gu/ and /fu.ró.gu/.

In Japanese, gemination is a highly productive process in loanword phonology as well (Kubozono et al., 2008). Hence, it is probable that Japanese speakers' knowledge of geminates in the language will influence word segmentation during artificial language learning. There have been studies suggesting the influence of phonology in speech perception (e.g. Berent et al., 2007, 2008; Berent, Lennertz, Smolensky, & Vaknin-Nusbaum, 2009; Dupoux, Kakehi, Hirose, Pallier, & Mehler, 1999; Kabak & Idsardi, 2007; Moreton, 2002; Pitt, 1998) and artificial language learning (e.g. Suomi et al. 1997, Vroomen et al. 1998). Thus, there is reasonable basis to assume the influence of gemination, a language phonotactic pattern, on how individuals segment words, particularly in an artificial language learning task.

According to the NINJAL 2005 (NINJAL, 2005) corpus (Table 3.2), which is comprised of text from contemporary Japanese magazines, the most geminated consonants are /k/ and /t/, followed by the nasals, /p/, /s/, and /ɕ/ in that order. The corpus contained a mix of native, Sino Japanese,[19] and loanwords; however, the loanwords data was filtered out to find gemination cases within native and Sino Japanese only. Instances of hybrid compound words[20] that include combinations of native & Sino, native & loanwords, and Sino & loanwords were also included. Because of the way the corpus is built, it was not possible to tease apart loanwords from hybrid compounds. This explains the few geminated cases of /d/ and /h/ in the NINJAL 2005 corpus, as such consonants only get geminated in loanwords.

Compared to native and Sino Japanese cases, there is more variability in the type of geminated consonants in loanwords, as shown in the right column of Table 3.2 (loanword corpus by Takemura et al. 2014). The voiceless stops /p, k, t/ have the highest number of geminates similar to the native and Sino Japanese lexicons; however, loanwords allow more types of consonants to be geminated, such as voiced stops /b, d, g/. For the experiments in this chapter, these two patterns, from both native/Sino Japanese and loanword corpus, will be taken into consideration to create the stimuli.

[19] Sino Japanese words are essentially words that were borrowed from China when Kanji (Chinese characters) were adopted starting around the 5th century.
[20] Hybrid compound words (or hybrid noun compounds) are composed of a mixture of two nouns whose origins differ from each other. In Japanese, words can be native (NJ), Sino Japanese (SJ) or loanwords (or foreign words abbreviated as FJ). Irwin (2005) says that hybrid compounds can be one of these six types: NJ-SJ, NJ-FJ, SJ-NJ, SJ-FJ, FJ-NJ, and FJ-SJ.

Consonant type	*Native & Sino Japanese words (NINJAL 2005 corpus)*	*Loanwords (Corpus by Takemura et al. 2014)*
p	195	656
k	545	1492
t	417	1124
s	169	238
ɕ	145	337
z	4	17
b	0	20
g	0	107
d	4	233
nasals	384	223
ɸ	0	49
v	n/a	0
h	1	42
liquids	0	14

Table 3.2: Counts of word-internal geminates of each consonant type based on the NINJAL (2005) corpus that is filtered to display native and Sino Japanese words (left) and loanword corpus (right) by Kawagoe and Takemura (2014).

3.2.2 Gemination and degemination in English

In English, gemination is not contrastive within morphemes. However, when words or morphemes are concatenated, homorganic consonants can be clustered adjacently and create phonetically "long" consonants - this concatenation of consonants is often called fake geminates and occur exclusively at word or morpheme boundaries. For example, the phrase "*bi**g** **g**ame*" demonstrates the gemination of /gg/ at the boundary of two words, "*bi**g***" and "***g**ame.*" This type of geminates at word boundaries, or word-external geminates, allows many types of consonants to geminate as it is listed in (A in Table 3.3). Another type of geminate occurs at word-internal morpheme boundaries. The /nn/ in the word "*mea**nn**ess*" is a word-internal geminate because the [n] is geminated at the edges of stem "*mea**n***" and suffix "*-**n**ess.*" Word-internal gemination can also occur at the edges of prefix and stem as in the word "*di**ss**atisfied"* as well. Only /n, s, l/ are attested to be geminated in this type (B in Table 3.3).

(A) Geminated consonants at word boundary		**(B) Geminated consonants at morpheme boundary**	
/m/	e.g. *To**m** **m**akes*	/n/	e.g. *mea**nn**ess*
/ʃ/	e.g. *ca**sh** **sh**op*	/s/	e.g. *di**ss**imilar*
/l/	e.g. *be**ll** **l**amp*	/l/	e.g. *who**ll**y* (only in some cases)
/p/	e.g. *Phili**p** **p**icks*		
/t/	e.g. *hi**t** **T**om*		
/n/	e.g. *pa**n** **n**etwork*		
/s/	e.g. *ma**ss** **s**laughter*		

Table 3.3: Possible geminated consonants (*fake geminates*) at the word boundary and at the morpheme boundary in English.

As shown above, word boundary (word-external) and morpheme boundary (word-internal) are the only two environments in which gemination is permitted in English. It would be interesting to see whether English speakers' knowledge that gemination occur only at morphological boundary would cue word segmentation when they hear a set of novel words.

As mentioned above, there has been a standard understanding that in English, the *in-* prefix degeminates and the *un-* prefix geminates. Kaye (2005) and Oh and Redford (2012) investigated the duration of both types and found that both types are indeed longer than corresponding singletons. Kaye (2005) compared the duration of /n/ in six words uttered by 10 speakers, the *un-*

prefixed: *unknown* and *unnamed* and *in*-prefixed *immature* with their counterpart words with no prefix: *known*, *named*, and *mature*. Kaye only tested these six words exclusively whilst there are other *in*-prefix and *un*- prefix words in English. He found that both *un*-prefixed and *in*-prefixed words were longer than their counterparts; however, he notes the variability among speakers and that not all speakers produced longer /n/ for prefixed words. Oh and Redford (2012) compared the duration /n/ in *in*-prefixed and *un*-prefixed words (*immovable, immoral, immemorial, immeasured, unnoticed, unnamed, unnerve, unnail*) with the morphologically simplex words (*ammonia, immensely, immunity, immigrational, annex, innate, annoyed, innerve*) by having native Korean speakers rate the duration in a scale of 1 to 7 (7 as extremely long). They found that those labeled as *in*-prefixed and *un*-prefixed words were judged to be longer than the phonological singleton /n/ words. Hence some *in*-prefixed and *un*-prefixed words show gemination. However, Ben Hedia & Plag (2017) point out that the word *immigration* that was labeled as one of the singleton /m/ words is actually morphologically complex and contains the *in*- prefix.[21] In their study, Ben Hedia & Plag (2017) found that both the *in*- prefix and the *un*- prefix geminate and are significantly longer than their singleton counterparts. They also noticed a durational contrast between *in*- that has locative meaning and *in*- that has negative meaning, and claim that the *in*- with negative meaning was longer than the other. Therefore, the notion that the *in*- prefix degeminates and the *un*- prefix geminates is not supported. Crucial for the current dissertation is that the above facts suggest that English speakers have experience with consistently long geminates, at least with some words. However, the difference between the geminates in Japanese and English is maintained because of the *true geminates–fake geminates* contrast in the two languages. Hence the following experiments

[21] The /m/ in "immigration" is a result of assimilation of the prefix *in*- and "migration."

test whether language experience with geminates affects how they are used in word segmentation for the two type of speakers.

3.3 Experiment 4[22]

Experiments 4 and 5 in this chapter were designed to investigate whether geminates cue word segmentation during artificial language learning for Japanese speakers. The results revealed that, the participants' knowledge of geminates could predict how they segment words from a speech string. In a task with relatively simple stimuli (Experiment 4), the strings were segmented so that geminates were preserved in words, for both Japanese and English speakers, despite the differences in the language experience background between the two. However, it was shown that English speakers seemed to be greatly affected by the complexity of the stimuli (Experiment 5), as their native phonology played a stronger role during segmentation.

The stimuli used in Experiment 4 contained word-internal geminates that are noticeably longer than their singleton counterparts. English speakers, whose language does not have *true geminates*, were also tested to compare their performance with that of Japanese speakers, whose language allows them. The expectation is that since phonotactic knowledge, especially vowel harmony, has been shown to guide word segmentation for both infants (Jusczyk et al., 1993, 1999; Mattys & Jusczyk, 2001) and adults (Suomi et al., 1997; Vroomen et al., 1998), knowledge about geminates, which is also a part of language-dependent phonotactics, will be used to segment words for both Japanese and English speakers. However, it is also expected that words with geminates will be more preferable to Japanese speakers than English speakers because of the phonemic consonant length contrast in Japanese. Since there are *true geminates* in Japanese, they are less forced by their native language phonotactics to segment the string into separate words by dividing

[22] The numbering for the experiments in this chapter continues from the previous chapter.

the geminates, and will therefore be more willing to internalize words with geminates. Whereas, English speakers will be more willing to separate the geminates into two separate words, given that their native language phonotactics allow a far more restricted geminate occurrence word-internally (only, as false geminates for [n, s, l]).

3.3.1 Methods

As in previous chapters, Experiment 4 employed a word segmentation experiment in an artificial language learning task, where all the stimuli were synthetically created. The test contained two parts – a learning phase, where participants listened to a continuous speech string of the stimuli, and a test phase, that asked questions about the words they heard in the string.

3.3.1.1 Participants

29 native Japanese speakers[23] (3 female and 26 male) and 26 native American English speakers (16 female and 10 male) participated in this experiment. Japanese speakers were recruited in Tokyo. They all claimed to be monolingual speakers, with minimal experience in foreign language. The participants here did not partake in the experiments in Chapter 2.

3.3.1.2 Materials

The stimuli for this experiment were all in a CVCCV disyllabic template, where CC sequences are geminates. The vowels in each stimulus were identical, to control for backness, rounding and height not cueing the word segmentation because it has been previously claimed that native language vocalic patterns cue word segmentation (Suomi et al., 1997; Vroomen et al., 1998).

[23] Originally, 35 Japanese speakers were recruited; however, results for 6 speakers were removed because they lived outside of Japan more than a month and/or claimed to be fluent in another language.

As in Chapter 2, two *languages types* created for the stimuli and each of them contained only one type of vowel.

For geminated consonants, the consonants /k, s, z/ were selected. According to the corpora in Table 3.2, /k/ has the highest rate of gemination, word-internally, in both native/Sino Japanese and loanwords. On the other hand, English does not have any word-internal /k/ geminates. The sibilants /s, z/ can also be geminated in Japanese; however, the frequency contrast is great. /s/ has 168 counts in a native/Sino Japanese corpus and 238 in loanwords. In contrast, there are only 4 /z/ geminates in native/Sino Japanese corpus and 17 in loanwords (Table 3.2), so /z/ geminates are underrepresented in Japanese. In English, /s/ can be geminated word-internally via morphological processes, but /z/ is not found to geminate word-internally. The differences in frequency and existence of geminates in each language conveys language-dependent patterns. The current experiment addresses such differences and investigates whether Japanese speakers perform differently from English speakers in word segmentation.

Word-internal geminated consonants (non-compounding)	**Japanese**	**English**
/kk/	✓(most common)	*
/ss/	✓(common)	✓
/zz/	? (underrepresented)	*

Table 3.4: List of consonants used for gemination in Experiment 4 and their attestation word-internally in Japanese and English. ✓codes for attested, * codes for unattested in the language, and ? codes for under-representation.

The duration of geminates and the ratio of singleton:geminates were controlled carefully during stimulus creation. Kawahara (2015) reports durations and ratio of singleton:geminates production by three female Japanese speakers. The duration of a singleton [k] is 67.3 ms and the corresponding geminate is 128.7 ms. Overall the duration for both is slightly shorter than that singleton [s] (83.2 ms) and corresponding geminates (134.5 ms), but the ratio between singleton–geminate duration is greater for [k]. There are no reports for singleton/geminate [z], most likely due to severe underrepresentation of z geminates in Japanese.[24] However, since voiced obstruents, according to the data in Table 3.5, tend to have greater singleton–geminate ratio than voiceless obstruents, it is reasonable to expect a greater ratio for voiced fricatives than voiceless ones.

Segment	Singleton	Geminate	Ratio
[p]	77.3 (7.8)	129.6 (8.1)	1.68
[t]	55.5 (4.6)	124.4 (7.3)	2.24
[k]	67.3 (7.1)	128.7 (7.1)	1.91
[b]	53.1 (3.8)	131.4 (8.8)	2.47
[d]	36.6 (1.9)	116.0 (10.4)	3.16
[g]	52.1 (3.7)	115.0 (13.2)	2.20
[ɸ]	83.5 (4.8)	144.7 (7.4)	1.73
[s]	83.2 (4.6)	134.5 (7.0	1.62
[ʃ]	85.9 (5.7)	138.4 (7.3)	1.61
[ç]	63.4 (2.5)	132.0 (6.2)	2.08
[h]	72.2 (4.2)	143.7 (6.4)	1.99

Table 3.5: Duration (in milliseconds) and ratio of singleton and geminates in Japanese. The number in parenthesis () shows margin of error for 95% confidence intervals. (Kawahara, 2015, p. 52).

Originally, the duration for geminates in the stimuli was set at 130 ms, and the singleton–geminate ratio and singleton durations were set at: /k/=1.91 ratio, 68.1 ms singleton duration; /s/=1.62, 80.2 ms singleton duration; /z/=1.70 ratio, 76.5 ms singleton duration. The word-initial

[24] Although the corpora frequencies in Table 3.2 indicates that /z/ geminates are attested in Japanese, they are not common and are quite underrepresented.

consonant C (Figure 3.3) was kept at 75ms, an average of the singleton duration. The stimuli were created synthetically, using a male voice on MacinTalk. Upon listening to the stimuli, I decided to lengthen the geminate duration because the geminates in the original stimuli did not sound long enough to be geminates, to me. The duration at 130 ms in the synthetic audio stimuli did not sound long enough for geminates. This is likely because the audio stimuli did not introduce another typical cue for gemination, which is the long duration of the preceding vowel in Japanese (Kawahara, 2006, 2013; Kawahara & Braver, 2014; Ofuka, 2003; Takeyasu, 2012). So, the absence of such a cue might have caused the distinction based solely on consonant duration difficult. In Japanese, therefore, the consonant duration for geminates was made to be 175 ms (Figure 3.3). For /k/, the 175 ms was the closure part of the segment. The release part of /k/ was not manipulated but it was left how it was produced by MacinTalk. The duration for singleton counterparts for /k, s, z/ (different from the word-initial C) used in test trials were kept at the rates mentioned above.

75ms	100ms	175ms	100ms
C	V	CC	V

Figure 3.3: Template and duration of each segment in the stimuli.

Using the template in Figure 3.3, stimuli with two *language types* were created for the learning task (Table 3.6). As in Chapter 2, two *languages* were used per experiment in this chapter to test the general effect of the /k, s, z/ geminates in the test words, and to avoid looking exclusively at the results of specific segment combination of the stimuli (e.g. only mε**zz**ε or tε**zz**ε with [ε] vowel for /z/ geminated words). The word-initial consonant of the stimuli is one of the following consonants /p, t, b, d, m, n/ and does not overlap with the geminated consonants /k, s, z/. This was done to avoid introducing different transitional probability for consonants.

Language 1	Language 2
mɛ**zz**ɛ	nʌ**zz**ʌ
tɛ**zz**ɛ	pʌ**zz**ʌ
nɛ**kk**ɛ	mʌ**kk**ʌ
bɛ**kk**ɛ	dʌ**kk**ʌ
pɛ**ss**ɛ	tʌ**ss**ʌ
dɛ**ss**ɛ	bʌ**ss**ʌ

Table 3.6: Stimuli for Experiment 4 containing only /ɛ/ in Language 1 and /ʌ/ in Language 2.

To synthesize the stimuli, I created them by syllables. For example, the stimuli *mɛzzɛ* was formed by synthesizing *mɛz* and *zɛ* separately. The two syllables were then concatenated to form *mɛzzɛ*. The duration of each segment was manipulated on Praat. All of the duration manipulation occurred at around 33% or 66% into the segment and not at the very edge or in the middle. When shortening or lengthening was done, it was made sure that adjustment occurred in reduction or increment of a pitch period at zero crossings. After all stimulus words were created, they were concatenated into two strings by *language type*, each lasting 10 minutes long (e.g. *…mɛzzɛtɛzzɛnɛkkɛbɛkkɛpɛssɛdɛssɛ…*). There were no pauses in between each stimulus words and the order of the words repeated were pseudo-random so that identical stimuli were not adjacent. The order in which the stimuli appeared in the string was generated by a randomization code written in R, which was later fed to Praat along with the audio stimuli to create two separate audio strings of *Language 1* and *Language 2*. Each stimulus word appeared the same number of times in the string and no pauses were introduced between the stimulus word.

As in previous experiments in Chapter 2, there was a learning phase (training phase) and a test phase. The above-mentioned stimulus creation was used for the learning phase. The test items for the test phase were also created synthetically using MacinTalk. The test items for this experiment consist of an actual stimulus word in one of the *language types* and a part-word of the stimulus word. This is listed below in Table 3.7.

Language 1		***Language 2***	
Stimuli	Part-word	Stimuli	Part-word
mɛ**zz**ɛ	**z**ɛtɛ	nʌ**zz**ʌ	**z**ʌpʌ
	zɛnɛ		**z**ʌmʌ
	zɛbɛ		**z**ʌdʌ
	zɛpɛ		**z**ʌtʌ
	zɛdɛ		**z**ʌbʌ
tɛ**zz**ɛ	**z**ɛmɛ	pʌ**zz**ʌ	**z**ʌnʌ
	zɛnɛ		**z**ʌmʌ
	zɛbɛ		**z**ʌdʌ
	zɛpɛ		**z**ʌtʌ
	zɛdɛ		**z**ʌbʌ
nɛ**kk**ɛ	**k**ɛmɛ	mʌ**kk**ʌ	**k**ʌnʌ
	kɛtɛ		**k**ʌpʌ
	kɛbɛ		**k**ʌdʌ
	kɛpɛ		**k**ʌtʌ
	kɛdɛ		**k**ʌbʌ
bɛ**kk**ɛ	**k**ɛmɛ	dʌ**kk**ʌ	**k**ʌnʌ
	kɛtɛ		**k**ʌpʌ
	kɛnɛ		**k**ʌmʌ
	kɛpɛ		**k**ʌtʌ
	kɛdɛ		**k**ʌbʌ
pɛ**ss**ɛ	**s**ɛmɛ	tʌ**ss**ʌ	**s**ʌnʌ
	sɛtɛ		**s**ʌpʌ
	sɛnɛ		**s**ʌmʌ
	sɛbɛ		**s**ʌdʌ
	sɛdɛ		**s**ʌbʌ
dɛ**ss**ɛ	**s**ɛmɛ	bʌ**ss**ʌ	**s**ʌnʌ
	sɛtɛ		**s**ʌpʌ
	sɛnɛ		**s**ʌmʌ
	sɛbɛ		**s**ʌdʌ
	sɛpɛ		**s**ʌtʌ

Table 3.7: List of Experiment 4 test items (forced choice task) for each *language type*.

As shown in Table 3.7, the part-word consists of a left-edge syllable that divides the gemination (e.g. ***zɛ*** of *mɛz**zɛ***) and a word-initial syllable of another stimulus word, that could have followed in the string (***tɛ*** of ***tɛ**zzɛ*). For example, the part-word could be *zɛtɛ* taken from the word right edge

CV *mɛzzɛ* and left edge CV *tɛzzɛ*. The template of the part-word is shown in Figure 3.4. The duration for the word-initial C in this template is the singleton counterpart of the geminated stimuli of the *languages* in Table 3.6. All the audio for the test items were in the same MacinTalk male voice as the stimuli in the *languages*.

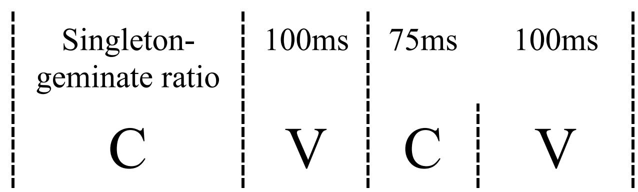

Figure 3.4: Template of the part-word for test items with duration for each segment. The word-initial C is the singleton counterpart to the geminated stimuli of the *languages*.

3.3.1.3 Procedure

To run the experiment, participants were placed in a quiet room with a MacBook computer and headsets (Koss R-80 Over ear headphones). All the audio stimuli were presented through headsets. During the experiment, the participants were first asked to listen to one of the *languages* for 10 minutes. Each participant was exposed to only one *language type* and they were told that these languages are new languages. This was the learning phase. In order to conduct a passive listening task, participants were asked to draw with the colored pencils and papers provided and not think too much while listening. After the learning phase was the test phase. Participants were given a forced choice task where they listened to one token of stimulus word (e.g. *mɛzzɛ*) in the *language* and one part-word (e.g. *zɛtɛ*). They were asked “Which was a word in this language?” and were instructed to choose one of the two. There were 30 possible stimulus word/part-word pairs, and since each trial was repeated twice, there were 60 test trials total. The entire procedure lasted about 20 to 30 minutes.

3.3.2 Experiment 4 Results

The results focus on the mean percent accuracy of the test trials on how well participants learned geminated stimulus word. The results presented here are examined separately by participant's native language (Japanese or English) but the performance of the two speaker groups were later compared to examine whether their native language interfered with the results. In the test trials (forced choice task), it was considered 'accurate' when participants chose the stimulus word over part-word. Therefore, selecting a geminated stimulus word as one of the words in the *language* is determined to be the correct choice in Experiment 4.

3.3.2.1 Results for Japanese speakers

First, when the mean accuracy was examined with the two *language types* combined, it was observed that Japanese participants learned the geminated stimulus words above chance (above 50% accuracy) for all three types of consonants /k, s, z/, as shown in Figure 3.5. A one-sample two-tailed t-test of the overall mean accuracy of Japanese participants for the three geminate cases showed that there is a statistically significant difference against the mean of 0.5 (50%) [$t(28)=5.41$, mean=0.72, sd=0.22, $p<0.05$]. The same test was run for each type of consonant separately (within consonant). There was a statistically significant difference against the mean of 0.5 (50%) for /k/ [$t(28)=4.49$, mean=0.71, sd=0.25, $p<0.05$]. A similar test was also significant for /s/ [$t(28)=5.19$, mean=0.72, sd=0.23, $p<0.05$], and /z/ [$t(28)=4.39$, mean=0.73, sd=0.28, $p<0.05$]. Since the accuracies were all above chance levels, the results suggest that the Japanese participants were able to learn the words containing geminated consonants /k, s, z/. The accuracy for the three consonants was roughly the same rate, slightly below 0.75. There was no significant difference in performance between the consonants. A one-way between-subjects ANOVA was conducted to compare the effect of consonant types /k, s, z/ on Japanese speakers' mean accuracy in Experiment 4. The test did not reveal a significant difference in mean accuracy between the consonants /k, s, z/ for Japanese participants [$F(2,54) = 0.10$, $p = 0.91$]. It seems that the frequency of geminates in the Japanese corpora discussed earlier (Table 3.2) does not reflect the accuracy rate of how geminated /k, s, z/ words are learned during word segmentation. Although /k/ was observed to have the highest gemination count in both native Japanese/Sino Japanese and loanword corpora, Japanese participants did not seem to learn the /k/ geminated words more (or less) than /s/ or /z/. More interestingly, words containing the underrepresented /z/ geminates in the Japanese corpora were learned as well as the well-represented /k/ and /s/.

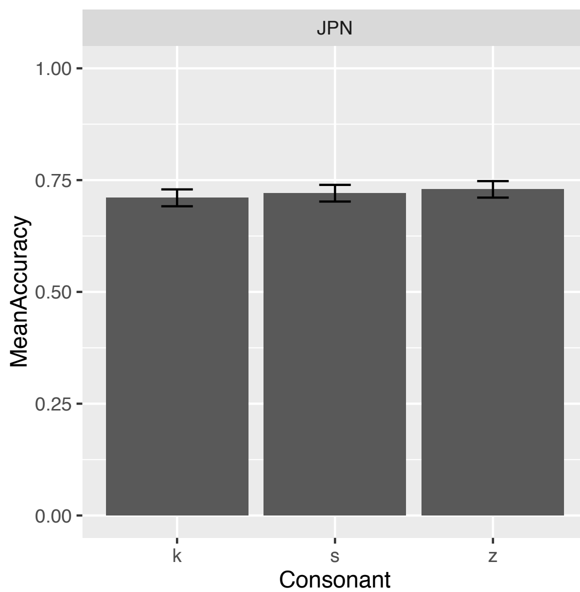

Figure 3.5: Mean accuracy rate of 29 Japanese speakers in Experiment 4 by consonant type /k, s, z/, two *language types* combined.

3.3.2.2 Results for English speakers

Similar to the Japanese results, English speakers also showed that they segmented the speech string retaining geminated words above chance, over 50% accuracy Figure 3.6. Their overall mean accuracy of learning /k, s, z/ words was above 50%. A one-sample two-tailed t-test of the overall mean accuracy of English participants showed that there is a statistically significant difference against the mean of 0.5 (50%) [t(25)=5.02, mean=0.67, sd=0.17, $p<0.05$]. A one-sample two-tailed t-test of the mean accuracy of English participants for each consonant was run separately as well (within consonant). The test showed that there is a statistically significant difference against the mean of 0.5 (50%) for /k/ [t(25)=2.80, mean=0.65, sd=0.27, $p<0.05$]. This was also true for /s/ [t(25)=5.26, mean=0.74, sd=0.23, $p<0.05$], and /z/ [t(25)=2.07, mean=0.62, sd=0.29, $p<0.05$].

A one-way ANOVA was run to compare the effect of consonant types /k, s, z/ on mean accuracy in Experiment 4. It did not reveal a significant difference in the mean accuracy between the consonants /k, s, z/ for English participants [$F(2,48) = 1.63$, $p = 0.20$]. This indicates that they learned geminated words at similar rates.

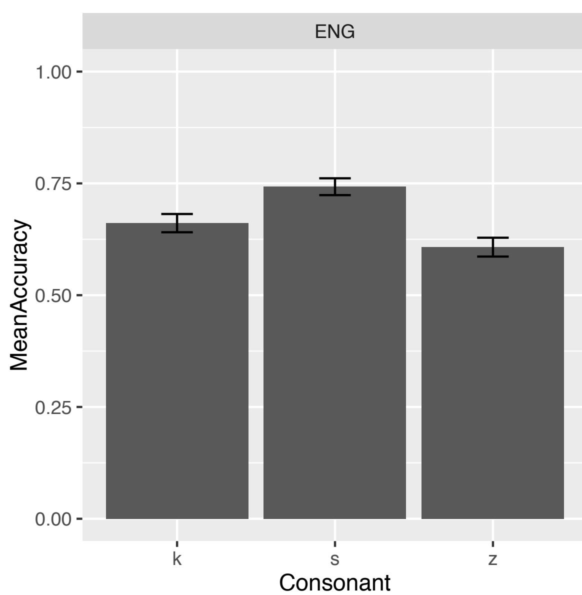

Figure 3.6: Mean accuracy rate of 26 English speakers in Experiment 4 by consonant type /k, s, z/, two *language types* combined.

3.3.2.3 Comparison between Japanese speakers and English speakers

The English speakers' results (Figure 3.7) were observed to be similar to the results of the Japanese speakers. A two-way ANOVA was conducted on a sample of 29 Japanese speakers and 26 English speakers to examine the effect of language as a between-subjects factor and consonant type /k, s, z/, as a within-subjects factor, on the mean accuracy as the dependent variable. There was no main effect of language [$F(1,53) = 0.88$, $p = 0.35$]. There was no main effect of consonant type [$F(2,106) = 1.09$, $p = 0.34$], and no interaction of language and consonant type [$F(2,106) = 1.36$, $p = 0.26$]. Although the mean accuracy of /z/ for English speakers are visually lower than that of Japanese speakers (Figure 3.7), the difference is not significant. Hence English speakers were able to learn new words with word-internal geminates that do not exist in their language as much as the word-internal /s/ geminate that is attested in English (as *fake geminates*).

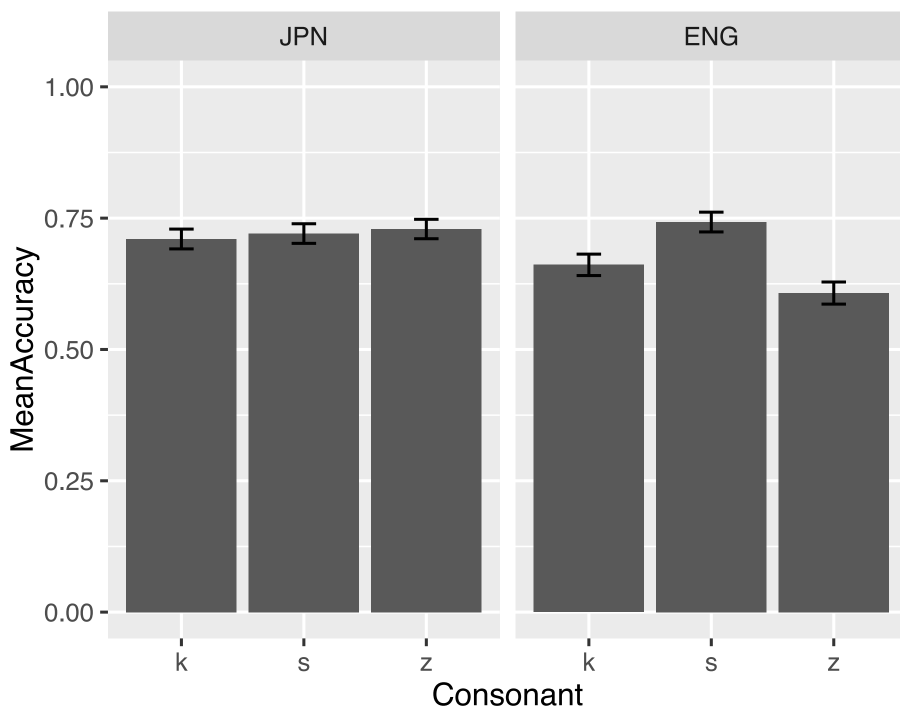

Figure 3.7: Mean accuracy rate of Experiment 4 by consonant type /k, s, z/, two *language types* combined. Results for Japanese speakers (left) and English speakers (right) together.

3.4 Experiment 5

The results in Experiment 4 indicated that both Japanese and English speakers were able to learn nonce words with geminates that are well represented as well as underrepresented in their native language during word segmentation. I decided to run a follow-up experiment because the simplicity of the stimulus words with only one type of vowel for each language may have led the participants to easily learn the geminated words, despite not all geminated consonants being properly represented in their respective language. Experiment 5 was designed with slightly more complicated stimuli to test whether the minimal variation of the stimuli itself contributed to the ease of learning in Experiment 4. With the more complicated stimuli Japanese speakers were able to continue to learn geminated words, even the underrepresented geminates in the language. On the contrary, for English speakers, their learnability rate decreased compared to the simpler stimuli employed in Experiment 4.

3.4.1 Methods

The methods and procedures are largely similar to Experiment 4. The notable difference is seen in the stimuli.

3.4.1.1 Participants

Participants in this experiment were 32 college aged native Japanese speakers (10 females and 22 male) and 24 college aged American English speakers (17 females and 7 male). The Japanese participants were recruited from the University in Tokyo and English speakers were recruited from Michigan State University community. These participants did not participate in any of the other experiments in Chapter 2 or 3. They all claimed to be monolingual speakers and have no experience living outside of Japan for more than 30 days.

3.4.1.2 Materials

Like Experiment 4, all stimuli were CVCCV and contained geminates of one of the three types of consonants /k, s, z/. None of the stimuli had /k, s, z/ as the word-initial consonant, to avoid introducing different transitional probability for consonants. The only difference from Experiment 4 stimuli was the vowels used. Instead of having only one type of vowel in each *language type*, there were three vowels introduced /ɪ, æ, ʌ/, in an effort to make the *language types* more complex so that participants will rely more on the phonology of their native language to segment words during the learning phase. As shown in Table 3.8, there will be two *language types* with six stimulus words each.

The stimuli creation followed the same procedure as Experiment 4. Each word was synthesized by syllables and concatenated into CVCCV. After stimulus words were created, they were concatenated into two 10-minute strings, according to the *language type*. The duration of the segments and geminates of the stimuli and test items (Table 3.9) were the same as what was shown in Figure 3.3 and Figure 3.4 of Experiment 4. MacinTalk software was used to create all synthetic audio stimuli and male voice was used.

Language 3	Language 4
mæ**zz**ʌ	nɪ**zz**ʌ
tʌ**zz**æ	pæ**zz**ɪ
nɪ**kk**ʌ	mɪ**kk**æ
bæ**kk**ɪ	dʌ**kk**ɪ
pɪ**ss**æ	tæ**ss**ʌ
dʌ**ss**ɪ	bʌ**ss**æ

Table 3.8: Stimuli for Experiment 5 containing /æ, ɪ, ʌ/ vowels in both *language types*.

Language 3			*Language 4*	
Stimuli	Part-word		Stimuli	Part-word
mæ**zz**ʌ	**z**ʌtʌ **z**ʌnɪ **z**ʌbæ **z**ʌpɪ **z**ʌdʌ		nɪ**zz**ʌ	**z**ʌpæ **z**ʌmɪ **z**ʌdʌ **z**ʌtæ **z**ʌbʌ
tʌ**zz**æ	**z**æmæ **z**ænɪ **z**æbæ **z**æpɪ **z**ædʌ		pæ**zz**ɪ	**z**ɪnɪ **z**ɪmɪ **z**ɪdʌ **z**ɪtæ **z**ɪbʌ
nɪ**kk**ʌ	**k**ʌmæ **k**ʌtʌ **k**ʌbæ **k**ʌpɪ **k**ʌdʌ		mɪ**kk**æ	**k**ænɪ **k**æpæ **k**ædʌ **k**ætæ **k**æbʌ
bæ**kk**ɪ	**k**ɪmæ **k**ɪtʌ **k**ɪnɪ **k**ɪpɪ **k**ɪdʌ		dʌ**kk**ɪ	**k**ɪnɪ **k**ɪpæ **k**ɪmɪ **k**ɪtæ **k**ɪbʌ
pɪ**ss**æ	**s**æmæ **s**ætʌ **s**ænɪ **s**æbæ **s**ædʌ		tæ**ss**ʌ	**s**ʌnɪ **s**ʌpæ **s**ʌmɪ **s**ʌdʌ **s**ʌbʌ
dʌ**ss**ɪ	**s**ɪmæ **s**ɪtʌ **s**ɪnɪ **s**ɪbæ **s**ɪpɪ		bʌ**ss**æ	**s**ænɪ **s**æpæ **s**æmɪ **s**ædʌ **s**ætæ

Table 3.9: List of Experiment 5 test items (forced choice task) for each *language type*.

3.4.1.3 Procedure

The same procedure as Experiment 4 was employed in Experiment 5. All participants were tested in a quiet room with a MacBook and headsets (Koss R-80 Over ear headphones). The experiment consisted of a learning phase where they listened to the string passively by drawing during the task; and a test phase that presented a forced choice task with 60 test trials (a total of 30 test trials were repeated twice). Each experiment session lasted about 20 to 30 minutes.

3.4.2 Experiment 5 Results

The mean accuracy rate of the test trials in the experiment was examined separately by participants' native language and the two results were later compared. Similar to Experiment 4, participants selecting a geminated stimulus word over a part-word is determined to be a correct choice in this experiment.

3.4.2.1 Results for Japanese speakers

Even with the more complex stimuli in Experiment 5, Japanese participants were able to learn novel /k, s, z/ geminated words well during word segmentation. Their overall mean accuracy rate for all three types of consonant gemination was around 75%, which is above chance, 50% (Figure 3.8). A one-sample two-tailed t-test of the mean accuracy of Japanese participants showed that there is a statistically significant difference against the mean of 0.5 (50%) for all consonant types /k, s, z/. [t(31)=7.97, mean=0.74, sd=0.17, $p<0.05$]. A one-sample two-tailed t-test was also run for each consonant type. The results showed that there is a statistically significant difference against the mean of 0.5 (50%) for /k/ [t(31)=6.24, mean=0.71, sd=0.19, $p<0.05$], for /s/: [t(31)=9.24, mean=0.78, sd=0.17, $p<0.05$], and /z/ [t(31)=5.43, mean=0.72, sd=0.23, $p<0.05$].

A one-way ANOVA was run to compare the effect of consonant types /k, s, z/ on Japanese speakers' mean accuracy in Experiment 5. The test did not reveal a significant difference in accuracy between the consonants /k, s, z/ for Japanese participants [$F(2,60) = 2.41$, $p = 0.10$].

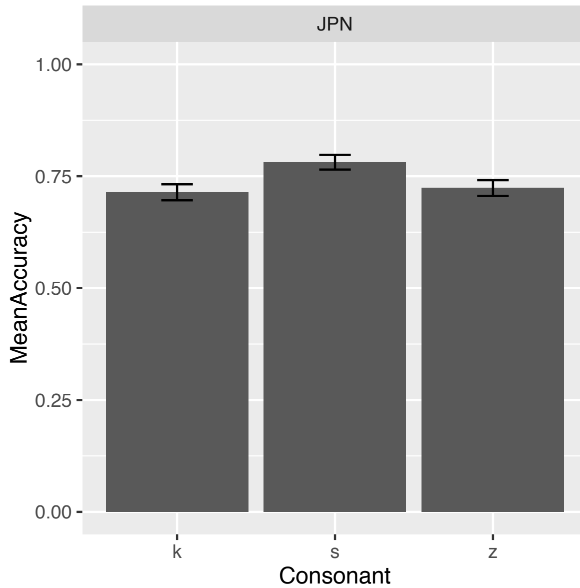

Figure 3.8: Mean accuracy of 32 Japanese speakers in Experiment 5 by consonant type /k, s, z/, two *language types* combined.

When Japanese speakers' performance in Experiment 5 was compared with their performance in Experiment 4, it was observed that there was no significant difference between the two (Figure 3.9). A two-way ANOVA was conducted on a sample of 29 Japanese speakers in Experiment 4 and 32 in Experiment 5 to examine the effect of experiment (Experiments 4 and 5) as a between-subjects factor and consonant type /k, s, z/ as a within-subjects factor, on the mean accuracy as the dependent variable. There was no main effect of experiment [$F(1,59) = 0.15$, $p = 0.70$]. There was no main effect of consonant type [$F(2,118) = 1.20$, $p = 0.30$], and no interaction of experiment and consonant type [$F(2,118) = 0.93$, $p = 0.39$].

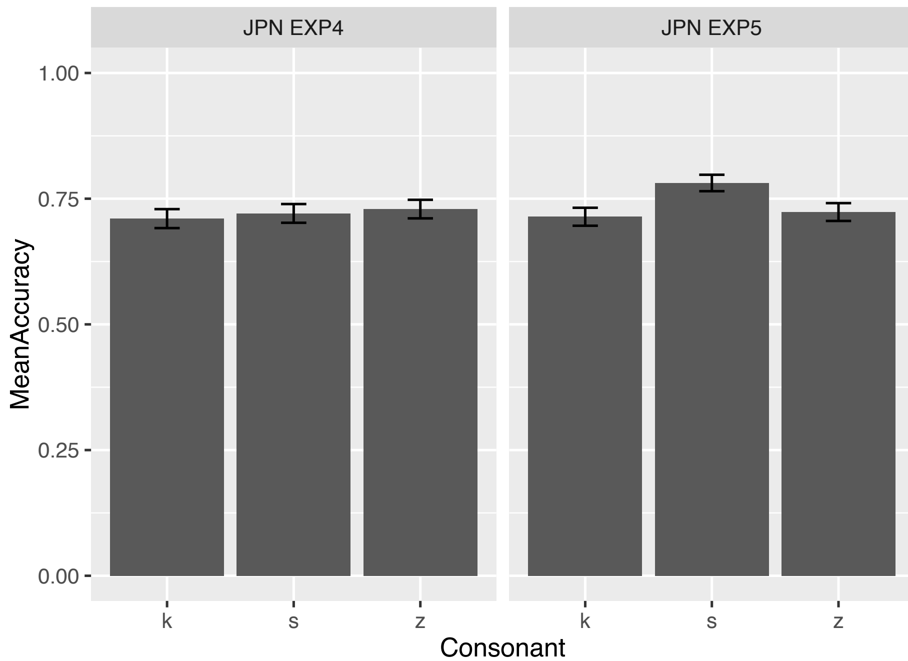

Figure 3.9: Comparison of Japanese participants' results (mean accuracy) in Experiment 4 (left) and Experiment 5 (right) for consonant /k, s, z/.

3.4.2.2 Results for English speakers

A one-way ANOVA to compare the effect of consonant types /k, s, z/ on English speakers' mean accuracy in Experiment 5. The test did not reveal a significant difference in accuracy between the consonants /k, s, z/ for English participants [$F(2,46) = 1.72$, $p = 0.19$]. This suggests that there were no clear differences in accuracy for geminate stimuli with different consonants.

A one-sample two-tailed t-test of the overall mean accuracy of English participants for Experiment 5 was also run and it showed that there is no statistically significant difference against the mean of 0.5 (50%) t(24)=1.62, mean=0.48, sd=0.57, p>0.05]. A one-sample two-tailed t-test was also run for each consonant type (within consonant). The results showed that there is no statistically significant difference against the mean of 0.5 (50%) for /k/ [t(24)=0.26, mean=0.51, sd=0.26, p>0.05], /s/ [t(24)=1.71, mean=0.48, sd=0.32, p>0.05], and /z/ [t(24)=1.98, mean=0.50, sd=0.25, p>0.05].

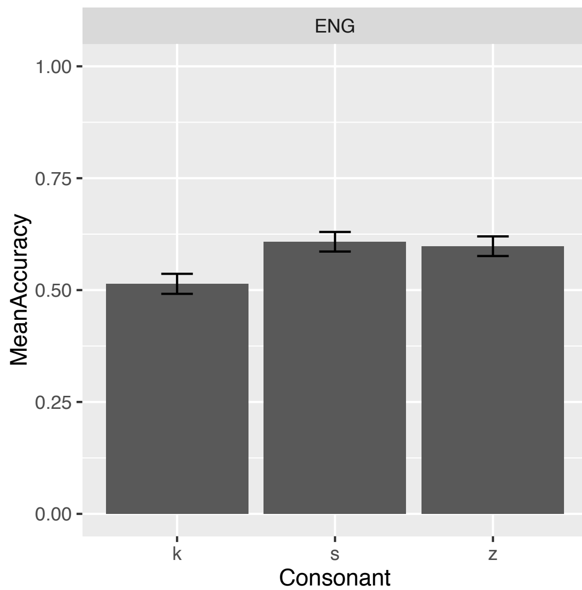

Figure 3.10: Mean accuracy of 24 English speakers in Experiment 5 by consonant type /k, s, z/, two *language types* combined.

Comparing the results in Experiment 5 with Experiment 4 for English speakers Figure 3.11, there was a marginally significant difference between the two experiments. A two-way ANOVA was conducted on a sample of 26 English speakers in Experiment 4 and 24 English speakers in Experiment 5 to examine the effect of experiment (Experiments 4 and 5) as a between-subjects factor and consonant type /k, s, z/ as a within-subjects factor, on the mean accuracy as the dependent variable. There was a marginally significant effect of experiment [$F(1,49) = 2.95$, $p = 0.09$]. There was no main effect of consonant type [$F(2,98) = 2.25$, $p = 0.11$], and no interaction of experiment and consonant type [$F(2,98) = 1.05$, $p = 0.35$]. The marginally significant main effect of experiment suggests that there is some evidence to believe that the English speakers did worse in Experiment 5 than in Experiment 4.

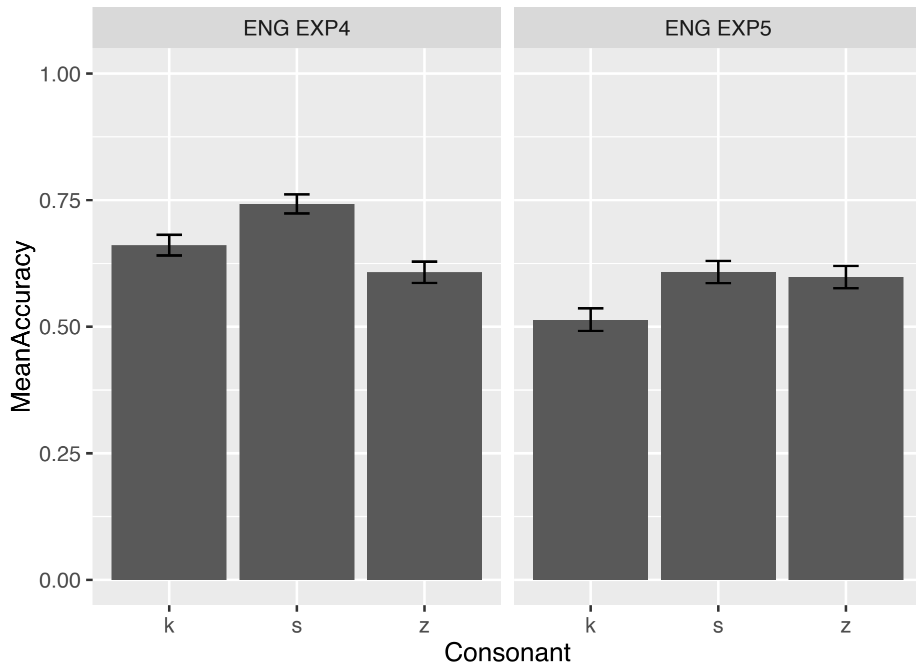

Figure 3.11: Comparison of English participants' results (mean accuracy) in Experiment 4 (left) and Experiment 5 (right) for consonant /k, s, z/.

3.4.2.3 Comparison between Japanese speakers and English speakers

Although, there was no significant difference between the Japanese results for Experiment 4 and Experiment 5, and there was no significant difference between the Japanese/English results in Experiment 4, there was a significant difference between the Japanese and English speakers results in Experiment 5 (Figure 3.12).

A two way ANOVA was conducted (using the ez package (Lawrence, 2015)) on a sample of 32 Japanese speakers and 24 English speakers in Experiment 5 to examine the effect of language as a between-subjects factor and a within-subjects factor, consonant type /k, s, z/, on the mean accuracy as the dependent variable. There was a main effect of language [$F(1,55) = 10.04$, $p = 0.002$]. There was a main effect of consonant type [$F(2,110) = 3.31$, $p = 0.04$], but no interaction of language and consonant type [$F(2,110) = 0.75$, $p = 0.48$]. Therefore, while the complexity of the stimuli did not influence Japanese speakers, it did indeed influence English speakers significantly. This effect will be discussed further in the following section.

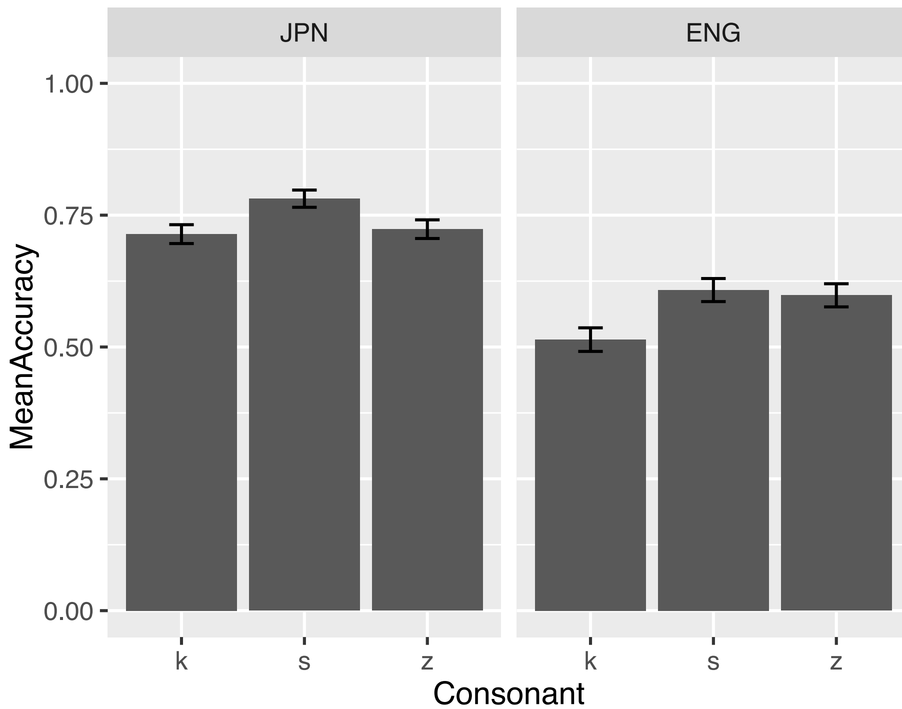

Figure 3.12: Mean accuracy of Experiment 5 by consonant type /k, s, z/, two *language types* combined. Results for Japanese speakers (left) and English speakers (right) together.

3.5 Discussion

Japanese speakers were able to learn and identify string segments with geminated /k, s, or z/ as words in the novel language. Their performance was consistent as the complexity of the stimuli did not affect how they segmented and learned geminated words. Adding a variation of different vowels in Experiment 5 did not change the rate of their learning, despite the fact that English speakers' learning rate were influenced by it.

To return to the first research question of this chapter, "does gemination guide word segmentation?" the experiments in this chapter demonstrated that it does for both language groups.

Japanese and English speakers' knowledge of geminates can predict how they segment novel-word speech string. Japanese speakers tend to retain geminates within words, and English speakers, while they were able to retain geminates when the stimuli were simple, were prone to divide the strings at geminates. The key explanation for the results is that the geminates as a word-edge cue worked in concert with the transitional probability (TP). When the stimuli were simple enough, the syllable-level TP may have guided the word segmentation, thus the similarity of segmentation patterns for both speakers in Experiment 4. As Table 3.10 shows, the stimuli word syllable TPs on the first six rows have TP of 1. Compare these TPs with the other syllable pairs below. The rest of the syllable transitions have much less TP, and this may have contributed to the results in Experiment 4. (The full list for *Language 1* and *2* for Experiment 4 is shown in Appendix H).

TP Type	Transition		Count	TP
Syllable TP	bɛk	kɛ	198	1
	dɛs	sɛ	216	1
	mɛz	zɛ	220	1
	nɛk	kɛ	202	1
	pɛs	sɛ	196	1
	tɛz	zɛ	214	1
	kɛ	mɛz	96	0.24
	sɛ	tɛz	90	0.218
	zɛ	dɛs	94	0.217
	zɛ	pɛs	90	0.208
	kɛ	dɛs	82	0.205
	sɛ	mɛz	84	0.204
	zɛ	nɛk	84	0.194
	sɛ	bɛk	76	0.184
	sɛ	nɛk	74	0.18
	kɛ	tɛz	70	0.175
	zɛ	bɛk	71	0.164
	kɛ	pɛs	58	0.145
	kɛ	bɛk	50	0.125
	zɛ	tɛz	54	0.125
	sɛ	pɛs	48	0.117
	kɛ	nɛk	44	0.11
	sɛ	dɛs	40	0.097
	zɛ	mɛz	40	0.092

Table 3.10: Syllable TP for Language 1, Experiment 4.

If TP was the only effective cue, there would not have been any difference between how Japanese speakers and English speakers learned the words. As mentioned in results section, English participants' mean accuracy lowered in Experiment 5 while Japanese results remained the same (Figure 3.13). When the stimuli were more complex (Experiment 5), speakers relied more on their native phonology, specifically on the information about geminates in their language. The TP alone cannot explain the results. Similar to Experiment 4, the TPs for within-stimuli word syllable TP are 1, but the part word syllable TP are all below 0.267 (Table 3.11). These differences in the TP do not explain the result differences between Japanese and English speakers in Experiment 5.

TP Type	Transition		Count	TP
Syllable TP	bæk	kɪ	206	1
	dʌs	sɪ	200	1
	mæz	zʌ	189	1
	nɪk	kʌ	172	1
	pɪs	sæ	184	1
	tʌz	zæ	184	1
	kʌ	dʌs	46	0.267
	zæ	bæk	47	0.255
	kɪ	dʌs	50	0.243
	sæ	bæk	44	0.24
	zæ	mæz	44	0.239
	sɪ	tʌz	47	0.235
	sɪ	bæk	46	0.23
	zʌ	nɪk	43	0.228
	kʌ	pɪs	37	0.215
	kɪ	tʌz	44	0.214
	sɪ	mæz	42	0.21
	sæ	dʌs	38	0.208
	kɪ	pɪs	42	0.204
	sæ	mæz	37	0.202
	zʌ	pɪs	37	0.196
	zʌ	tʌz	37	0.196
	zæ	pɪs	35	0.19
	zʌ	bæk	36	0.19
	zʌ	dʌs	36	0.19
	kʌ	bæk	32	0.186
	kʌ	mæz	32	0.186
	sæ	nɪk	33	0.18
	kɪ	nɪk	36	0.175
	sæ	tʌz	31	0.169
	kɪ	mæz	34	0.165
	sɪ	pɪs	33	0.165
	zæ	dʌs	30	0.163
	sɪ	nɪk	32	0.16
	zæ	nɪk	28	0.152
	kʌ	tʌz	25	0.145

Table 3.11: Syllable TP for Language 3, Experiment 5.

The difference in the performance of Japanese and English speakers demonstrates that the word segmentation can be affected by the phonotactics of the native language of the listener. The inventory of the two languages reflected how the two types of speakers segmented the strings. Earlier in the chapter it was discussed that consonant length, singleton and geminate, is phonemic in Japanese, but not in English. Japanese has what are called *true geminates*, which are productive in both native/Sino Japanese and loanwords. On the other hand, English has *fake geminates*, and allows some consonants such as /s/ to be geminated word-internally by morphological process. The difference in phonemic inventory and the productiveness of word-internal geminates may have caused the differences in their learning. Moreover, what is remarkable about Japanese results is that /z/ geminates were learned even though they are underrepresented in the language. This suggests that there is generalization beyond segments with respect to learning words with geminates. Despite the lack of geminates for certain segment in the language inventory, Japanese speakers generalized the consonant length pattern of other segments to learn a new geminate pattern.

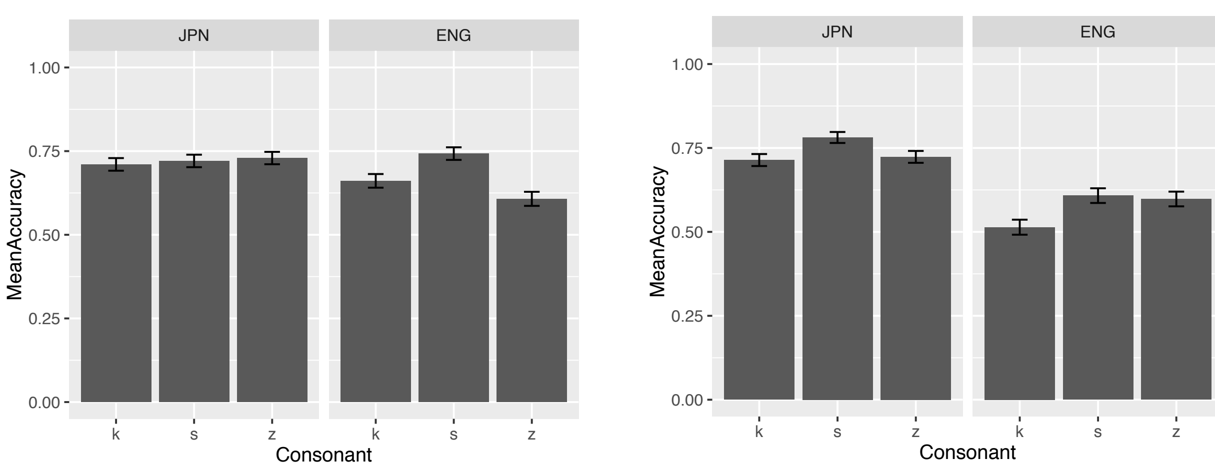

Figure 3.13: Side to side comparison of Experiment 4 and 5 results. Left: Experiment 4. Right: Experiment 5.

3.5.1 Learning beyond native phonotactic restrictions

The performance difference between Japanese and English speakers was not observed until Experiment 5. The phonotactics of their native languages did not limit the learning completely because 1) Japanese speakers learned geminated /z/ words which is underrepresented in their native language inventory, and 2) English speakers learned geminated words that do not exist in their native language, when the task is easier.

First, in the Japanese corpora, /z/ geminates were observed to be the least frequently geminated consonant among the three /k, s, z/. Native/Sino Japanese disfavors voiced geminates (Kubozono et al., 2008), so it is expected that listeners have less experience with geminated /z/. The frequency of loanword /z/ geminates is also very low because loanword phonology has a constraint against voiced geminates as well. Despite such constraints, Japanese participants learned the /z/ geminated words as well as /k/ or /s/ geminated words, even when the *language* was challenged to be more complex in Experiment 5 with more vowels being introduced. The rate of gemination cueing word segmentation remained consistent no matter the characteristics of the *language* to which they listened. The underrepresented /z/ geminates were learned well above chance for Japanese speakers, which suggest the ability to learn is not limited by simple segmental phonotactics, but in fact more dependent on an abstract generalization about geminates in general.

In contrast, English speakers did not show consistent segmentation pattern in the two experiments. It appears that the complexity of stimuli influenced how they segmented words from the string. As discussed earlier, consonant length is not contrastive in English and that the word-internal geminates that exist in the language are results of morphological processes (i.e., *fake geminates)*. The consonant /s/ is found as a word-internal *fake geminate* in the language; however, /k/ or /z/ are not. Regardless, during the learning phase in the Experiment 4, when the *languages* were uncomplicated with only one type of vowel, English speakers resisted from segmenting the string at the germination site, instead they preserved them as part of the same word. Perhaps this suggest that the native phonotactics do not limit the possibility of learning new words of novel *languages*; however, it is unknown whether geminates biased the segmentation or whether it was simply the transitional probability (TP) that guided it. Because the stimuli in Experiment 4 had a simple structure with one vowel type, it is reasonably easy to track the stimuli without cues other than the TP. Nonetheless, it needs another experiment to determine what precisely caused the results, yet from the current experiments, one can infer that geminates were not a strong of a cue for English speakers as they were to Japanese Speakers. In contrast, when the task was harder (Experiment 5), the English participants were breaking up words at the germination site, which suggests that their phonological knowledge is more at play when the *language* learning task is harder.

3.5.2 Differences between Japanese and English speakers

Although the results have led to infer that English speakers learned beyond their phonotactics, there are further details to the results that cannot be ignored. The results sections above presented *language type* combined results; however, when separating the results by *language type* for English speakers, one observes that the English participants were not consistent with the mean accuracy rate in the test trials. As shown in Figure 3.14, there is no consistency between *Language 1* and Language *2* of Experiment 4, or between Language 3 and 4 of Experiment 5. Contrast this with the results for Japanese speakers in Figure 3.15. While Japanese results remain consistent throughout the *languages*, English participants show variability in how well they learned geminated words for each *language type*. Even though the statistical analysis still holds that Japanese and English speakers both learned the geminated words in Experiment 4 (left plots on Figure 3.14), a closer look at the results indicate that English speakers behaved differently for *Language 1* and *2*. Stimulus words in *Language 1*, especially /s/ geminated words had higher mean accuracy rate. They were more willing to segment the *Language 1* string so that the geminates were preserved within the words. Similarly, *Language 3* and *4* in Experiment 5 (right plots on Figure 3.14) do not have the same pattern since *Language 4* has much higher mean accuracy rate than Language 3. This may suggest that English speakers heavily rely on the acoustics of the stimuli and that it was more of an acoustic task than a phonological one for them.

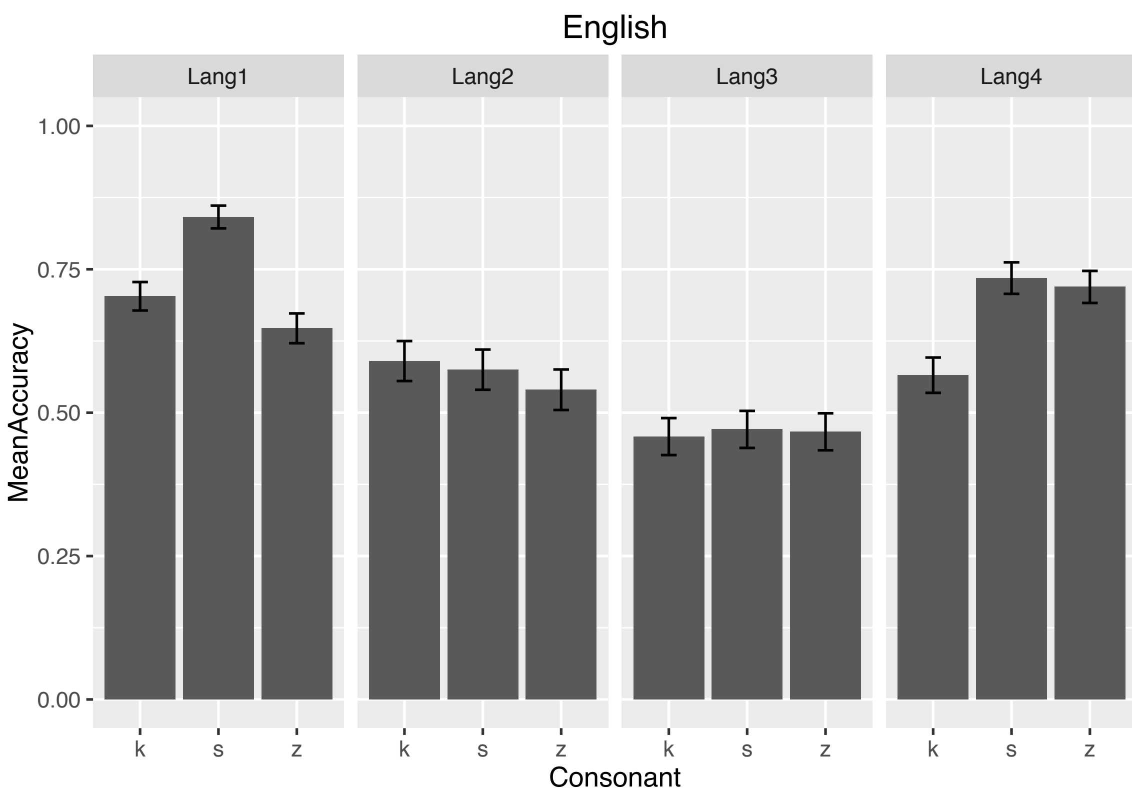

Figure 3.14: English results by *language type*. Language 1 and 2 of Experiment 4 on the left; and Language 3 and 4 of Experiment 5 on the right.

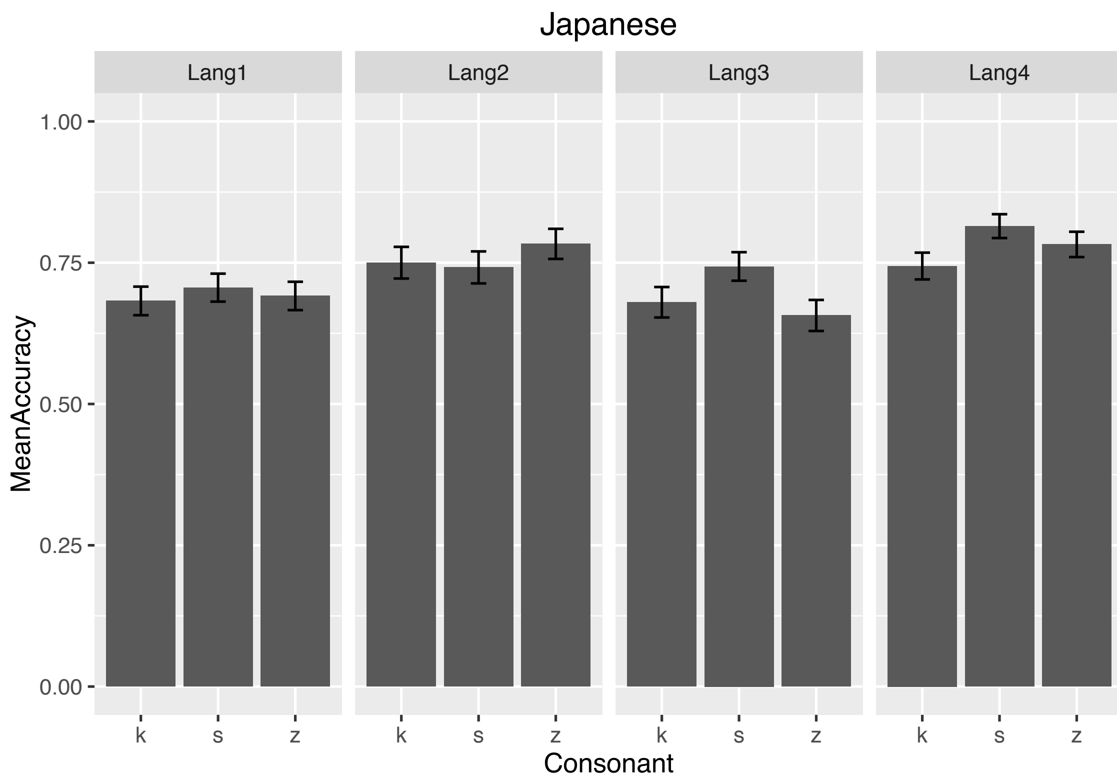

Figure 3.15: Japanese results by *language type*. From left to right: Language 1 and 2 of Experiment 4; and Language 3 and 4 of Experiment 5.

This very difference in the behavior between Japanese speakers and English speakers demonstrates that language experience influences how listeners perceive geminated words, or target languages in general (Best, 1995; Flege, 1995). The set of *language types* in each experiment were made to be equal in complexity with no outstanding transitional probability so that one was not more outstandingly easy to learn than the other. Even so, the two groups of speakers behaved differently; one instance was mentioned in this section about Japanese speakers' consistency and English speakers' inconsistency in learning geminates by *language type*, and another instance was how the complexity of *language* affected Japanese speakers and English speakers differently (Figure 3.12). The contrast of the behaviors of two speaker groups are indicative of the language experience differences.

3.5.3 Outstanding issues

3.5.3.1 Geminates to singleton mapping

The main purpose of the experiments in this chapter were to test if geminates cued word segmentation. The forced choice task was utilized to examine what kind of segment from the string participants internalized as words by presenting one stimulus word and one part-word in each trial, both being actual sequences they heard in the string multiple times. Therefore, the trials did not test directly whether the listener perceived the presented geminates as long consonants or a singleton. When participants heard geminates in during the learning phase (string listening) and the test phase (forced choice task), it is unclear if they have actually learnt *mɛssɛ* or the alternative *mɛsɛ* for example. This is especially the case for English participants, as they do not have language experience with phonemic contrast between geminates and singletons. Boomershine, Hall, Hume, & Johnson (2008) claim that when two languages that differs in contrast, either phonemic or allophonic in a specific sound pair (e.g. [d]/[ð] contrast in English and Spanish), the speaker of the language with a phonemic contrast for that specific sound pair reported the pair as more perceptually distinct than the speaker of the language with no phonemic contrast for that pair. Likewise, the English participants in the current study possibly did not perceive the consonant length contrast very distinctively and may have mapped the geminated consonants into singleton during the experiments. One possible solution to find out whether participants actually learnt the stimuli from the string is to include the two options, one with geminates and one with a singleton counterpart in the forced choice task (e.g. *mɛssɛ* and *mɛsɛ*). This would be a direct way to see if they heard the difference between the two counterparts. If the results indicate chance-level performance, then it may suggest that the participants were not able to perceive the difference. Another possible solution is to have them pronounce what they have learned, instead of providing the options to them. Writing down the words of novel words in their native language may be difficult to interpret, hence asking them to utter the words they heard in the string might be one way to find out what they have learned. However, it is important to note that this may be problematic due to the native speakers' phonological interference with their pronunciation of the stimuli. They may have learned to recognize the words but the exposure to a language string does not necessarily train them to pronounce those words.

Such arguments may lead to suggest that for those English participants who selected the stimulus word in the test phase (forced choice task) may not actually have learned geminated words but a singleton alternative of that word. It is uncertain what English speakers actually learned unless they are given explicit questions about it. Even so, the differences that was observed in Experiment 4 and 5 results for English speakers demonstrate that they used geminated sequences to segment words to some degree. The only dissimilarity between Experiment 4 and 5 was the number of vowel types in the *languages* to establish differences in complexity. The outcome that they learned geminated words well above average in the simpler *languages* but not in the more complex *languages* implies that they are able to learn geminates as long consonants as long as the language environment is simple enough to hear the consonant length distinction, perhaps with a considerable guidance of TP.

3.5.3.2 Artificial language learning and natural language learning

This chapter relied on an artificial language learning paradigm using novel *languages* and stimuli that were entirely synthetic. The study followed the paradigm of a number of past word segmentation studies (e.g. Ettlinger et al., 2011; Saffran et al., 1999; Thiessen & Saffran, 2003) to have better control over the *language* presented to participants. The purpose of synthetic stimuli was to control the phonetic details in the audio to eliminate potential cues to word segmentation that are not geminates or transitional probability. Nevertheless, it is not completely clear whether the results from the artificial language learning can be used to learn about what Japanese and English speakers actually would do in a natural language learning. A more in-depth study of synthetic vs. naturalistic stimuli is needed in future work.

3.6 Conclusion

To conclude, geminates can guide word segmentation. They can signal the segmentation for language speakers with (Japanese) and without (English) phonemic consonant length contrast. It must be noted that the effectiveness of such language-dependent cues is determined by the language experience of the listener. Words with geminates can be internalized by listeners whose native language exhibits phonemic consonant length contrast like Japanese; however, they are not always internalized by listeners whose native language does not have consonant length contrast like English, which suggests that the native language-dependent cues can and are used in word-segmentation. It must also be noted that the geminate cues tested in this chapter are accompanied by syllable-level transitional probability cues. Hence the learning of the novel language string was influenced by both geminates and the transitional probability, which is similar to Ettlinger et al.'s (2011) argument that the Sonority Sequencing Principle as a cue worked together with the transitional probability cue.

CHAPTER 4 DISCUSSION

4.1 Overview of the Sonority Sequencing Principle and geminates experiments

This dissertation has explored two types of possible factors that guide word segmentation for Japanese speakers, language-independent knowledge, the Sonority Sequencing Principle (SSP), and language-dependent knowledge, the presence of geminates (or long consonants). The results of the experiments in Chapter 2 on the SSP (Experiment 1, 2 and 3) and Chapter 3 on geminates (Experiment 4 and 5) indicate that, in word segmentation, the language-dependent knowledge of the presence of geminates was a better cue than the language-independent knowledge of SSP.

The roles of the two types of cues were investigated using an artificial language learning paradigm in an identical experimental set up. The procedure in all experiments had a learning phase (string listening) and a test phase (forced choice task). The only differences in the methods were the stimuli and the test items in each experiment. Hence, it is fair to compare the results of the two cues directly.

For the SSP, the results indicated that it did not guide word segmentation for Japanese speakers in a series of three experiments. The experiments followed a conventional procedure for artificial language learning tasks, with a learning phase (listening to a "language" string) and a test phase (either a forced choice task or a *yes-no* question task). Each of the experiments had the same purpose to test the SSP's role but also had slightly different motivations. The first experiment, Experiment 1 employed a yes-no question task and used a set of stimuli with pitch variation that was a byproduct of MacinTalk synthesizer. In order to eliminate the possibility of pitch affecting the word segmentation, Experiment 2 removed the pitch differences to keep it consistent throughout the strings. This experiment also introduced a forced choice task instead of *yes-no* questions to make the tasks similar to Ettlinger et al.'s (2011) as possible. However, since the results did not replicate Ettlinger et al.'s (2011), Experiment 3 was conducted using Ettlinger et al.'s (2011) exact stimuli and experimental set up. The results demonstrated the consistent indication that the SSP is not an effective cue in word segmentation for Japanese speakers. One could potentially attribute this to one of two possibilities: (a) the lack of (or severely impoverished set of) complex onset in Japanese, (b) the lack of effect of SSP on word-segmentation.

The English speakers' results allow us to identify that it is the second of the above possible reasons that is more likely. The English speakers showed that the SSP did not guide word segmentation for them either, despite the possibility that their experience with consonant clusters and the SSP in English would elicit sensitivity towards sonority. The negative effect of the SSP for English speakers implies that the lack of effect for Japanese speakers was not solely due to their lack of experience with consonant clusters. Instead it seems to be the case that the SSP is not a useful cue for word segmentation to speakers with any native language experience.

It is important to mention here that the very nature of the SSP may have been the reason that it was not useful in the task. Essentially, the SSP governs syllable structure patterns. It is not a principle about words. It describes that a general pattern of syllables have a rise in sonority as one moves towards the nucleus in an onset, and a fall in sonority as one moves away from the nucleus in a coda (Clements, 1990; Jespersen, 1904; Kiparsky, 1979; Elizabeth Selkirk, 1984). There is nothing directly associated about the SSP with general word structure in languages. At best, it may provide the framework for languages with a large number of monosyllabic words; however, it not true for either Japanese or English. This may well have been the reason this particular knowledge was not used in the word segmentation task for both Japanese and English speakers.

On the other hand, the knowledge of geminates was argued to play a role in word segmentation, in Chapter 3. As predicted, the Japanese results of two experiments indicated the effectiveness of geminates. It can be argued that their language experience with phonemic singleton-geminates contrast contributed to their behavior. Experiment 4 introduced simpler *languages* where the stimulus words only contained one type of vowel per *language type*. Experiment 5 was designed with more complex stimuli to test whether the positive effect observed in Experiment 4 was due to the easiness of the *language*. In both instances, Japanese speakers learned words with geminates. In addition, Experiment 4 and 5 results demonstrated the same degree of geminates' effectiveness. This particular cue's effect on word-segmentation did not weaken by the complexity of the *language* for the Japanese speakers. Such consistency indicates the stability and dependability of geminates as cues to word segmentation for speakers whose native language has contrastive consonant length – singleton and geminates. The speakers of English, which has no such geminate contrast, did not exhibit the same consistency. The complexity of the stimuli was an important factor for them. Although they seemed to learn words with geminates when the stimuli were simple in Experiment 4, the effectiveness lowered when the stimuli became more complex in Experiment 5. This suggests that when the task got harder, their phonological knowledge was more recruited, and they were more likely to break up words at the point of gemination. This is similar to speech perception tasks whereas the task complexity increases either due to the addition of noise to stimuli or due to an increase in the complexity of the experimental procedure, the effect of abstract phonological/phonetic knowledge increases on participant responses (Pisoni & Lazarus, 1974; Slowiaczek, Nusbaum, & Pisono, 1987). Experiment 5 is likely a much better representative of natural language learning, as it had more variation in vowels in the stimuli. In this condition, there is clear evidence that language-specific knowledge has more impact on word segmentation than the language-independent SSP.

4.2 Listeners' strategies to word segmentation

4.2.1 Phonological and phonetic motivation

Here I will discuss some possible strategies used by the listeners during word segmentation. Although the experiment was specifically designed with a passive listening task with specific cues, language-independent or language-dependent, it is not clear if the segmentation was either motivated by the phonetic cues, phonological cues or both.

As seen in Chapter 3, both Japanese and English speakers retained words with geminated consonants when the stimuli were simple in Experiment 4; however, in Experiment 5, only Japanese participants, and not the English speakers, showed consistency by maintaining the segmentation to include the geminates. This shows that speakers' native phonology played a stronger role when the stimuli complexity increased in Experiment 5. When the stimuli were simple with only one vowel type (Experiment 4), speakers of both language background might have simply tracked the syllable TPs (all stimuli were in the CVCCV template with V being the same vowel, so there were fewer TPs to keep track of), but when the stimuli became more complicated, they appeared to have relied on their native phonologies. Regardless of the stronger role in phonology in Experiment 5, the Japanese participants maintained similar results in Experiment 5 as Experiment 4 because their phonological knowledge helped them recognize geminated words and even generalize and extend their native phonological pattern to an underrepresented geminate /zz/ in their language.

On the other hand, it is difficult to evaluate what strategy participants have used in Chapter 2 because the results did not reveal any SSP bias. However, it seems likely that they focused on phonetic details and relied on native phonological knowledge during the segmentation equally. Since the stimuli in Experiment 1, 2, and 3 were much more complex than those Experiment 4, one can assume that both Japanese and English speakers relied heavily on their native phonology. For the Japanese and English speakers' results in Experiment 1, the trend were quite similar. For example, looking at the complex stimuli in Language 1, when the Yes response rate was low for the English participants, it was also low for Japanese participants ***lz***_otfu_, SSP score = -1); and when the Yes response rate was higher for the English participants, it was also higher for the Japanese participants (***vt***_eko_, SSP score = -2) (Figure 4.1). Such parallel trends in the Yes responses for the two language groups can also be observed for the other test words (***lz***_otfu_, ***vt***_eko_, ***dg***_usa_, and ***kf***_ami_). Hence there may be something phonetically specific about these stimuli that triggered such similar responses from these two speakers.

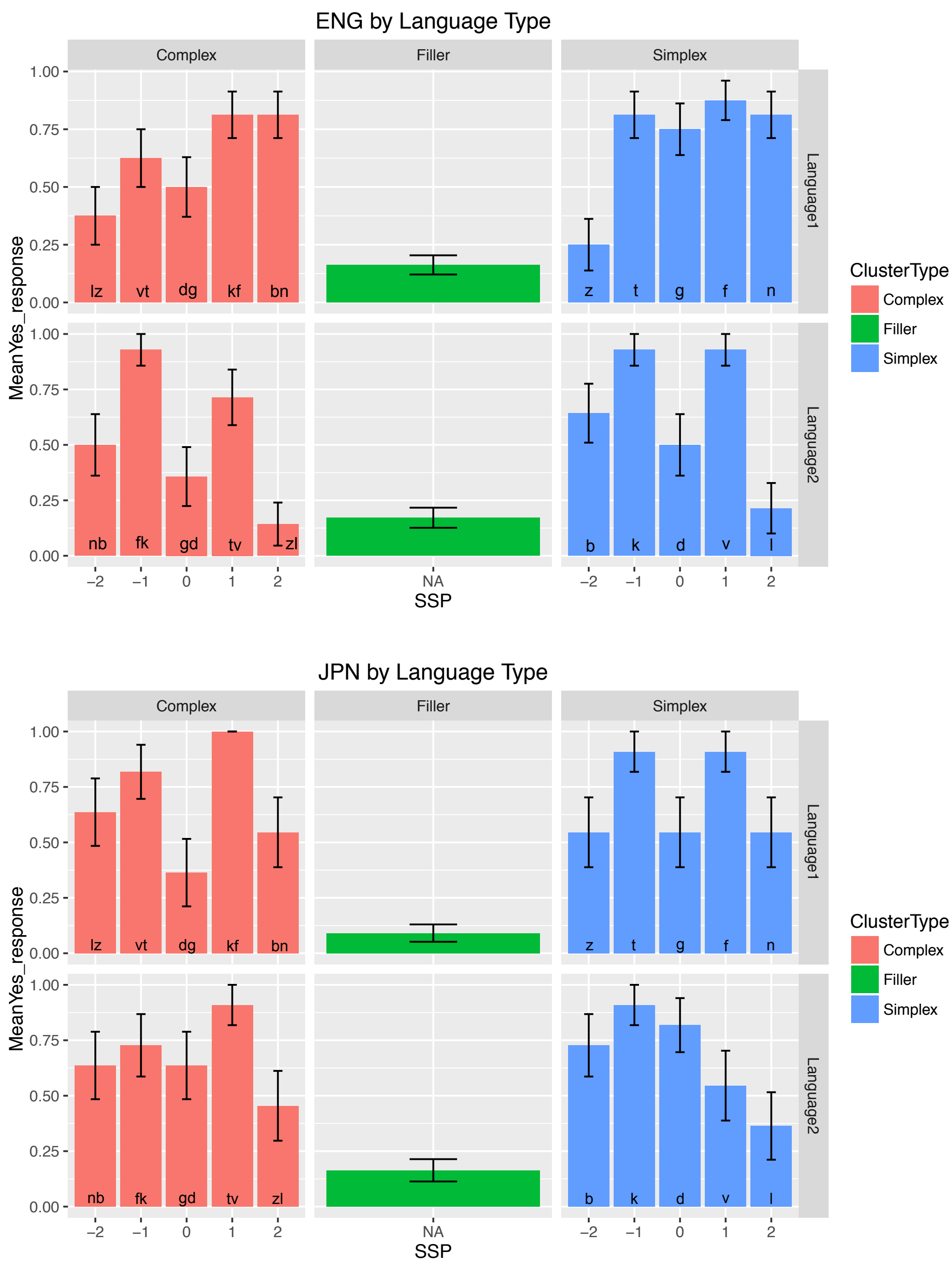

Figure 4.1: Mean Yes response by SSP score for English (top) and Japanese (bottom) speakers by *language type* from Experiment 1. Each bar for complex and simplex items is labeled with the word initial consonant/s of that item.

4.2.2 Iambic-trochaic law

For geminates, there might have been another prominent strategy used by the listeners, mainly the principle of the *Iambic-Trochaic Law* (ITL) (Hayes, 1995) . The ITL was formed based on Woodrow's (1909, 1911, 1951) findings about how nonspeech sounds were grouped perceptually: when there was a difference in duration, the grouping was iambic (right-prominent grouping), but when there was a difference in intensity (loudness), a trochaic rhythmic grouping (left-prominent grouping) was observed. Although Woodrow's findings were based on nonspeech sounds, it can be applied to linguistic experience. Hence Hayes (1995) proposed the following:

(1) The Iambic-Trochaic Law (Hayes, 1995)

a. Elements contrasting in intensity naturally from grouping with initial prominence.

b. Elements contrasting in duration naturally form grouping with final prominence.

Studies have found the ITL's relevance to linguistic experience. For example, in a word segmentation study, Saffran et al. (Saffran, Newport, et al., 1996) saw that English speakers segmented nonsense trisyllabic words more correctly when the word stimuli contained word-final lengthening than when word stimuli contained word-initial lengthening. In another study, Hay and Diehl (2007) investigated whether the ITL is language-dependent (language-specific) or language-independent by testing two groups of speakers: English and French. They tested using altered /ga/ syllables differing in intensity or duration and had both group of speakers group the sounds into a two-beat rhythmic pattern. The results indicated that participants followed trochaic grouping for syllables with varying intensity, and adhered to iambic grouping for syllables that contrast in duration. Moreover, they found that there was no significant difference in results between English and French participants, which suggests the general bias of ITL in perception regardless of the linguistic background of the listener.

If it is indeed the case that the ITL bias is language-independent, it could have biased the responses of the participants, especially for the gemination experiments in Chapter 3 that introduces stimuli with altering singleton-geminates consonants in the speech string. The stimuli in Experiment 4 and 5 were all in CVCCV template with one word initial singleton consonant, one word medial geminated consonant, and two short vowels. The geminated consonants were more than twice as long than the singleton consonants, and the two vowels were the same duration (Figure 3.3[25]). The first syllable was a heavy CVC syllable and the second one was a light CV. There is a durational difference in the syllable, which is *strong-weak*, and the pattern is different from what ITL predicts, *weak-strong*. The participants heard […]CVC.CV.CVC.CV.CVC.CV[…] throughout the entire speech string, and if ITL played a role in the perception, they would have chunked it into a *weak-strong* "word". In Experiment 4, both Japanese and English participants segmented the speech string correctly into CVCCV stimulus words retaining the geminates. Even though this is not what ITL would predict, because of the simple structure of the stimuli, that only had one type of vowel across the entire string, speakers were able to segment correctly. However, when the stimulus words were more complex in Experiment 5, with more types of vowels introduced, participants whose language does not have *true geminates* relied more on the ITL. In the test phase, the two options were CVCCV original stimuli and part-word CVCV that consists of a left-edge syllable that divides the gemination (e.g. ***zɛ*** of *mɛz**zɛ***) and a word-initial syllable of another stimulus word, that could have followed in the string (***tɛ*** of ***tɛ***zzɛ). The option did not provide an iambic grouping of *weak-strong* syllable sequence; therefore, the only option left to pick was a non-*strong-weak* word. Although English phonology could have been the only

[25] Due to formatting restrictions, this figure cannot be presented again on this page. Please refer back to Figure 3.3 in Chapter 3.

motivation for the results; however, it is also possible that the native phonology could have worked in concert with the ITL for the English speakers' results in Experiment 5.

4.3 Implications

This section will discuss how the empirical data integrate to theoretical framework and to a natural language learning framework.

4.3.1 Theoretical implications

4.3.1.1 Learning underrepresented geminates

The major findings of the present dissertation were that language-dependent geminates were more useful in word segmentation than language-independent SSP. However, there is another important finding, which is that speakers are not completely beholden to the segmental phonotactic restrictions in their native language. Through reasonable amount of exposure of the target language, Japanese speakers were able to use both well represented and underrepresented geminates in their language to segment words. In Chapter 3, the underrepresented /z/ geminates in the strings were preserved in the segmentation, just as well as the well represented /k/ and /s/ geminates in Japanese. This suggests that listeners generalized the geminates beyond segments to learn words with new geminate pattern. In contrast, the English speakers were not able to do so consistently. The phonology of their native language is responsible for the very difference.

The consonant duration contrast is phonemic in Japanese; thus, they are familiar with *true geminates*. However, since there are relevant phonological rules, not all consonants are geminated, or at the minimum, certain types of consonants are not geminated in the surface form. Voiced consonants are prohibited to geminate in Japanese, so their voiced feature is deleted to form voiceless geminates instead (Ito & Mester, 1986; Kubozono et al., 2008; McCawley, 1968). Accordingly, /zz/ would become [ss] in the surface form. Therefore /z/ geminates are not common in the lexical inventory, as shown in the corpora (Table 4.1). Nevertheless, Japanese speakers learned /z/ geminated words well above chance, which entails the plasticity of perception and learnability of patterns beyond their native language experience. Japanese speakers were able to shift their phonological restrictions to learn new patterns as their knowledge extends in a structured way. Since geminates are readily available in their native language, they were able to generalize and accept all geminates instead of the ones in their language experience.

Consonant type	***Native & Sino Japanese words (NINJAL 2005 corpus)***	***Loanwords (Corpus by Takemura et al. 2014)***
p	195	656
k	545	1492
t	417	1124
s	169	238
ɕ	145	337
z	4	17
b	0	20
g	0	107
d	4	233
nasals	384	223
ɸ	0	49
v	n/a	0
h	1	42
liquids	0	14

Table 4.1: Counts of word-internal geminates of each consonant type based on the NINJAL (2005) corpus that is filtered to display native and Sino Japanese words (left) and loanword corpus (right) by Kawagoe and Takemura (2014). (This is the same table found in Table 3.2, Chapter 3)

By looking only at the results for Experiment 4 in Chapter 3, it appears as though English speakers were able to learn word-internal geminates for consonants that are not attested in their native language, even if they only have experience with *fake geminates* that arises from morphological processes. Out of the three geminated consonants in the experiments in Chapter 3, /s/ is the only known consonant to geminate via affixation in English. Nonetheless, English speakers appear to have demonstrated that they are capable of learning /k/ and /z/ geminated words as well, in the same capacity as Japanese speakers. Their mean accuracy rate of learning geminated words did not show a significant difference from the Japanese speakers. Moreover, the argument that non-phonemic *fake geminates* in English are actually phonetically long contra prior claims that English morphological geminates are not consistently long seems to account for the Experiment 4 results. When Kaye (2005) and Oh and Redford (2012) investigated the prior understanding that *in*-prefix degeminate and *un-* prefix geminate, they found that both types geminate but some pertinent words do not. Ben Hedia & Plag (2017) also support that it is not the case that only certain kinds of prefixes geminate. They also find that locative *in-* and negative *un-* have durational differences, but both are significantly longer than singleton counterparts. Their claim implies that English speakers have fair amount of experiences with surface geminates that are clearly longer than the singleton counterparts, even though the consonant duration is not phonemic. These facts could be used to conjecture that, in Chapter 4, English speakers were much more willing to learn /k/ and /z/ geminates in the study and were able to generalize their knowledge of non-phonemic consonants length in English into possibly a phonemic representation in the new language. Despite all this, the results in Experiment 5 in Chapter 3 showed that geminated words were less likely to be learned as such by English speakers when the task itself became more difficult. This demonstrates that regardless of the above conjecture, the simplicity of the stimuli in

Experiment 4 might have enabled the speakers to track each stimuli word in the string by TP instead of geminates cueing the segmentation. For English speakers, segmentation by preserving /k, s, z/ geminates was much easier when the *languages* themselves were simple enough to accommodate the task. Contrastingly, Japanese speakers were able to consistently learn their underrepresented geminates /z/, even though there were differences in language difficulty: Experiment 4 introduced a much simpler language structure than Experiment 5. The phonology of native language of the speakers, specifically on phonemic/non-phonemic consonant length contrast, affected the difference.

4.3.1.2 Universality of the Sonority Sequencing Principle

The current dissertation was structured to examine what the useful cues to word segmentation are for Japanese and English speakers, and compared two types of cues – language-independent and language-dependent. The SSP was proposed as a language-independent universal bias in this dissertation, yet there are claims that it is not. If it is the case that the SSP is not innate universal knowledge, then the language-independent/dependent comparison in the present dissertation is no longer valid. It would also mean that the SSP belongs to the same language-dependent category as geminates and inferring from the results, there are differences in effectiveness of each cue within the same category. Instead of explaining the SSP phenomenon as innate bias, Daland et al. (2011) argue that the lexical statistics in the language can predict the sonority projections. The SSP or the sonority well-formedness can be accounted for by a computational model of phonotactics that is based on lexical type statistics. With the existing patterns, the model can learn to generalize and show preference to syllables towards a more phonologically similar type of syllables in the language. Therefore, the supposition that SSP is innate is not necessarily needed to decide the well-formedness of a syllable even if that particular pattern that is fed to the model does not exist in the particular language.

The present dissertation leaned towards Berent's argument (2008, 2007) and assumed the SSP to be language-independent. In spite of Daland et al.' (2011) claims, there is indeed some evidence of the language-independent nature of the SSP. Daland et al.'s (2011) results do not extend to what Berent claims as she tested languages with very impoverished onset clusters. Hence, the decision to test the SSP as language-independent cue and geminates as language-dependent cue was reasonable.

4.3.2 Implication for natural language learning

The present dissertation employed the artificial language learning paradigm with nonsense synthetic stimuli creating new *languages*. This paradigm has been used in a number of word segmentation studies in the past (e.g. Ettlinger et al., 2011; Ren et al., 2010; Saffran, Aslin, et al., 1996; Saffran et al., 1999; Saffran, Newport, et al., 1996), mainly because it allows the control of the phonetic details of the stimuli to be more manageable. This dissertation used synthetic stimuli to control the phonetic details in the audio to eliminate other unnecessary potential cues. The intention of employing an artificial language learning paradigm is clear, yet there may be disagreement about what its findings entails about natural language learning processes.

The findings in this dissertation are based on adult language participants; therefore, the closest to a natural language setting is the second language learning of adult speakers. Adult second language learners experience a similar situation where they are exposed to a continuous stream of target language and try to find the break between possible words so they can store them in memory. Japanese speaker in this study were exposed to languages with /k, s, z/ geminated words, which they learned well above chance. Such findings give a good prediction about how they will learn in a natural language setting if the target language contained geminates, especially /z/ geminates that are underrepresented in Japanese. It can be predicted that they have a good chance of segmenting the speech string to retain the /z/ geminates and internalize the word, like in Hungarian that has phonological /z/ geminates for example. On the other hand, one can anticipate that English speakers may be less likely to retain /z/ geminates, and perhaps even allow the string if the string itself was simple enough to accommodate the sequence. Just as how it was observed in the current artificial language study, native phonology will influence the learning of target language in the second language learning (Finn & Kam, 2008). Although, the findings in the experiment cannot tell the exact outcome of second language learning, it can certainly predict how the learners will perform.

4.4 Methodological concerns regarding word segmentation paradigm

Finally, it is necessary to discuss the potential issues about the word segmentation methodology. One of the larger concerns that was encountered was the definiteness of word segmentation. The methods of the experiments are built in order to find out how *words* are segmented in the audio language string. The experiments were specifically designed to investigate what words are learned. The procedure explicitly asks the participants "Was XXX a word in this language?" (Experiment 1) or "Which was a word in this language?" (Experiment 2, 3, 4, & 5) prompting answers for the words. Prior to the learning phase (string listening), they were also told that they will be asked about what *words* they heard in the proceeding section. However, it is unclear if the response they gave was reflective of *words* they learned or something else. As participants heard a continuous stream of sounds, they were led to segment the string into units. These units may not have necessarily been words, rather some kind of (potentially, overlapping) constituents that could have been morphological units, phrases or even just fragments that are not linked to any linguistic unit/category.

The positive correlation for complex (onset stimuli) and simplex (onset stimuli) words in Chapter 2 that tested the SSP demonstrates that participants likely learned possible sequences of the string and not have explicitly segmented as words. This response should not be possible if they are really giving "word" responses. Unlike the rest of the experiments, Experiment 1 in Chapter 2 followed a distinct procedure for the test phase than the rest of the experiments in the current study. Instead of a forced choice task, it introduced a series of "yes-no" questions about the test items. Experiment 1 employed such a task to obtain participants' responses to each test item separately, rather than allowing them to choose between two items (stimulus word vs. part-word). The test items consisted of stimulus words that contained complex onset clusters (e.g. ***bn****ife*), part-words that contained simple onset (e.g. ***n****ife*), and fillers (test items for Experiment 1 Table 2.3). Such a procedure was designed to examine participants' response to complex and simplex results separately in order to see if the string listening had caused them to store definite segments in their memory. The results of Experiment 1 demonstrated a strong positive correlation between complex (stimulus words) and simplex (part-word) results, as shown demonstrated in Figure 4.2.

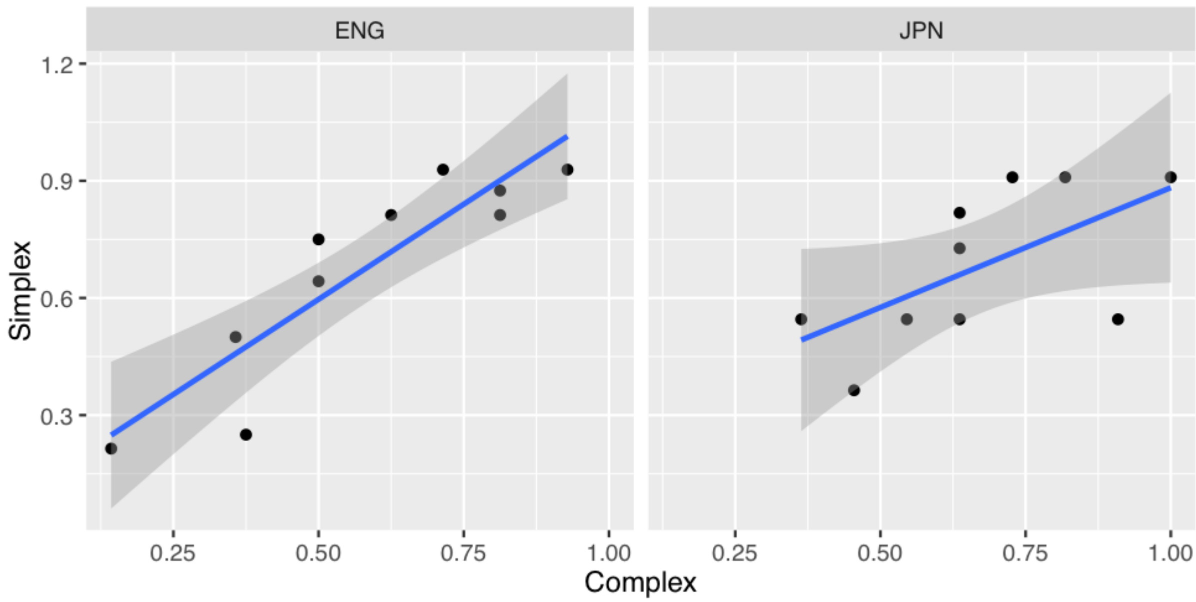

Figure 4.2: Strong positive correlation between complex onset stimuli and simple onset stimuli (part-word) observed in Experiment 1 for English speakers (left) and Japanese speakers (right).

The positive correlation means that for Japanese and English speakers, when they were asked if they think a stimulus ***bn**ife* was a word and its part-word ***n**ife* was a word in the language, they were prone to give a similar *yes* or *no* answer to both segment strings. If they have said *yes* to ***bn**ife*, and internalized it as a definite word, then they should have said *no* to ***n**ife*, yet that was not the case. Instead, participants did not exactly mark definite edges of words. This suggests that participants possibly memorized the possible sequences in the string they heard. One possibility is that they may have learned ***b***- as a prefix of ***n**ife*. Hence, they actually learned both ***bn**ife* and ***n**ife* as words but with a different morphological unit. Both Japanese and English have prefixes in their languages, for example, some Japanese prefixes include: *mi* 'undone' (*mi-kansei* 'incompletion'); *mu* 'zero' (*mu-seigen* 'limitless'); and *han* 'anti' (*han-seifu* 'anti-government'). Some prefixes in English include: *un-* (undo); *re-* (redo); *dis-* (disagree) and *extra-* (extraterrestrial). Although both languages do not have single-consonant prefix like ***b***-, hearing the options for both ***bn**ife* and ***n**ife* in the test trial could have led them to assume the possibility of ***b***- as a prefix as Japanese and English speakers have the knowledge of the existence of prefix in their languages. There is also the possibility of hearing an illusory vowel between /b/ and /n/ in ***bn****ife* which lead the participants to believe the prefix to be /bɯ/ for Japanese speakers (e.g. Dupoux et al., 1999; Monahan, Takahashi, Nakao, & Idsardi, 2009) and /bə/ for English speakers for instance. Although this cannot be confirmed here as it was not the focal point of the current study, there is a chance that participants heard an illusory vowel between consonant clusters that are illicit in their native language.

The possibility of having learned any sequences of the string and not explicitly words could be relevant for Chapter 3 as well. In both Chapter 2 and 3, the strings were heard for 10 to 18 minutes with only five or six stimulus word each, and participants may have learned overlapped segments as a word (or as other form of unit, if it was the case that they didn't learn 'words'). For example, in a possible string sequence in Chapter 3 Experiment 4 as Figure 4.3, participants could have learned both *mɛzzɛ* and *zɛtɛ* as words. Since the two choices in forced choice task were both actual sequences presented in the string, they both may have sound like a probable choice. Although the syllable-level transitional probability was higher for *mɛz*→*zɛ* than *zɛ*→*tɛ*, the two choices are likely 'words' in the language.

…nɛkkɛmɛzzɛbɛkkɛmɛzzɛtɛzzɛ…

↑ ↑

Figure 4.3: Sample sequence of a *language* string in Chapter 3 Experiment 4.

Regardless, word segmentation experiments have a risk of allowing participants to internalize and respond to a unit that is not necessarily a word. So, there is no guarantee of segmenting definite word edges by the listener. In order to test how listeners segment words from a stream of words, an experimental design like the one used in this dissertation is necessary and the risk mentioned is unavoidable.

Another concern about the methodology is that any cue that is being introduced in the experiment, that is other than the TP, will have to work at least with the syllable-level TP. Generally, word segmentation studies set several stimulus words to test with. Since the segments in the words will always appear as units, the order of those segments is locked and generate syllable-level TP. Unless the investigation focuses on the syllable-level TP, it is impossible to work only with one kind of cue in word segmentation experiment. The cues such as the SSP and geminates were not the only cues introduced in the language strings. Thus, the researcher must also always consider the existence of the TP.

CHAPTER 5 CONCLUSION

5.1 Summary

The main questions raised in this dissertation concerned what type of cue guided word segmentation for Japanese and English speakers. A series of experiments tested the effectiveness of language-independent (the SSP) and language-dependent (geminates) cues, and the results of the two were compared. Geminates, that were introduced as language-dependent cues were effective, while the SSP as language-independent cue was observed not to be useful for Japanese speakers. When contrasted with English speakers, it was revealed that geminates consistently signaled word segmentation for Japanese speakers, while for English speakers, the cue was only useful when the makeup of the *language* was simple enough to accommodate its effectiveness. As with the SSP, it was not observed to be a useful guide for English speakers as well. This leads to the conclusion that language-dependent cues may perhaps be more effective cues to word segmentation than language-independent cues.

In the findings, the presence of geminates in the experience was used by the speakers in segmenting words in a way that their native language segmental phonotactics would not directly support. The Japanese speakers showed that underrepresented /z/ geminates in their native language was learned in the novel languages, in addition to well represented /k/ and /s/ geminates. Yet it may be argued that the preservation of /z/ geminates in segmentation were not exactly the result of learning the underrepresented pattern. Some might argue that, for Japanese speakers, after readily learning /k/ and /s/ geminated words, there was no choice but to acquire the /z/ geminated words that was left in the string using TP. However, the fact that they retained /z/ geminates in both experiments with simple stimuli (Experiment 4) and with complex stimuli (Experiment 5) consistently, unlike English speakers, is a strong evidence to suggest Japanese speakers' learning of such underrepresented /z/ geminates.

5.2 Outstanding questions and future directions

As stated above, it was observed that geminates and not the SSP guided word segmentation for Japanese and English speakers. Like the effectiveness of gemination for English speakers (Chapter 3), the SSP may be useful if the stimuli were made simpler. It would be worthwhile investigating whether the simplicity of the *language* would accommodate the effectiveness of the SSP. Additionally, since the SSP word segmentation study involves consonant cluster that are illicit in participant's native language, they may have heard an illusory vowel between the clusters. The current dissertation did not explicitly examine this possibility; therefore, it might be worthy designing an experiment to see whether this was the case.

Another thing to further explore is to test other possible language-independent cues. The present dissertation assumed the universality of the SSP (Berent, Balaban, Lennertz, & Vaknin-Nusbaum, 2010; Berent et al., 2007) and assigned it as language-independent knowledge, yet its essential nature that it is about syllables and not words, may have greatly affected its role in word segmentation. It would be reasonable to test a different language-independent cue against language-dependent cue to see whether the contrast that was found between the two in this dissertation is still maintained. Furthermore, in this dissertation, the two types of cues were tested separately in different experiments. Instead, designing one experiment to examine their role directly against each other may help understand their differences more clearly. Some cues to test in the future could be prosody. For example the *language-independent* cue could be the *Iambic-Trochaic Law* (ITL) and test that against the language specific prosody as the language dependent cue.

APPENDICIES

APPENDIX A: Ordered list of stimuli in the speech string for Language 1 of Experiment 1 & 2 in Chapter 2.

The "." indicates syllable breaks and "#" marks stimulus word breaks.

Language 1 (Experiment 1 & 2)
bni.fe#kfɑ.mi#dgu.sɑ#vte.ko#lzo.tʃu#kfɑ.mi#dgu.sɑ#vte.ko#lzo.tʃu#bni.fe#dgu.sɑ#lzo.tʃu#vte.
ko#dgu.sɑ#kfɑ.mi#bni.fe#vte.ko#kfɑ.mi#lzo.tʃu#dgu.sɑ#bni.fe#lzo.tʃu#vte.ko#bni.fe#dgu.sɑ#
kfɑ.mi#vte.ko#bni.fe#lzo.tʃu#kfɑ.mi#vte.ko#dgu.sɑ#kfɑ.mi#lzo.tʃu#bni.fe#dgu.sɑ#vte.ko#lzo.
tʃu#dgu.sɑ#bni.fe#vte.ko#kfɑ.mi#bni.fe#lzo.tʃu#vte.ko#kfɑ.mi#bni.fe#dgu.sɑ#lzo.tʃu#vte.ko#
dgu.sɑ#kfɑ.mi#bni.fe#dgu.sɑ#lzo.tʃu#bni.fe#vte.ko#kfɑ.mi#lzo.tʃu#dgu.sɑ#bni.fe#lzo.tʃu#kfɑ.
mi#vte.ko#bni.fe#dgu.sɑ#kfɑ.mi#bni.fe#vte.ko#dgu.sɑ#lzo.tʃu#vte.ko#dgu.sɑ#kfɑ.mi#bni.fe#l
zo.tʃu#vte.ko#kfɑ.mi#dgu.sɑ#vte.ko#lzo.tʃu#vte.ko#bni.fe#kfɑ.mi#dgu.sɑ#vte.ko#lzo.tʃu#kfɑ.
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vte.ko#dgu.sɑ#lzo.tʃu#vte.ko#dgu.sɑ#kfɑ.mi#bni.fe#lzo.tʃu#vte.ko#kfɑ.mi#dgu.sɑ#vte.ko#lzo
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i.fe#dgu.sɑ#kfɑ.mi#vte.ko#bni.fe#lzo.tʃu#kfɑ.mi#vte.ko#dgu.sɑ#kfɑ.mi#lzo.tʃu#bni.fe#dgu.sɑ
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vte.ko#kfa.mi#lzo.tʃu#dgu.sa#bni.fe#lzo.tʃu#vte.ko#bni.fe#dgu.sa#kfa.mi#vte.ko#bni.fe#lzo.t
ʃu#kfa.mi#vte.ko#dgu.sa#kfa.mi#lzo.tʃu#bni.fe#dgu.sa#vte.ko#lzo.tʃu#dgu.sa#bni.fe#vte.ko#
kfa.mi#bni.fe#lzo.tʃu#vte.ko#kfa.mi#bni.fe#dgu.sa#lzo.tʃu#vte.ko#dgu.sa#kfa.mi#bni.fe#dgu.
sa#lzo.tʃu#bni.fe#vte.ko#kfa.mi#lzo.tʃu#dgu.sa#bni.fe#lzo.tʃu#kfa.mi#vte.ko#bni.fe#dgu.sa#
kfa.mi#bni.fe#vte.ko#dgu.sa#lzo.tʃu#vte.ko#dgu.sa#kfa.mi#bni.fe#lzo.tʃu#vte.ko#kfa.mi#dgu
.sa#vte.ko#lzo.tʃu#vte.ko#bni.fe#kfa.mi#dgu.sa#vte.ko#lzo.tʃu#kfa.mi#dgu.sa#vte.ko#lzo.tʃu
#bni.fe#dgu.sa#lzo.tʃu#vte.ko#dgu.sa#kfa.mi#bni.fe#vte.ko#kfa.mi#lzo.tʃu#dgu.sa#bni.fe#lzo
.tʃu#vte.ko#bni.fe#dgu.sa#kfa.mi#vte.ko#bni.fe#lzo.tʃu#kfa.mi#vte.ko#dgu.sa#kfa.mi#lzo.tʃu
#bni.fe#dgu.sa#vte.ko#lzo.tʃu#dgu.sa#bni.fe#vte.ko#kfa.mi#bni.fe#lzo.tʃu#vte.ko#kfa.mi#bni
.fe#dgu.sa#lzo.tʃu#vte.ko#dgu.sa#kfa.mi#bni.fe#dgu.sa#lzo.tʃu#bni.fe#vte.ko#kfa.mi#lzo.tʃu
#dgu.sa#bni.fe#lzo.tʃu#kfa.mi#vte.ko#bni.fe#dgu.sa#kfa.mi#bni.fe#vte.ko#dgu.sa#lzo.tʃu#vte
.ko#dgu.sa#kfa.mi#bni.fe#lzo.tʃu#vte.ko#kfa.mi#dgu.sa#vte.ko#lzo.tʃu#vte.ko#bni.fe#kfa.mi
#dgu.sa#vte.ko#lzo.tʃu#kfa.mi#dgu.sa#vte.ko#lzo.tʃu#bni.fe#dgu.sa#lzo.tʃu#vte.ko#dgu.sa#k
fa.mi#bni.fe#vte.ko#kfa.mi#lzo.tʃu#dgu.sa#bni.fe#lzo.tʃu#vte.ko#bni.fe#dgu.sa#kfa.mi#vte.k
o#bni.fe#lzo.tʃu#kfa.mi#vte.ko#dgu.sa#kfa.mi#lzo.tʃu#bni.fe#dgu.sa#vte.ko#lzo.tʃu#dgu.sa#
bni.fe#vte.ko#kfa.mi#bni.fe#lzo.tʃu#vte.ko#kfa.mi#bni.fe#dgu.sa#lzo.tʃu#vte.ko#dgu.sa#kfa.
mi#bni.fe#dgu.sa#lzo.tʃu#bni.fe#vte.ko#kfa.mi#lzo.tʃu#dgu.sa#bni.fe#lzo.tʃu#kfa.mi#vte.ko#
bni.fe#dgu.sa#kfa.mi#bni.fe#vte.ko#dgu.sa#lzo.tʃu#vte.ko#dgu.sa#kfa.mi#bni.fe#lzo.tʃu#vte.

ko#kfɑ.mi#dgu.sɑ#vte.ko#lzo.tʃu#vte.ko#bni.fe#kfɑ.mi#dgu.sɑ#vte.ko#lzo.tʃu#kfɑ.mi#dgu.sɑ
#vte.ko#lzo.tʃu#bni.fe#dgu.sɑ#lzo.tʃu#vte.ko#dgu.sɑ#kfɑ.mi#bni.fe#vte.ko#kfɑ.mi#lzo.tʃu#dg
u.sɑ#bni.fe#lzo.tʃu#vte.ko#bni.fe#dgu.sɑ#kfɑ.mi#vte.ko#bni.fe#lzo.tʃu#kfɑ.mi#vte.ko#dgu.sɑ
#kfɑ.mi#lzo.tʃu#bni.fe#dgu.sɑ#vte.ko#lzo.tʃu#dgu.sɑ#bni.fe#vte.ko#kfɑ.mi#bni.fe#lzo.tʃu#vte
.ko#kfɑ.mi#bni.fe#dgu.sɑ#lzo.tʃu#vte.ko#dgu.sɑ#kfɑ.mi#bni.fe#dgu.sɑ#lzo.tʃu#bni.fe#vte.ko#
kfɑ.mi#lzo.tʃu#dgu.sɑ#bni.fe#lzo.tʃu#kfɑ.mi#vte.ko#bni.fe#dgu.sɑ#kfɑ.mi#bni.fe#vte.ko#dgu.
sɑ#lzo.tʃu#vte.ko#dgu.sɑ#kfɑ.mi#bni.fe#lzo.tʃu#vte.ko#kfɑ.mi#dgu.sɑ#vte.ko#lzo.tʃu#vte.ko#
bni.fe#kfɑ.mi#dgu.sɑ#vte.ko#lzo.tʃu#kfɑ.mi#dgu.sɑ#vte.ko#lzo.tʃu#bni.fe#dgu.sɑ#lzo.tʃu#vte.
ko#dgu.sɑ#kfɑ.mi#bni.fe#vte.ko#kfɑ.mi#lzo.tʃu#dgu.sɑ#bni.fe#lzo.tʃu#vte.ko#

APPENDIX B: Ordered list of stimuli in the speech string for Language 2 of Experiment 1 & 2 in Chapter 2.

The "." indicates syllable breaks and "#" marks stimulus word breaks.

Language 2 (Experiment 1 & 2)
nbi.fe#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.ko#fkɑ.
mi#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi
#tve.ko#gdu.sɑ#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#gdu.sɑ#nbi.fe#zlo.tʃu#fkɑ.mi#tve.ko#nbi.fe#gd
u.sɑ#zlo.tʃu#tve.ko#zlo.tʃu#nbi.fe#fkɑ.mi#zlo.tʃu#gdu.sɑ#nbi.fe#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.k
o#zlo.tʃu#fkɑ.mi#nbi.fe#tve.ko#gdu.sɑ#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fk
ɑ.mi#tve.ko#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.ko#gdu.sɑ#zlo.tʃu#nbi.fe#tve.k
o#fkɑ.mi#zlo.tʃu#nbi.fe#tve.ko#nbi.fe#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#tv
e.ko#gdu.sɑ#nbi.fe#tve.ko#fkɑ.mi#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.
mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi#tve.ko#gdu.sɑ#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#gdu.sɑ#nbi.fe#
zlo.tʃu#fkɑ.mi#tve.ko#nbi.fe#gdu.sɑ#zlo.tʃu#tve.ko#zlo.tʃu#nbi.fe#fkɑ.mi#zlo.tʃu#gdu.sɑ#nbi.
fe#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#fkɑ.mi#nbi.fe#tve.ko#gdu.sɑ#zlo.tʃu#nbi.fe#gdu.sɑ#
fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi#tve.ko#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.
ko#gdu.sɑ#zlo.tʃu#nbi.fe#tve.ko#fkɑ.mi#zlo.tʃu#nbi.fe#tve.ko#nbi.fe#fkɑ.mi#gdu.sɑ#tve.ko#z
lo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.ko#fkɑ.mi#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.
ko#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi#tve.ko#gdu.sɑ#zlo.tʃu#fkɑ.mi
#nbi.fe#zlo.tʃu#gdu.sɑ#nbi.fe#zlo.tʃu#fkɑ.mi#tve.ko#nbi.fe#gdu.sɑ#zlo.tʃu#tve.ko#zlo.tʃu#nbi
.fe#fkɑ.mi#zlo.tʃu#gdu.sɑ#nbi.fe#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#fkɑ.mi#nbi.fe#tve.ko
#gdu.sɑ#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi#tve.ko#gdu.sɑ#fkɑ.mi#zl
o.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.ko#gdu.sɑ#zlo.tʃu#nbi.fe#tve.ko#fkɑ.mi#zlo.tʃu#nbi.fe#tve.ko
#nbi.fe#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.ko#fkɑ
.mi#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi
#tve.ko#gdu.sɑ#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#gdu.sɑ#nbi.fe#zlo.tʃu#fkɑ.mi#tve.ko#nbi.fe#gd
u.sɑ#zlo.tʃu#tve.ko#zlo.tʃu#nbi.fe#fkɑ.mi#zlo.tʃu#gdu.sɑ#nbi.fe#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.k
o#zlo.tʃu#fkɑ.mi#nbi.fe#tve.ko#gdu.sɑ#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fk
ɑ.mi#tve.ko#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.ko#gdu.sɑ#zlo.tʃu#nbi.fe#tve.k
o#fkɑ.mi#zlo.tʃu#nbi.fe#tve.ko#nbi.fe#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#tv
e.ko#gdu.sɑ#nbi.fe#tve.ko#fkɑ.mi#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.
mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi#tve.ko#gdu.sɑ#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#gdu.sɑ#nbi.fe#
zlo.tʃu#fkɑ.mi#tve.ko#nbi.fe#gdu.sɑ#zlo.tʃu#tve.ko#zlo.tʃu#nbi.fe#fkɑ.mi#zlo.tʃu#gdu.sɑ#nbi.
fe#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#fkɑ.mi#nbi.fe#tve.ko#gdu.sɑ#zlo.tʃu#nbi.fe#gdu.sɑ#
fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi#tve.ko#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.
ko#gdu.sɑ#zlo.tʃu#nbi.fe#tve.ko#fkɑ.mi#zlo.tʃu#nbi.fe#tve.ko#nbi.fe#fkɑ.mi#gdu.sɑ#tve.ko#z
lo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.ko#fkɑ.mi#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.
ko#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi#tve.ko#gdu.sɑ#zlo.tʃu#fkɑ.mi
#nbi.fe#zlo.tʃu#gdu.sɑ#nbi.fe#zlo.tʃu#fkɑ.mi#tve.ko#nbi.fe#gdu.sɑ#zlo.tʃu#tve.ko#zlo.tʃu#nbi
.fe#fkɑ.mi#zlo.tʃu#gdu.sɑ#nbi.fe#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#fkɑ.mi#nbi.fe#tve.ko
#gdu.sɑ#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi#tve.ko#gdu.sɑ#fkɑ.mi#zl
o.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.ko#gdu.sɑ#zlo.tʃu#nbi.fe#tve.ko#fkɑ.mi#zlo.tʃu#nbi.fe#tve.ko
#nbi.fe#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.ko#fkɑ

.mi#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi
#tve.ko#gdu.sɑ#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#gdu.sɑ#nbi.fe#zlo.tʃu#fkɑ.mi#tve.ko#nbi.fe#gd
u.sɑ#zlo.tʃu#tve.ko#zlo.tʃu#nbi.fe#fkɑ.mi#zlo.tʃu#gdu.sɑ#nbi.fe#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.k
o#zlo.tʃu#fkɑ.mi#nbi.fe#tve.ko#gdu.sɑ#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fk
ɑ.mi#tve.ko#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.ko#gdu.sɑ#zlo.tʃu#nbi.fe#tve.k
o#fkɑ.mi#zlo.tʃu#nbi.fe#tve.ko#nbi.fe#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#tv
e.ko#gdu.sɑ#nbi.fe#tve.ko#fkɑ.mi#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.
mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi#tve.ko#gdu.sɑ#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#gdu.sɑ#nbi.fe#
zlo.tʃu#fkɑ.mi#tve.ko#nbi.fe#gdu.sɑ#zlo.tʃu#tve.ko#zlo.tʃu#nbi.fe#fkɑ.mi#zlo.tʃu#gdu.sɑ#nbi.
fe#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#fkɑ.mi#nbi.fe#tve.ko#gdu.sɑ#zlo.tʃu#nbi.fe#gdu.sɑ#
fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi#tve.ko#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.
ko#gdu.sɑ#zlo.tʃu#nbi.fe#tve.ko#fkɑ.mi#zlo.tʃu#nbi.fe#tve.ko#nbi.fe#fkɑ.mi#gdu.sɑ#tve.ko#z
lo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.ko#fkɑ.mi#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.
ko#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi#tve.ko#gdu.sɑ#zlo.tʃu#fkɑ.mi
#nbi.fe#zlo.tʃu#gdu.sɑ#nbi.fe#zlo.tʃu#fkɑ.mi#tve.ko#nbi.fe#gdu.sɑ#zlo.tʃu#tve.ko#zlo.tʃu#nbi
.fe#fkɑ.mi#zlo.tʃu#gdu.sɑ#nbi.fe#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#fkɑ.mi#nbi.fe#tve.ko
#gdu.sɑ#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi#tve.ko#gdu.sɑ#fkɑ.mi#zl
o.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.ko#gdu.sɑ#zlo.tʃu#nbi.fe#tve.ko#fkɑ.mi#zlo.tʃu#nbi.fe#tve.ko
#nbi.fe#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.ko#fkɑ
.mi#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi
#tve.ko#gdu.sɑ#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#gdu.sɑ#nbi.fe#zlo.tʃu#fkɑ.mi#tve.ko#nbi.fe#gd
u.sɑ#zlo.tʃu#tve.ko#zlo.tʃu#nbi.fe#fkɑ.mi#zlo.tʃu#gdu.sɑ#nbi.fe#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.k
o#zlo.tʃu#fkɑ.mi#nbi.fe#tve.ko#gdu.sɑ#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fk
ɑ.mi#tve.ko#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.ko#gdu.sɑ#zlo.tʃu#nbi.fe#tve.k
o#fkɑ.mi#zlo.tʃu#nbi.fe#tve.ko#nbi.fe#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#tv
e.ko#gdu.sɑ#nbi.fe#tve.ko#fkɑ.mi#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.
mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi#tve.ko#gdu.sɑ#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#gdu.sɑ#nbi.fe#
zlo.tʃu#fkɑ.mi#tve.ko#nbi.fe#gdu.sɑ#zlo.tʃu#tve.ko#zlo.tʃu#nbi.fe#fkɑ.mi#zlo.tʃu#gdu.sɑ#nbi.
fe#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#fkɑ.mi#nbi.fe#tve.ko#gdu.sɑ#zlo.tʃu#nbi.fe#gdu.sɑ#
fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi#tve.ko#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.
ko#gdu.sɑ#zlo.tʃu#nbi.fe#tve.ko#fkɑ.mi#zlo.tʃu#nbi.fe#tve.ko#nbi.fe#fkɑ.mi#gdu.sɑ#tve.ko#z
lo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.ko#fkɑ.mi#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.
ko#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi#tve.ko#gdu.sɑ#zlo.tʃu#fkɑ.mi
#nbi.fe#zlo.tʃu#gdu.sɑ#nbi.fe#zlo.tʃu#fkɑ.mi#tve.ko#nbi.fe#gdu.sɑ#zlo.tʃu#tve.ko#zlo.tʃu#nbi
.fe#fkɑ.mi#zlo.tʃu#gdu.sɑ#nbi.fe#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#fkɑ.mi#nbi.fe#tve.ko
#gdu.sɑ#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi#tve.ko#gdu.sɑ#fkɑ.mi#zl
o.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.ko#gdu.sɑ#zlo.tʃu#nbi.fe#tve.ko#fkɑ.mi#zlo.tʃu#nbi.fe#tve.ko
#nbi.fe#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.ko#fkɑ
.mi#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi
#tve.ko#gdu.sɑ#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#gdu.sɑ#nbi.fe#zlo.tʃu#fkɑ.mi#tve.ko#nbi.fe#gd
u.sɑ#zlo.tʃu#tve.ko#zlo.tʃu#nbi.fe#fkɑ.mi#zlo.tʃu#gdu.sɑ#nbi.fe#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.k
o#zlo.tʃu#fkɑ.mi#nbi.fe#tve.ko#gdu.sɑ#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#nbi.fe#fk
ɑ.mi#tve.ko#gdu.sɑ#fkɑ.mi#zlo.tʃu#tve.ko#gdu.sɑ#nbi.fe#tve.ko#gdu.sɑ#zlo.tʃu#nbi.fe#tve.k
o#fkɑ.mi#zlo.tʃu#nbi.fe#tve.ko#nbi.fe#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#tv
e.ko#gdu.sɑ#nbi.fe#tve.ko#fkɑ.mi#zlo.tʃu#fkɑ.mi#gdu.sɑ#tve.ko#zlo.tʃu#nbi.fe#gdu.sɑ#fkɑ.
mi#zlo.tʃu#tve.ko#nbi.fe#fkɑ.mi#tve.ko#gdu.sɑ#zlo.tʃu#fkɑ.mi#nbi.fe#zlo.tʃu#gdu.sɑ#nbi.fe#

zlo.tʃu#fka.mi#tve.ko#nbi.fe#gdu.sa#zlo.tʃu#tve.ko#zlo.tʃu#nbi.fe#fka.mi#zlo.tʃu#gdu.sa#nbi.
fe#zlo.tʃu#fka.mi#gdu.sa#tve.ko#zlo.tʃu#fka.mi#nbi.fe#tve.ko#gdu.sa#zlo.tʃu#nbi.fe#gdu.sa#
fka.mi#zlo.tʃu#tve.ko#nbi.fe#fka.mi#tve.ko#gdu.sa#fka.mi#zlo.tʃu#tve.ko#gdu.sa#nbi.fe#tve.
ko#gdu.sa#zlo.tʃu#nbi.fe#tve.ko#fka.mi#zlo.tʃu#nbi.fe#tve.ko#nbi.fe#fka.mi#gdu.sa#tve.ko#z
lo.tʃu#fka.mi#nbi.fe#zlo.tʃu#tve.ko#gdu.sa#nbi.fe#tve.ko#fka.mi#zlo.tʃu#fka.mi#gdu.sa#tve.
ko#zlo.tʃu#nbi.fe#gdu.sa#fka.mi#zlo.tʃu#tve.ko#nbi.fe#fka.mi#tve.ko#gdu.sa#zlo.tʃu#fka.mi
#nbi.fe#zlo.tʃu#gdu.sa#nbi.fe#zlo.tʃu#fka.mi#tve.ko#nbi.fe#gdu.sa#zlo.tʃu#tve.ko#zlo.tʃu#nbi
.fe#fka.mi#zlo.tʃu#gdu.sa#nbi.fe#zlo.tʃu#fka.mi#gdu.sa#tve.ko#zlo.tʃu#fka.mi#nbi.fe#tve.ko
#gdu.sa#zlo.tʃu#nbi.fe#gdu.sa#fka.mi#zlo.tʃu#tve.ko#nbi.fe#fka.mi#tve.ko#gdu.sa#fka.mi#zl
o.tʃu#tve.ko#gdu.sa#nbi.fe#tve.ko#gdu.sa#zlo.tʃu#nbi.fe#tve.ko#fka.mi#zlo.tʃu#nbi.fe#tve.ko
#gdu.sa#fka.mi#tve.ko#zlo.tʃu#nbi.fe#

APPENDIX C: Ordered list of stimuli in the speech string for Language 1 of Experiment 4 in Chapter 3.

The “.” indicates syllable breaks and “#” marks stimulus word breaks.

Language 1 (Experiment 4)
bɛk.kɛ#tɛz.zɛ#dɛs.sɛ#tɛz.zɛ#pɛs.sɛ#tɛz.zɛ#nɛk.kɛ#dɛs.sɛ#pɛs.sɛ#mɛz.zɛ#nɛk.kɛ#dɛs.sɛ#pɛs.sɛ#
mɛz.zɛ#dɛs.sɛ#tɛz.zɛ#nɛk.kɛ#mɛz.zɛ#pɛs.sɛ#nɛk.kɛ#tɛz.zɛ#bɛk.kɛ#nɛk.kɛ#tɛz.zɛ#mɛz.zɛ#nɛk.
kɛ#mɛz.zɛ#nɛk.kɛ#mɛz.zɛ#bɛk.kɛ#mɛz.zɛ#dɛs.sɛ#pɛs.sɛ#bɛk.kɛ#mɛz.zɛ#bɛk.kɛ#dɛs.sɛ#bɛk.kɛ
#nɛk.kɛ#mɛz.zɛ#dɛs.sɛ#bɛk.kɛ#mɛz.zɛ#nɛk.kɛ#mɛz.zɛ#nɛk.kɛ#mɛz.zɛ#tɛz.zɛ#nɛk.kɛ#mɛz.zɛ#
nɛk.kɛ#dɛs.sɛ#mɛz.zɛ#tɛz.zɛ#dɛs.sɛ#mɛz.zɛ#tɛz.zɛ#bɛk.kɛ#nɛk.kɛ#dɛs.sɛ#mɛz.zɛ#dɛs.sɛ#pɛs.s
ɛ#nɛk.kɛ#tɛz.zɛ#pɛs.sɛ#bɛk.kɛ#dɛs.sɛ#bɛk.kɛ#nɛk.kɛ#tɛz.zɛ#pɛs.sɛ#tɛz.zɛ#mɛz.zɛ#tɛz.zɛ#pɛs.
sɛ#nɛk.kɛ#bɛk.kɛ#nɛk.kɛ#mɛz.zɛ#bɛk.kɛ#dɛs.sɛ#pɛs.sɛ#nɛk.kɛ#pɛs.sɛ#tɛz.zɛ#dɛs.sɛ#bɛk.kɛ#p
ɛs.sɛ#mɛz.zɛ#tɛz.zɛ#dɛs.sɛ#pɛs.sɛ#tɛz.zɛ#pɛs.sɛ#mɛz.zɛ#bɛk.kɛ#pɛs.sɛ#bɛk.kɛ#mɛz.zɛ#pɛs.sɛ
#tɛz.zɛ#dɛs.sɛ#pɛs.sɛ#bɛk.kɛ#mɛz.zɛ#nɛk.kɛ#pɛs.sɛ#dɛs.sɛ#pɛs.sɛ#mɛz.zɛ#bɛk.kɛ#pɛs.sɛ#tɛz.z
ɛ#pɛs.sɛ#nɛk.kɛ#bɛk.kɛ#pɛs.sɛ#mɛz.zɛ#pɛs.sɛ#dɛs.sɛ#nɛk.kɛ#pɛs.sɛ#dɛs.sɛ#bɛk.kɛ#mɛz.zɛ#bɛ
k.kɛ#pɛs.sɛ#dɛs.sɛ#mɛz.zɛ#tɛz.zɛ#pɛs.sɛ#tɛz.zɛ#nɛk.kɛ#dɛs.sɛ#tɛz.zɛ#pɛs.sɛ#mɛz.zɛ#bɛk.kɛ#d
ɛs.sɛ#mɛz.zɛ#tɛz.zɛ#dɛs.sɛ#pɛs.sɛ#tɛz.zɛ#pɛs.sɛ#mɛz.zɛ#nɛk.kɛ#bɛk.kɛ#dɛs.sɛ#mɛz.zɛ#bɛk.kɛ
#tɛz.zɛ#bɛk.kɛ#nɛk.kɛ#tɛz.zɛ#mɛz.zɛ#pɛs.sɛ#tɛz.zɛ#pɛs.sɛ#dɛs.sɛ#nɛk.kɛ#mɛz.zɛ#dɛs.sɛ#mɛz.
zɛ#pɛs.sɛ#dɛs.sɛ#bɛk.kɛ#dɛs.sɛ#mɛz.zɛ#tɛz.zɛ#pɛs.sɛ#dɛs.sɛ#tɛz.zɛ#nɛk.kɛ#dɛs.sɛ#pɛs.sɛ#tɛz.
zɛ#pɛs.sɛ#nɛk.kɛ#bɛk.kɛ#mɛz.zɛ#nɛk.kɛ#pɛs.sɛ#nɛk.kɛ#mɛz.zɛ#bɛk.kɛ#tɛz.zɛ#dɛs.sɛ#pɛs.sɛ#b
ɛk.kɛ#dɛs.sɛ#bɛk.kɛ#tɛz.zɛ#mɛz.zɛ#tɛz.zɛ#pɛs.sɛ#tɛz.zɛ#mɛz.zɛ#nɛk.kɛ#dɛs.sɛ#bɛk.kɛ#mɛz.zɛ
#tɛz.zɛ#mɛz.zɛ#dɛs.sɛ#nɛk.kɛ#bɛk.kɛ#pɛs.sɛ#bɛk.kɛ#nɛk.kɛ#dɛs.sɛ#pɛs.sɛ#dɛs.sɛ#mɛz.zɛ#bɛk
.kɛ#mɛz.zɛ#dɛs.sɛ#mɛz.zɛ#tɛz.zɛ#dɛs.sɛ#tɛz.zɛ#mɛz.zɛ#dɛs.sɛ#tɛz.zɛ#pɛs.sɛ#mɛz.zɛ#dɛs.sɛ#m
ɛz.zɛ#pɛs.sɛ#nɛk.kɛ#dɛs.sɛ#mɛz.zɛ#pɛs.sɛ#nɛk.kɛ#bɛk.kɛ#mɛz.zɛ#pɛs.sɛ#tɛz.zɛ#dɛs.sɛ#mɛz.z
ɛ#dɛs.sɛ#mɛz.zɛ#dɛs.sɛ#pɛs.sɛ#tɛz.zɛ#mɛz.zɛ#bɛk.kɛ#nɛk.kɛ#tɛz.zɛ#bɛk.kɛ#tɛz.zɛ#dɛs.sɛ#bɛk
.kɛ#nɛk.kɛ#dɛs.sɛ#nɛk.kɛ#dɛs.sɛ#tɛz.zɛ#dɛs.sɛ#nɛk.kɛ#pɛs.sɛ#nɛk.kɛ#pɛs.sɛ#dɛs.sɛ#bɛk.kɛ#tɛ
z.zɛ#bɛk.kɛ#mɛz.zɛ#bɛk.kɛ#nɛk.kɛ#mɛz.zɛ#tɛz.zɛ#pɛs.sɛ#dɛs.sɛ#tɛz.zɛ#nɛk.kɛ#mɛz.zɛ#pɛs.sɛ
#tɛz.zɛ#mɛz.zɛ#nɛk.kɛ#pɛs.sɛ#bɛk.kɛ#dɛs.sɛ#tɛz.zɛ#bɛk.kɛ#mɛz.zɛ#bɛk.kɛ#dɛs.sɛ#pɛs.sɛ#tɛz.
zɛ#bɛk.kɛ#mɛz.zɛ#tɛz.zɛ#nɛk.kɛ#mɛz.zɛ#pɛs.sɛ#mɛz.zɛ#tɛz.zɛ#nɛk.kɛ#tɛz.zɛ#dɛs.sɛ#bɛk.kɛ#d
ɛs.sɛ#nɛk.kɛ#dɛs.sɛ#tɛz.zɛ#nɛk.kɛ#bɛk.kɛ#tɛz.zɛ#nɛk.kɛ#tɛz.zɛ#dɛs.sɛ#tɛz.zɛ#dɛs.sɛ#bɛk.kɛ#d
ɛs.sɛ#bɛk.kɛ#mɛz.zɛ#nɛk.kɛ#tɛz.zɛ#bɛk.kɛ#tɛz.zɛ#nɛk.kɛ#bɛk.kɛ#tɛz.zɛ#mɛz.zɛ#nɛk.kɛ#bɛk.k
ɛ#pɛs.sɛ#tɛz.zɛ#mɛz.zɛ#pɛs.sɛ#mɛz.zɛ#bɛk.kɛ#nɛk.kɛ#pɛs.sɛ#dɛs.sɛ#nɛk.kɛ#bɛk.kɛ#tɛz.zɛ#dɛs
.sɛ#tɛz.zɛ#nɛk.kɛ#bɛk.kɛ#tɛz.zɛ#dɛs.sɛ#nɛk.kɛ#tɛz.zɛ#nɛk.kɛ#tɛz.zɛ#dɛs.sɛ#mɛz.zɛ#tɛz.zɛ#nɛ
k.kɛ#dɛs.sɛ#mɛz.zɛ#bɛk.kɛ#pɛs.sɛ#nɛk.kɛ#bɛk.kɛ#dɛs.sɛ#tɛz.zɛ#dɛs.sɛ#pɛs.sɛ#mɛz.zɛ#pɛs.sɛ#
dɛs.sɛ#pɛs.sɛ#bɛk.kɛ#tɛz.zɛ#dɛs.sɛ#pɛs.sɛ#nɛk.kɛ#tɛz.zɛ#dɛs.sɛ#mɛz.zɛ#nɛk.kɛ#dɛs.sɛ#bɛk.kɛ
#mɛz.zɛ#tɛz.zɛ#pɛs.sɛ#tɛz.zɛ#pɛs.sɛ#bɛk.kɛ#tɛz.zɛ#pɛs.sɛ#tɛz.zɛ#mɛz.zɛ#tɛz.zɛ#dɛs.sɛ#bɛk.kɛ
#nɛk.kɛ#mɛz.zɛ#bɛk.kɛ#nɛk.kɛ#bɛk.kɛ#nɛk.kɛ#mɛz.zɛ#pɛs.sɛ#nɛk.kɛ#mɛz.zɛ#nɛk.kɛ#pɛs.sɛ#t
ɛz.zɛ#nɛk.kɛ#bɛk.kɛ#mɛz.zɛ#tɛz.zɛ#mɛz.zɛ#pɛs.sɛ#dɛs.sɛ#tɛz.zɛ#pɛs.sɛ#mɛz.zɛ#bɛk.kɛ#dɛs.sɛ
#pɛs.sɛ#bɛk.kɛ#nɛk.kɛ#bɛk.kɛ#tɛz.zɛ#nɛk.kɛ#dɛs.sɛ#mɛz.zɛ#pɛs.sɛ#dɛs.sɛ#bɛk.kɛ#pɛs.sɛ#nɛk.
kɛ#mɛz.zɛ#dɛs.sɛ#nɛk.kɛ#tɛz.zɛ#nɛk.kɛ#tɛz.zɛ#dɛs.sɛ#tɛz.zɛ#nɛk.kɛ#tɛz.zɛ#bɛk.kɛ#dɛs.sɛ#bɛk
.kɛ#pɛs.sɛ#tɛz.zɛ#bɛk.kɛ#nɛk.kɛ#pɛs.sɛ#nɛk.kɛ#dɛs.sɛ#nɛk.kɛ#bɛk.kɛ#pɛs.sɛ#nɛk.kɛ#bɛk.kɛ#n
ɛk.kɛ#mɛz.zɛ#dɛs.sɛ#mɛz.zɛ#pɛs.sɛ#bɛk.kɛ#mɛz.zɛ#dɛs.sɛ#tɛz.zɛ#bɛk.kɛ#tɛz.zɛ#bɛk.kɛ#mɛz.z
ɛ#bɛk.kɛ#pɛs.sɛ#dɛs.sɛ#bɛk.kɛ#nɛk.kɛ#mɛz.zɛ#nɛk.kɛ#dɛs.sɛ#bɛk.kɛ#nɛk.kɛ#pɛs.sɛ#dɛs.sɛ#m
ɛz.zɛ#dɛs.sɛ#bɛk.kɛ#pɛs.sɛ#tɛz.zɛ#mɛz.zɛ#tɛz.zɛ#mɛz.zɛ#tɛz.zɛ#mɛz.zɛ#bɛk.kɛ#dɛs.sɛ#nɛk.kɛ

#bεk.kε#dεs.sε#pεs.sε#mεz.zε#tεz.zε#dεs.sε#tεz.zε#dεs.sε#nεk.kε#mεz.zε#dεs.sε#bεk.kε#mεz.
zε#bεk.kε#mεz.zε#tεz.zε#dεs.sε#mεz.zε#dεs.sε#mεz.zε#dεs.sε#pεs.sε#dεs.sε#tεz.zε#mεz.zε#p
εs.sε#nεk.kε#tεz.zε#mεz.zε#dεs.sε#bεk.kε#tεz.zε#pεs.sε#bεk.kε#nεk.kε#bεk.kε#dεs.sε#pεs.sε#
nεk.kε#bεk.kε#mεz.zε#nεk.kε#pεs.sε#tεz.zε#nεk.kε#dεs.sε#mεz.zε#tεz.zε#pεs.sε#mεz.zε#pεs.
sε#bεk.kε#nεk.kε#mεz.zε#tεz.zε#nεk.kε#bεk.kε#mεz.zε#pεs.sε#nεk.kε#bεk.kε#dεs.sε#nεk.kε#
tεz.zε#dεs.sε#mεz.zε#tεz.zε#nεk.kε#mεz.zε#pεs.sε#dεs.sε#tεz.zε#mεz.zε#tεz.zε#mεz.zε#nεk.k
ε#bεk.kε#dεs.sε#nεk.kε#pεs.sε#dεs.sε#pεs.sε#mεz.zε#pεs.sε#dεs.sε#tεz.zε#nεk.kε#dεs.sε#pεs.
sε#tεz.zε#nεk.kε#bεk.kε#dεs.sε#bεk.kε#mεz.zε#dεs.sε#nεk.kε#pεs.sε#mεz.zε#tεz.zε#nεk.kε#tε
z.zε#bεk.kε#nεk.kε#pεs.sε#nεk.kε#bεk.kε#mεz.zε#bεk.kε#tεz.zε#dεs.sε#bεk.kε#mεz.zε#pεs.sε
#tεz.zε#pεs.sε#tεz.zε#pεs.sε#nεk.kε#dεs.sε#bεk.kε#dεs.sε#pεs.sε#mεz.zε#bεk.kε#pεs.sε#nεk.k
ε#mεz.zε#bεk.kε#tεz.zε#dεs.sε#tεz.zε#pεs.sε#tεz.zε#nεk.kε#dεs.sε#pεs.sε#mεz.zε#nεk.kε#dεs.
sε#pεs.sε#mεz.zε#dεs.sε#tεz.zε#nεk.kε#mεz.zε#pεs.sε#nεk.kε#tεz.zε#bεk.kε#nεk.kε#tεz.zε#m
εz.zε#nεk.kε#mεz.zε#nεk.kε#mεz.zε#bεk.kε#mεz.zε#dεs.sε#pεs.sε#bεk.kε#mεz.zε#bεk.kε#dεs
.sε#bεk.kε#nεk.kε#mεz.zε#dεs.sε#bεk.kε#mεz.zε#nεk.kε#mεz.zε#nεk.kε#mεz.zε#tεz.zε#nεk.k
ε#mεz.zε#nεk.kε#dεs.sε#mεz.zε#tεz.zε#dεs.sε#mεz.zε#tεz.zε#bεk.kε#nεk.kε#dεs.sε#mεz.zε#d
εs.sε#pεs.sε#nεk.kε#tεz.zε#pεs.sε#bεk.kε#dεs.sε#bεk.kε#nεk.kε#tεz.zε#pεs.sε#tεz.zε#mεz.zε#t
εz.zε#pεs.sε#nεk.kε#bεk.kε#nεk.kε#mεz.zε#bεk.kε#dεs.sε#pεs.sε#nεk.kε#pεs.sε#tεz.zε#dεs.sε
#bεk.kε#pεs.sε#mεz.zε#tεz.zε#dεs.sε#pεs.sε#tεz.zε#pεs.sε#mεz.zε#bεk.kε#pεs.sε#bεk.kε#mεz.
zε#pεs.sε#tεz.zε#dεs.sε#pεs.sε#bεk.kε#mεz.zε#nεk.kε#pεs.sε#dεs.sε#pεs.sε#mεz.zε#bεk.kε#pε
s.sε#tεz.zε#pεs.sε#nεk.kε#bεk.kε#pεs.sε#mεz.zε#pεs.sε#dεs.sε#nεk.kε#pεs.sε#dεs.sε#bεk.kε#
mεz.zε#bεk.kε#pεs.sε#dεs.sε#mεz.zε#tεz.zε#pεs.sε#tεz.zε#nεk.kε#dεs.sε#tεz.zε#pεs.sε#mεz.zε
#bεk.kε#dεs.sε#mεz.zε#tεz.zε#dεs.sε#pεs.sε#tεz.zε#pεs.sε#mεz.zε#nεk.kε#bεk.kε#dεs.sε#mεz.
zε#bεk.kε#tεz.zε#bεk.kε#nεk.kε#tεz.zε#mεz.zε#pεs.sε#tεz.zε#pεs.sε#dεs.sε#nεk.kε#mεz.zε#dε
s.sε#mεz.zε#pεs.sε#dεs.sε#bεk.kε#dεs.sε#mεz.zε#tεz.zε#pεs.sε#dεs.sε#tεz.zε#nεk.kε#dεs.sε#p
εs.sε#tεz.zε#pεs.sε#nεk.kε#bεk.kε#mεz.zε#nεk.kε#pεs.sε#nεk.kε#mεz.zε#bεk.kε#tεz.zε#dεs.sε
#pεs.sε#bεk.kε#dεs.sε#bεk.kε#tεz.zε#mεz.zε#tεz.zε#pεs.sε#tεz.zε#mεz.zε#nεk.kε#dεs.sε#bεk.
kε#mεz.zε#tεz.zε#mεz.zε#dεs.sε#nεk.kε#bεk.kε#pεs.sε#bεk.kε#nεk.kε#dεs.sε#pεs.sε#dεs.sε#
mεz.zε#bεk.kε#mεz.zε#dεs.sε#mεz.zε#tεz.zε#dεs.sε#tεz.zε#mεz.zε#dεs.sε#tεz.zε#pεs.sε#mεz.
zε#dεs.sε#mεz.zε#pεs.sε#nεk.kε#dεs.sε#mεz.zε#pεs.sε#nεk.kε#bεk.kε#mεz.zε#pεs.sε#tεz.zε#d
εs.sε#mεz.zε#dεs.sε#mεz.zε#dεs.sε#pεs.sε#tεz.zε#mεz.zε#bεk.kε#nεk.kε#tεz.zε#bεk.kε#tεz.zε
#dεs.sε#bεk.kε#nεk.kε#dεs.sε#nεk.kε#dεs.sε#tεz.zε#dεs.sε#nεk.kε#pεs.sε#nεk.kε#pεs.sε#dεs.s
ε#bεk.kε#tεz.zε#bεk.kε#mεz.zε#bεk.kε#nεk.kε#mεz.zε#tεz.zε#pεs.sε#dεs.sε#tεz.zε#nεk.kε#mε
z.zε#pεs.sε#tεz.zε#mεz.zε#nεk.kε#pεs.sε#bεk.kε#dεs.sε#tεz.zε#bεk.kε#mεz.zε#bεk.kε#dεs.sε#
pεs.sε#tεz.zε#bεk.kε#mεz.zε#tεz.zε#nεk.kε#mεz.zε#pεs.sε#mεz.zε#tεz.zε#nεk.kε#tεz.zε#dεs.s
ε#bεk.kε#dεs.sε#nεk.kε#dεs.sε#tεz.zε#nεk.kε#bεk.kε#tεz.zε#nεk.kε#tεz.zε#dεs.sε#tεz.zε#dεs.s
ε#bεk.kε#dεs.sε#bεk.kε#mεz.zε#nεk.kε#tεz.zε#bεk.kε#tεz.zε#nεk.kε#bεk.kε#tεz.zε#mεz.zε#nε
k.kε#bεk.kε#pεs.sε#tεz.zε#mεz.zε#pεs.sε#mεz.zε#bεk.kε#nεk.kε#pεs.sε#dεs.sε#nεk.kε#bεk.kε
#tεz.zε#dεs.sε#tεz.zε#nεk.kε#bεk.kε#tεz.zε#dεs.sε#nεk.kε#tεz.zε#nεk.kε#tεz.zε#dεs.sε#mεz.zε
#tεz.zε#nεk.kε#dεs.sε#mεz.zε#bεk.kε#pεs.sε#nεk.kε#bεk.kε#dεs.sε#tεz.zε#dεs.sε#pεs.sε#mεz.
zε#pεs.sε#dεs.sε#pεs.sε#bεk.kε#tεz.zε#dεs.sε#pεs.sε#nεk.kε#tεz.zε#dεs.sε#mεz.zε#nεk.kε#dεs
.sε#bεk.kε#mεz.zε#tεz.zε#pεs.sε#tεz.zε#pεs.sε#bεk.kε#tεz.zε#pεs.sε#tεz.zε#mεz.zε#tεz.zε#dεs
.sε#bεk.kε#nεk.kε#mεz.zε#bεk.kε#nεk.kε#bεk.kε#nεk.kε#mεz.zε#pεs.sε#nεk.kε#mεz.zε#nεk.k
ε#pεs.sε#tεz.zε#nεk.kε#bεk.kε#mεz.zε#tεz.zε#mεz.zε#pεs.sε#dεs.sε#tεz.zε#pεs.sε#mεz.zε#bεk
.kε#dεs.sε#pεs.sε#bεk.kε#nεk.kε#bεk.kε#tεz.zε#nεk.kε#dεs.sε#mεz.zε#pεs.sε#dεs.sε#bεk.kε#p
εs.sε#nεk.kε#mεz.zε#dεs.sε#nεk.kε#tεz.zε#nεk.kε#tεz.zε#dεs.sε#tεz.zε#nεk.kε#tεz.zε#bεk.kε#
dεs.sε#bεk.kε#pεs.sε#tεz.zε#bεk.kε#nεk.kε#pεs.sε#nεk.kε#dεs.sε#nεk.kε#bεk.kε#pεs.sε#nεk.k

ε#bεk.kε#nεk.kε#mεz.zε#dεs.sε#mεz.zε#pεs.sε#bεk.kε#mεz.zε#dεs.sε#tεz.zε#bεk.kε#tεz.zε#bε
k.kε#mεz.zε#bεk.kε#pεs.sε#dεs.sε#bεk.kε#nεk.kε#mεz.zε#nεk.kε#dεs.sε#bεk.kε#nεk.kε#pεs.s
ε#dεs.sε#mεz.zε#dεs.sε#bεk.kε#pεs.sε#tεz.zε#mεz.zε#tεz.zε#mεz.zε#tεz.zε#mεz.zε#bεk.kε#dε
s.sε#nεk.kε#bεk.kε#dεs.sε#pεs.sε#mεz.zε#tεz.zε#dεs.sε#tεz.zε#dεs.sε#nεk.kε#mεz.zε#dεs.sε#b
εk.kε#mεz.zε#bεk.kε#mεz.zε#tεz.zε#dεs.sε#mεz.zε#dεs.sε#mεz.zε#dεs.sε#pεs.sε#dεs.sε#tεz.zε
#mεz.zε#pεs.sε#nεk.kε#tεz.zε#mεz.zε#dεs.sε#bεk.kε#tεz.zε#pεs.sε#bεk.kε#nεk.kε#bεk.kε#dεs
.sε#pεs.sε#nεk.kε#bεk.kε#mεz.zε#nεk.kε#pεs.sε#tεz.zε#nεk.kε#dεs.sε#mεz.zε#tεz.zε#pεs.sε#
mεz.zε#pεs.sε#bεk.kε#nεk.kε#mεz.zε#tεz.zε#nεk.kε#bεk.kε#mεz.zε#pεs.sε#nεk.kε#bεk.kε#dε
s.sε#nεk.kε#tεz.zε#dεs.sε#mεz.zε#tεz.zε#nεk.kε#mεz.zε#pεs.sε#dεs.sε#tεz.zε#mεz.zε#tεz.zε#
mεz.zε#nεk.kε#bεk.kε#dεs.sε#nεk.kε#pεs.sε#dεs.sε#pεs.sε#mεz.zε#pεs.sε#dεs.sε#tεz.zε#nεk.k
ε#dεs.sε#pεs.sε#tεz.zε#nεk.kε#bεk.kε#dεs.sε#bεk.kε#mεz.zε#dεs.sε#nεk.kε#pεs.sε#mεz.zε#tεz
.zε#nεk.kε#tεz.zε#bεk.kε#nεk.kε#pεs.sε#nεk.kε#bεk.kε#mεz.zε#bεk.kε#tεz.zε#dεs.sε#bεk.kε#
mεz.zε#pεs.sε#tεz.zε#pεs.sε#tεz.zε#pεs.sε#nεk.kε#dεs.sε#bεk.kε#dεs.sε#pεs.sε#mεz.zε#bεk.kε
#pεs.sε#nεk.kε#mεz.zε#

APPENDIX D: Ordered list of stimuli in the speech string for Language 2 of Experiment 4 in Chapter 3.

The "." indicates syllable breaks and "#" marks stimulus word breaks.

Language 2 (Experiment 4)
pʌz.zʌ#nʌz.zʌ#bʌs.sʌ#nʌz.zʌ#tʌs.sʌ#nʌz.zʌ#bʌs.sʌ#mʌk.kʌ#dʌk.kʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#
pʌz.zʌ#mʌk.kʌ#tʌs.sʌ#dʌk.kʌ#mʌk.kʌ#bʌs.sʌ#dʌk.kʌ#mʌk.kʌ#tʌs.sʌ#bʌs.sʌ#tʌs.sʌ#dʌk.kʌ#
bʌs.sʌ#tʌs.sʌ#mʌk.kʌ#nʌz.zʌ#bʌs.sʌ#pʌz.zʌ#tʌs.sʌ#pʌz.zʌ#nʌz.zʌ#mʌk.kʌ#nʌz.zʌ#pʌz.zʌ#b
ʌs.sʌ#pʌz.zʌ#dʌk.kʌ#tʌs.sʌ#dʌk.kʌ#tʌs.sʌ#dʌk.kʌ#pʌz.zʌ#nʌz.zʌ#dʌk.kʌ#nʌz.zʌ#bʌs.sʌ#nʌ
z.zʌ#mʌk.kʌ#tʌs.sʌ#dʌk.kʌ#tʌs.sʌ#nʌz.zʌ#pʌz.zʌ#tʌs.sʌ#nʌz.zʌ#pʌz.zʌ#nʌz.zʌ#bʌs.sʌ#mʌk.
kʌ#nʌz.zʌ#mʌk.kʌ#bʌs.sʌ#mʌk.kʌ#pʌz.zʌ#nʌz.zʌ#mʌk.kʌ#dʌk.kʌ#pʌz.zʌ#tʌs.sʌ#mʌk.kʌ#n
ʌz.zʌ#bʌs.sʌ#tʌs.sʌ#mʌk.kʌ#pʌz.zʌ#mʌk.kʌ#dʌk.kʌ#bʌs.sʌ#pʌz.zʌ#dʌk.kʌ#tʌs.sʌ#bʌs.sʌ#m
ʌk.kʌ#dʌk.kʌ#pʌz.zʌ#dʌk.kʌ#mʌk.kʌ#bʌs.sʌ#dʌk.kʌ#bʌs.sʌ#pʌz.zʌ#bʌs.sʌ#dʌk.kʌ#pʌz.zʌ#
mʌk.kʌ#bʌs.sʌ#tʌs.sʌ#mʌk.kʌ#bʌs.sʌ#tʌs.sʌ#bʌs.sʌ#pʌz.zʌ#nʌz.zʌ#bʌs.sʌ#pʌz.zʌ#nʌz.zʌ#p
ʌz.zʌ#dʌk.kʌ#bʌs.sʌ#dʌk.kʌ#nʌz.zʌ#bʌs.sʌ#mʌk.kʌ#tʌs.sʌ#pʌz.zʌ#mʌk.kʌ#nʌz.zʌ#dʌk.kʌ#
nʌz.zʌ#mʌk.kʌ#pʌz.zʌ#mʌk.kʌ#dʌk.kʌ#tʌs.sʌ#bʌs.sʌ#mʌk.kʌ#nʌz.zʌ#mʌk.kʌ#bʌs.sʌ#nʌz.z
ʌ#tʌs.sʌ#mʌk.kʌ#bʌs.sʌ#tʌs.sʌ#mʌk.kʌ#nʌz.zʌ#pʌz.zʌ#mʌk.kʌ#tʌs.sʌ#dʌk.kʌ#pʌz.zʌ#bʌs.s
ʌ#tʌs.sʌ#bʌs.sʌ#dʌk.kʌ#tʌs.sʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#pʌz.zʌ#tʌs.sʌ#nʌz.zʌ#mʌk.kʌ#dʌk.kʌ
#mʌk.kʌ#dʌk.kʌ#tʌs.sʌ#pʌz.zʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#dʌk.kʌ#pʌz.zʌ#tʌs.sʌ#nʌz.zʌ#pʌz.zʌ
#bʌs.sʌ#pʌz.zʌ#mʌk.kʌ#dʌk.kʌ#pʌz.zʌ#bʌs.sʌ#pʌz.zʌ#tʌs.sʌ#mʌk.kʌ#pʌz.zʌ#dʌk.kʌ#mʌk.k
ʌ#dʌk.kʌ#tʌs.sʌ#mʌk.kʌ#pʌz.zʌ#dʌk.kʌ#bʌs.sʌ#tʌs.sʌ#bʌs.sʌ#pʌz.zʌ#bʌs.sʌ#mʌk.kʌ#nʌz.z
ʌ#bʌs.sʌ#mʌk.kʌ#pʌz.zʌ#nʌz.zʌ#dʌk.kʌ#pʌz.zʌ#dʌk.kʌ#tʌs.sʌ#mʌk.kʌ#dʌk.kʌ#tʌs.sʌ#dʌk.
kʌ#bʌs.sʌ#pʌz.zʌ#dʌk.kʌ#nʌz.zʌ#pʌz.zʌ#mʌk.kʌ#pʌz.zʌ#tʌs.sʌ#bʌs.sʌ#nʌz.zʌ#tʌs.sʌ#nʌz.z
ʌ#tʌs.sʌ#pʌz.zʌ#nʌz.zʌ#mʌk.kʌ#bʌs.sʌ#dʌk.kʌ#bʌs.sʌ#mʌk.kʌ#bʌs.sʌ#pʌz.zʌ#nʌz.zʌ#bʌs.s
ʌ#mʌk.kʌ#pʌz.zʌ#mʌk.kʌ#pʌz.zʌ#bʌs.sʌ#pʌz.zʌ#bʌs.sʌ#mʌk.kʌ#bʌs.sʌ#tʌs.sʌ#pʌz.zʌ#nʌz.
zʌ#pʌz.zʌ#dʌk.kʌ#tʌs.sʌ#nʌz.zʌ#mʌk.kʌ#bʌs.sʌ#tʌs.sʌ#nʌz.zʌ#mʌk.kʌ#dʌk.kʌ#bʌs.sʌ#nʌz.
zʌ#bʌs.sʌ#dʌk.kʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#pʌz.zʌ#tʌs.sʌ#pʌz.zʌ#nʌz.zʌ#tʌs.sʌ#pʌz.zʌ#mʌk.k
ʌ#tʌs.sʌ#pʌz.zʌ#tʌs.sʌ#pʌz.zʌ#tʌs.sʌ#nʌz.zʌ#mʌk.kʌ#dʌk.kʌ#pʌz.zʌ#bʌs.sʌ#mʌk.kʌ#nʌz.zʌ
#pʌz.zʌ#tʌs.sʌ#dʌk.kʌ#nʌz.zʌ#dʌk.kʌ#pʌz.zʌ#bʌs.sʌ#tʌs.sʌ#pʌz.zʌ#dʌk.kʌ#tʌs.sʌ#pʌz.zʌ#n
ʌz.zʌ#bʌs.sʌ#mʌk.kʌ#dʌk.kʌ#bʌs.sʌ#mʌk.kʌ#dʌk.kʌ#bʌs.sʌ#pʌz.zʌ#mʌk.kʌ#tʌs.sʌ#nʌz.zʌ#
dʌk.kʌ#nʌz.zʌ#bʌs.sʌ#pʌz.zʌ#dʌk.kʌ#nʌz.zʌ#bʌs.sʌ#mʌk.kʌ#dʌk.kʌ#tʌs.sʌ#nʌz.zʌ#tʌs.sʌ#d
ʌk.kʌ#pʌz.zʌ#nʌz.zʌ#mʌk.kʌ#pʌz.zʌ#dʌk.kʌ#pʌz.zʌ#tʌs.sʌ#mʌk.kʌ#nʌz.zʌ#tʌs.sʌ#mʌk.kʌ#
pʌz.zʌ#nʌz.zʌ#mʌk.kʌ#pʌz.zʌ#tʌs.sʌ#mʌk.kʌ#tʌs.sʌ#nʌz.zʌ#tʌs.sʌ#dʌk.kʌ#nʌz.zʌ#bʌs.sʌ#n
ʌz.zʌ#bʌs.sʌ#mʌk.kʌ#bʌs.sʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#dʌk.kʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#dʌk.kʌ#
nʌz.zʌ#pʌz.zʌ#bʌs.sʌ#pʌz.zʌ#mʌk.kʌ#tʌs.sʌ#dʌk.kʌ#tʌs.sʌ#pʌz.zʌ#nʌz.zʌ#tʌs.sʌ#bʌs.sʌ#dʌ
k.kʌ#bʌs.sʌ#tʌs.sʌ#bʌs.sʌ#pʌz.zʌ#tʌs.sʌ#nʌz.zʌ#pʌz.zʌ#tʌs.sʌ#mʌk.kʌ#dʌk.kʌ#nʌz.zʌ#mʌk.
kʌ#tʌs.sʌ#pʌz.zʌ#bʌs.sʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#mʌk.kʌ#tʌs.sʌ#bʌs.sʌ#tʌs.sʌ#mʌk.kʌ#nʌz.z
ʌ#dʌk.kʌ#pʌz.zʌ#dʌk.kʌ#pʌz.zʌ#tʌs.sʌ#bʌs.sʌ#pʌz.zʌ#nʌz.zʌ#tʌs.sʌ#bʌs.sʌ#dʌk.kʌ#bʌs.sʌ#
nʌz.zʌ#mʌk.kʌ#bʌs.sʌ#pʌz.zʌ#tʌs.sʌ#bʌs.sʌ#pʌz.zʌ#dʌk.kʌ#bʌs.sʌ#dʌk.kʌ#bʌs.sʌ#pʌz.zʌ#d
ʌk.kʌ#pʌz.zʌ#nʌz.zʌ#bʌs.sʌ#tʌs.sʌ#pʌz.zʌ#nʌz.zʌ#dʌk.kʌ#pʌz.zʌ#mʌk.kʌ#pʌz.zʌ#nʌz.zʌ#d
ʌk.kʌ#nʌz.zʌ#pʌz.zʌ#bʌs.sʌ#mʌk.kʌ#pʌz.zʌ#bʌs.sʌ#dʌk.kʌ#pʌz.zʌ#mʌk.kʌ#nʌz.zʌ#bʌs.sʌ#
nʌz.zʌ#tʌs.sʌ#pʌz.zʌ#mʌk.kʌ#dʌk.kʌ#mʌk.kʌ#pʌz.zʌ#nʌz.zʌ#pʌz.zʌ#tʌs.sʌ#dʌk.kʌ#bʌs.sʌ#
pʌz.zʌ#mʌk.kʌ#pʌz.zʌ#tʌs.sʌ#bʌs.sʌ#mʌk.kʌ#bʌs.sʌ#mʌk.kʌ#bʌs.sʌ#pʌz.zʌ#bʌs.sʌ#pʌz.zʌ#
tʌs.sʌ#dʌk.kʌ#mʌk.kʌ#tʌs.sʌ#nʌz.zʌ#dʌk.kʌ#pʌz.zʌ#mʌk.kʌ#bʌs.sʌ#dʌk.kʌ#bʌs.sʌ#nʌz.zʌ#

dʌk.kʌ#mʌk.kʌ#pʌz.zʌ#nʌz.zʌ#dʌk.kʌ#bʌs.sʌ#pʌz.zʌ#mʌk.kʌ#tʌs.sʌ#pʌz.zʌ#mʌk.kʌ#nʌz.z
ʌ#mʌk.kʌ#dʌk.kʌ#nʌz.zʌ#mʌk.kʌ#dʌk.kʌ#pʌz.zʌ#dʌk.kʌ#nʌz.zʌ#bʌs.sʌ#tʌs.sʌ#dʌk.kʌ#nʌz.
zʌ#bʌs.sʌ#dʌk.kʌ#tʌs.sʌ#dʌk.kʌ#nʌz.zʌ#tʌs.sʌ#bʌs.sʌ#tʌs.sʌ#nʌz.zʌ#pʌz.zʌ#bʌs.sʌ#pʌz.zʌ#
tʌs.sʌ#mʌk.kʌ#dʌk.kʌ#pʌz.zʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#pʌz.zʌ#tʌs.sʌ#nʌz.zʌ#pʌz.zʌ#mʌk.kʌ#
tʌs.sʌ#mʌk.kʌ#pʌz.zʌ#dʌk.kʌ#mʌk.kʌ#nʌz.zʌ#dʌk.kʌ#nʌz.zʌ#bʌs.sʌ#pʌz.zʌ#dʌk.kʌ#pʌz.zʌ
#tʌs.sʌ#pʌz.zʌ#dʌk.kʌ#pʌz.zʌ#tʌs.sʌ#bʌs.sʌ#dʌk.kʌ#mʌk.kʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#nʌz.zʌ#
bʌs.sʌ#dʌk.kʌ#pʌz.zʌ#bʌs.sʌ#tʌs.sʌ#bʌs.sʌ#tʌs.sʌ#nʌz.zʌ#tʌs.sʌ#bʌs.sʌ#nʌz.zʌ#tʌs.sʌ#nʌz.
zʌ#dʌk.kʌ#tʌs.sʌ#dʌk.kʌ#pʌz.zʌ#nʌz.zʌ#dʌk.kʌ#tʌs.sʌ#bʌs.sʌ#mʌk.kʌ#pʌz.zʌ#nʌz.zʌ#pʌz.z
ʌ#mʌk.kʌ#dʌk.kʌ#pʌz.zʌ#mʌk.kʌ#bʌs.sʌ#tʌs.sʌ#bʌs.sʌ#nʌz.zʌ#dʌk.kʌ#nʌz.zʌ#tʌs.sʌ#bʌs.s
ʌ#tʌs.sʌ#nʌz.zʌ#mʌk.kʌ#pʌz.zʌ#bʌs.sʌ#tʌs.sʌ#dʌk.kʌ#mʌk.kʌ#nʌz.zʌ#bʌs.sʌ#nʌz.zʌ#tʌs.sʌ
#bʌs.sʌ#nʌz.zʌ#pʌz.zʌ#nʌz.zʌ#dʌk.kʌ#mʌk.kʌ#pʌz.zʌ#mʌk.kʌ#dʌk.kʌ#bʌs.sʌ#pʌz.zʌ#nʌz.z
ʌ#bʌs.sʌ#nʌz.zʌ#tʌs.sʌ#nʌz.zʌ#bʌs.sʌ#mʌk.kʌ#dʌk.kʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#pʌz.zʌ#mʌk.k
ʌ#tʌs.sʌ#dʌk.kʌ#mʌk.kʌ#bʌs.sʌ#dʌk.kʌ#mʌk.kʌ#tʌs.sʌ#bʌs.sʌ#tʌs.sʌ#dʌk.kʌ#bʌs.sʌ#tʌs.sʌ
#mʌk.kʌ#nʌz.zʌ#bʌs.sʌ#pʌz.zʌ#tʌs.sʌ#pʌz.zʌ#nʌz.zʌ#mʌk.kʌ#nʌz.zʌ#pʌz.zʌ#bʌs.sʌ#pʌz.zʌ
#dʌk.kʌ#tʌs.sʌ#dʌk.kʌ#tʌs.sʌ#dʌk.kʌ#pʌz.zʌ#nʌz.zʌ#dʌk.kʌ#nʌz.zʌ#bʌs.sʌ#nʌz.zʌ#mʌk.kʌ
#tʌs.sʌ#dʌk.kʌ#tʌs.sʌ#nʌz.zʌ#pʌz.zʌ#tʌs.sʌ#nʌz.zʌ#pʌz.zʌ#nʌz.zʌ#bʌs.sʌ#mʌk.kʌ#nʌz.zʌ#
mʌk.kʌ#bʌs.sʌ#mʌk.kʌ#pʌz.zʌ#nʌz.zʌ#mʌk.kʌ#dʌk.kʌ#pʌz.zʌ#tʌs.sʌ#mʌk.kʌ#nʌz.zʌ#bʌs.s
ʌ#tʌs.sʌ#mʌk.kʌ#pʌz.zʌ#mʌk.kʌ#dʌk.kʌ#bʌs.sʌ#pʌz.zʌ#dʌk.kʌ#tʌs.sʌ#bʌs.sʌ#mʌk.kʌ#dʌk.
kʌ#pʌz.zʌ#dʌk.kʌ#mʌk.kʌ#bʌs.sʌ#dʌk.kʌ#bʌs.sʌ#pʌz.zʌ#bʌs.sʌ#dʌk.kʌ#pʌz.zʌ#mʌk.kʌ#bʌ
s.sʌ#tʌs.sʌ#mʌk.kʌ#bʌs.sʌ#tʌs.sʌ#bʌs.sʌ#pʌz.zʌ#nʌz.zʌ#bʌs.sʌ#pʌz.zʌ#nʌz.zʌ#pʌz.zʌ#dʌk.
kʌ#bʌs.sʌ#dʌk.kʌ#nʌz.zʌ#bʌs.sʌ#mʌk.kʌ#tʌs.sʌ#pʌz.zʌ#mʌk.kʌ#nʌz.zʌ#dʌk.kʌ#nʌz.zʌ#mʌ
k.kʌ#pʌz.zʌ#mʌk.kʌ#dʌk.kʌ#tʌs.sʌ#bʌs.sʌ#mʌk.kʌ#nʌz.zʌ#mʌk.kʌ#bʌs.sʌ#nʌz.zʌ#tʌs.sʌ#m
ʌk.kʌ#bʌs.sʌ#tʌs.sʌ#mʌk.kʌ#nʌz.zʌ#pʌz.zʌ#mʌk.kʌ#tʌs.sʌ#dʌk.kʌ#pʌz.zʌ#bʌs.sʌ#tʌs.sʌ#bʌ
s.sʌ#dʌk.kʌ#tʌs.sʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#pʌz.zʌ#tʌs.sʌ#nʌz.zʌ#mʌk.kʌ#dʌk.kʌ#mʌk.kʌ#dʌ
k.kʌ#tʌs.sʌ#pʌz.zʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#dʌk.kʌ#pʌz.zʌ#tʌs.sʌ#nʌz.zʌ#pʌz.zʌ#bʌs.sʌ#pʌz.
zʌ#mʌk.kʌ#dʌk.kʌ#pʌz.zʌ#bʌs.sʌ#pʌz.zʌ#tʌs.sʌ#mʌk.kʌ#pʌz.zʌ#dʌk.kʌ#mʌk.kʌ#dʌk.kʌ#tʌ
s.sʌ#mʌk.kʌ#pʌz.zʌ#dʌk.kʌ#bʌs.sʌ#tʌs.sʌ#bʌs.sʌ#pʌz.zʌ#bʌs.sʌ#mʌk.kʌ#nʌz.zʌ#bʌs.sʌ#mʌ
k.kʌ#pʌz.zʌ#nʌz.zʌ#dʌk.kʌ#pʌz.zʌ#dʌk.kʌ#tʌs.sʌ#mʌk.kʌ#dʌk.kʌ#tʌs.sʌ#dʌk.kʌ#bʌs.sʌ#pʌ
z.zʌ#dʌk.kʌ#nʌz.zʌ#pʌz.zʌ#mʌk.kʌ#pʌz.zʌ#tʌs.sʌ#bʌs.sʌ#nʌz.zʌ#tʌs.sʌ#nʌz.zʌ#tʌs.sʌ#pʌz.
zʌ#nʌz.zʌ#mʌk.kʌ#bʌs.sʌ#dʌk.kʌ#bʌs.sʌ#mʌk.kʌ#bʌs.sʌ#pʌz.zʌ#nʌz.zʌ#bʌs.sʌ#mʌk.kʌ#pʌ
z.zʌ#mʌk.kʌ#pʌz.zʌ#bʌs.sʌ#pʌz.zʌ#bʌs.sʌ#mʌk.kʌ#bʌs.sʌ#tʌs.sʌ#pʌz.zʌ#nʌz.zʌ#pʌz.zʌ#dʌ
k.kʌ#tʌs.sʌ#nʌz.zʌ#mʌk.kʌ#bʌs.sʌ#tʌs.sʌ#nʌz.zʌ#mʌk.kʌ#dʌk.kʌ#bʌs.sʌ#nʌz.zʌ#bʌs.sʌ#dʌ
k.kʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#pʌz.zʌ#tʌs.sʌ#pʌz.zʌ#nʌz.zʌ#tʌs.sʌ#pʌz.zʌ#mʌk.kʌ#tʌs.sʌ#pʌz.
zʌ#tʌs.sʌ#pʌz.zʌ#tʌs.sʌ#nʌz.zʌ#mʌk.kʌ#dʌk.kʌ#pʌz.zʌ#bʌs.sʌ#mʌk.kʌ#nʌz.zʌ#pʌz.zʌ#tʌs.s
ʌ#dʌk.kʌ#nʌz.zʌ#dʌk.kʌ#pʌz.zʌ#bʌs.sʌ#tʌs.sʌ#pʌz.zʌ#dʌk.kʌ#tʌs.sʌ#pʌz.zʌ#nʌz.zʌ#bʌs.sʌ
#mʌk.kʌ#dʌk.kʌ#bʌs.sʌ#mʌk.kʌ#dʌk.kʌ#bʌs.sʌ#pʌz.zʌ#mʌk.kʌ#tʌs.sʌ#nʌz.zʌ#dʌk.kʌ#nʌz.
zʌ#bʌs.sʌ#pʌz.zʌ#dʌk.kʌ#nʌz.zʌ#bʌs.sʌ#mʌk.kʌ#dʌk.kʌ#tʌs.sʌ#nʌz.zʌ#tʌs.sʌ#dʌk.kʌ#pʌz.z
ʌ#nʌz.zʌ#mʌk.kʌ#pʌz.zʌ#dʌk.kʌ#pʌz.zʌ#tʌs.sʌ#mʌk.kʌ#nʌz.zʌ#tʌs.sʌ#mʌk.kʌ#pʌz.zʌ#nʌz.
zʌ#mʌk.kʌ#pʌz.zʌ#tʌs.sʌ#mʌk.kʌ#tʌs.sʌ#nʌz.zʌ#tʌs.sʌ#dʌk.kʌ#nʌz.zʌ#bʌs.sʌ#nʌz.zʌ#bʌs.s
ʌ#mʌk.kʌ#bʌs.sʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#dʌk.kʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#dʌk.kʌ#nʌz.zʌ#pʌz.
zʌ#bʌs.sʌ#pʌz.zʌ#mʌk.kʌ#tʌs.sʌ#dʌk.kʌ#tʌs.sʌ#pʌz.zʌ#nʌz.zʌ#tʌs.sʌ#bʌs.sʌ#dʌk.kʌ#bʌs.sʌ
#tʌs.sʌ#bʌs.sʌ#pʌz.zʌ#tʌs.sʌ#nʌz.zʌ#pʌz.zʌ#tʌs.sʌ#mʌk.kʌ#dʌk.kʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#
pʌz.zʌ#bʌs.sʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#mʌk.kʌ#tʌs.sʌ#bʌs.sʌ#tʌs.sʌ#mʌk.kʌ#nʌz.zʌ#dʌk.kʌ#
pʌz.zʌ#dʌk.kʌ#pʌz.zʌ#tʌs.sʌ#bʌs.sʌ#pʌz.zʌ#nʌz.zʌ#tʌs.sʌ#bʌs.sʌ#dʌk.kʌ#bʌs.sʌ#nʌz.zʌ#m
ʌk.kʌ#bʌs.sʌ#pʌz.zʌ#tʌs.sʌ#bʌs.sʌ#pʌz.zʌ#dʌk.kʌ#bʌs.sʌ#dʌk.kʌ#bʌs.sʌ#pʌz.zʌ#dʌk.kʌ#pʌ
z.zʌ#nʌz.zʌ#bʌs.sʌ#tʌs.sʌ#pʌz.zʌ#nʌz.zʌ#dʌk.kʌ#pʌz.zʌ#mʌk.kʌ#pʌz.zʌ#nʌz.zʌ#dʌk.kʌ#nʌ

z.zʌ#pʌz.zʌ#bʌs.sʌ#mʌk.kʌ#pʌz.zʌ#bʌs.sʌ#dʌk.kʌ#pʌz.zʌ#mʌk.kʌ#nʌz.zʌ#bʌs.sʌ#nʌz.zʌ#tʌ
s.sʌ#pʌz.zʌ#mʌk.kʌ#dʌk.kʌ#mʌk.kʌ#pʌz.zʌ#nʌz.zʌ#pʌz.zʌ#tʌs.sʌ#dʌk.kʌ#bʌs.sʌ#pʌz.zʌ#m
ʌk.kʌ#pʌz.zʌ#tʌs.sʌ#bʌs.sʌ#mʌk.kʌ#bʌs.sʌ#mʌk.kʌ#bʌs.sʌ#pʌz.zʌ#bʌs.sʌ#pʌz.zʌ#tʌs.sʌ#dʌ
k.kʌ#mʌk.kʌ#tʌs.sʌ#nʌz.zʌ#dʌk.kʌ#pʌz.zʌ#mʌk.kʌ#bʌs.sʌ#dʌk.kʌ#bʌs.sʌ#nʌz.zʌ#dʌk.kʌ#
mʌk.kʌ#pʌz.zʌ#nʌz.zʌ#dʌk.kʌ#bʌs.sʌ#pʌz.zʌ#mʌk.kʌ#tʌs.sʌ#pʌz.zʌ#mʌk.kʌ#nʌz.zʌ#mʌk.k
ʌ#dʌk.kʌ#nʌz.zʌ#mʌk.kʌ#dʌk.kʌ#pʌz.zʌ#dʌk.kʌ#nʌz.zʌ#bʌs.sʌ#tʌs.sʌ#dʌk.kʌ#nʌz.zʌ#bʌs.s
ʌ#dʌk.kʌ#tʌs.sʌ#dʌk.kʌ#nʌz.zʌ#tʌs.sʌ#bʌs.sʌ#tʌs.sʌ#nʌz.zʌ#pʌz.zʌ#bʌs.sʌ#pʌz.zʌ#tʌs.sʌ#
mʌk.kʌ#dʌk.kʌ#pʌz.zʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#pʌz.zʌ#tʌs.sʌ#nʌz.zʌ#pʌz.zʌ#mʌk.kʌ#tʌs.sʌ#
mʌk.kʌ#pʌz.zʌ#dʌk.kʌ#mʌk.kʌ#nʌz.zʌ#dʌk.kʌ#nʌz.zʌ#bʌs.sʌ#pʌz.zʌ#dʌk.kʌ#pʌz.zʌ#tʌs.sʌ
#pʌz.zʌ#dʌk.kʌ#pʌz.zʌ#tʌs.sʌ#bʌs.sʌ#dʌk.kʌ#mʌk.kʌ#nʌz.zʌ#mʌk.kʌ#tʌs.sʌ#nʌz.zʌ#bʌs.sʌ
#dʌk.kʌ#pʌz.zʌ#bʌs.sʌ#tʌs.sʌ#bʌs.sʌ#tʌs.sʌ#nʌz.zʌ#tʌs.sʌ#bʌs.sʌ#nʌz.zʌ#tʌs.sʌ#nʌz.zʌ#dʌ
k.kʌ#tʌs.sʌ#dʌk.kʌ#pʌz.zʌ#nʌz.zʌ#dʌk.kʌ#tʌs.sʌ#bʌs.sʌ#mʌk.kʌ#pʌz.zʌ#nʌz.zʌ#pʌz.zʌ#mʌ
k.kʌ#dʌk.kʌ#pʌz.zʌ#mʌk.kʌ#bʌs.sʌ#tʌs.sʌ#bʌs.sʌ#nʌz.zʌ#dʌk.kʌ#nʌz.zʌ#tʌs.sʌ#bʌs.sʌ#tʌs.
sʌ#nʌz.zʌ#mʌk.kʌ#pʌz.zʌ#bʌs.sʌ#tʌs.sʌ#dʌk.kʌ#mʌk.kʌ#nʌz.zʌ#bʌs.sʌ#nʌz.zʌ#tʌs.sʌ#bʌs.s
ʌ#nʌz.zʌ#pʌz.zʌ#nʌz.zʌ#dʌk.kʌ#mʌk.kʌ#pʌz.zʌ#mʌk.kʌ#dʌk.kʌ#bʌs.sʌ#

APPENDIX E: Ordered list of stimuli in the speech string for Language 3 of Experiment 5 in Chapter 3.

The "." indicates syllable breaks and "#" marks stimulus word breaks.

Language 3 (Experiment 5)
bæk.kɪ#dʌs.sɪ#mæz.zʌ#pɪs.sæ#nɪk.kʌ#pɪs.sæ#tʌz.zæ#nɪk.kʌ#tʌz.zæ#nɪk.kʌ#pɪs.sæ#mæz.zʌ#d
ʌs.sɪ#bæk.kɪ#mæz.zʌ#nɪk.kʌ#dʌs.sɪ#tʌz.zæ#bæk.kɪ#pɪs.sæ#tʌz.zæ#pɪs.sæ#nɪk.kʌ#bæk.kɪ#dʌs.
sɪ#pɪs.sæ#bæk.kɪ#mæz.zʌ#tʌz.zæ#pɪs.sæ#bæk.kɪ#pɪs.sæ#dʌs.sɪ#pɪs.sæ#tʌz.zæ#pɪs.sæ#dʌs.sɪ#t
ʌz.zæ#nɪk.kʌ#tʌz.zæ#dʌs.sɪ#mæz.zʌ#dʌs.sɪ#mæz.zʌ#nɪk.kʌ#bæk.kɪ#tʌz.zæ#nɪk.kʌ#bæk.kɪ#nɪ
k.kʌ#bæk.kɪ#nɪk.kʌ#dʌs.sɪ#pɪs.sæ#dʌs.sɪ#tʌz.zæ#mæz.zʌ#bæk.kɪ#pɪs.sæ#mæz.zʌ#pɪs.sæ#nɪk.
kʌ#bæk.kɪ#mæz.zʌ#bæk.kɪ#dʌs.sɪ#tʌz.zæ#pɪs.sæ#mæz.zʌ#tʌz.zæ#nɪk.kʌ#bæk.kɪ#dʌs.sɪ#tʌz.z
æ#pɪs.sæ#dʌs.sɪ#nɪk.kʌ#pɪs.sæ#mæz.zʌ#pɪs.sæ#bæk.kɪ#pɪs.sæ#mæz.zʌ#bæk.kɪ#nɪk.kʌ#tʌz.zæ
#mæz.zʌ#dʌs.sɪ#mæz.zʌ#dʌs.sɪ#bæk.kɪ#tʌz.zæ#bæk.kɪ#dʌs.sɪ#bæk.kɪ#nɪk.kʌ#dʌs.sɪ#mæz.zʌ
#nɪk.kʌ#pɪs.sæ#bæk.kɪ#mæz.zʌ#nɪk.kʌ#dʌs.sɪ#pɪs.sæ#mæz.zʌ#nɪk.kʌ#mæz.zʌ#dʌs.sɪ#nɪk.kʌ
#dʌs.sɪ#bæk.kɪ#tʌz.zæ#pɪs.sæ#dʌs.sɪ#mæz.zʌ#pɪs.sæ#bæk.kɪ#pɪs.sæ#dʌs.sɪ#tʌz.zæ#bæk.kɪ#nɪ
k.kʌ#bæk.kɪ#mæz.zʌ#tʌz.zæ#mæz.zʌ#dʌs.sɪ#nɪk.kʌ#bæk.kɪ#nɪk.kʌ#pɪs.sæ#nɪk.kʌ#mæz.zʌ#d
ʌs.sɪ#pɪs.sæ#tʌz.zæ#pɪs.sæ#bæk.kɪ#tʌz.zæ#nɪk.kʌ#tʌz.zæ#dʌs.sɪ#pɪs.sæ#tʌz.zæ#nɪk.kʌ#mæz.
zʌ#nɪk.kʌ#mæz.zʌ#nɪk.kʌ#dʌs.sɪ#pɪs.sæ#tʌz.zæ#bæk.kɪ#nɪk.kʌ#pɪs.sæ#mæz.zʌ#dʌs.sɪ#tʌz.z
æ#nɪk.kʌ#tʌz.zæ#dʌs.sɪ#mæz.zʌ#pɪs.sæ#mæz.zʌ#pɪs.sæ#nɪk.kʌ#dʌs.sɪ#pɪs.sæ#bæk.kɪ#pɪs.sæ
#nɪk.kʌ#dʌs.sɪ#pɪs.sæ#tʌz.zæ#nɪk.kʌ#mæz.zʌ#bæk.kɪ#dʌs.sɪ#nɪk.kʌ#mæz.zʌ#tʌz.zæ#mæz.zʌ
#tʌz.zæ#pɪs.sæ#mæz.zʌ#pɪs.sæ#bæk.kɪ#tʌz.zæ#dʌs.sɪ#nɪk.kʌ#dʌs.sɪ#bæk.kɪ#pɪs.sæ#tʌz.zæ#b
æk.kɪ#nɪk.kʌ#tʌz.zæ#pɪs.sæ#bæk.kɪ#tʌz.zæ#nɪk.kʌ#pɪs.sæ#dʌs.sɪ#bæk.kɪ#mæz.zʌ#nɪk.kʌ#tʌz
.zæ#bæk.kɪ#pɪs.sæ#bæk.kɪ#tʌz.zæ#nɪk.kʌ#mæz.zʌ#tʌz.zæ#dʌs.sɪ#tʌz.zæ#bæk.kɪ#dʌs.sɪ#tʌz.z
æ#bæk.kɪ#nɪk.kʌ#pɪs.sæ#bæk.kɪ#dʌs.sɪ#tʌz.zæ#nɪk.kʌ#pɪs.sæ#bæk.kɪ#dʌs.sɪ#pɪs.sæ#tʌz.zæ#d
ʌs.sɪ#bæk.kɪ#dʌs.sɪ#mæz.zʌ#dʌs.sɪ#bæk.kɪ#dʌs.sɪ#tʌz.zæ#bæk.kɪ#tʌz.zæ#bæk.kɪ#mæz.zʌ#tʌz
.zæ#bæk.kɪ#nɪk.kʌ#tʌz.zæ#nɪk.kʌ#mæz.zʌ#nɪk.kʌ#mæz.zʌ#bæk.kɪ#nɪk.kʌ#tʌz.zæ#mæz.zʌ#pɪ
s.sæ#dʌs.sɪ#pɪs.sæ#mæz.zʌ#bæk.kɪ#dʌs.sɪ#bæk.kɪ#tʌz.zæ#pɪs.sæ#nɪk.kʌ#bæk.kɪ#dʌs.sɪ#bæk.
kɪ#dʌs.sɪ#mæz.zʌ#tʌz.zæ#dʌs.sɪ#bæk.kɪ#dʌs.sɪ#bæk.kɪ#mæz.zʌ#dʌs.sɪ#mæz.zʌ#bæk.kɪ#pɪs.s
æ#bæk.kɪ#pɪs.sæ#tʌz.zæ#dʌs.sɪ#tʌz.zæ#mæz.zʌ#nɪk.kʌ#mæz.zʌ#bæk.kɪ#pɪs.sæ#bæk.kɪ#mæz.
zʌ#dʌs.sɪ#nɪk.kʌ#pɪs.sæ#bæk.kɪ#nɪk.kʌ#dʌs.sɪ#pɪs.sæ#nɪk.kʌ#bæk.kɪ#dʌs.sɪ#nɪk.kʌ#pɪs.sæ#tʌ
z.zæ#nɪk.kʌ#mæz.zʌ#dʌs.sɪ#nɪk.kʌ#dʌs.sɪ#mæz.zʌ#dʌs.sɪ#tʌz.zæ#bæk.kɪ#nɪk.kʌ#tʌz.zæ#dʌs.
sɪ#tʌz.zæ#pɪs.sæ#mæz.zʌ#nɪk.kʌ#dʌs.sɪ#tʌz.zæ#mæz.zʌ#pɪs.sæ#bæk.kɪ#mæz.zʌ#bæk.kɪ#nɪk.
kʌ#bæk.kɪ#pɪs.sæ#mæz.zʌ#nɪk.kʌ#mæz.zʌ#dʌs.sɪ#pɪs.sæ#tʌz.zæ#bæk.kɪ#tʌz.zæ#nɪk.kʌ#bæk.
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æ#tʌz.zæ#pɪs.sæ#bæk.kɪ#pɪs.sæ#dʌs.sɪ#mæz.zʌ#nɪk.kʌ#bæk.kɪ#pɪs.sæ#nɪk.kʌ#bæk.kɪ#dʌs.sɪ#
pɪs.sæ#tʌz.zæ#bæk.kɪ#dʌs.sɪ#bæk.kɪ#mæz.zʌ#dʌs.sɪ#pɪs.sæ#dʌs.sɪ#pɪs.sæ#nɪk.kʌ#dʌs.sɪ#nɪk.
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.sæ#bæk.kɪ#nɪk.kʌ#dʌs.sɪ#pɪs.sæ#bæk.kɪ#dʌs.sɪ#nɪk.kʌ#dʌs.sɪ#bæk.kɪ#mæz.zʌ#tʌz.zæ#pɪs.sæ
#bæk.kɪ#mæz.zʌ#pɪs.sæ#mæz.zʌ#tʌz.zæ#mæz.zʌ#nɪk.kʌ#dʌs.sɪ#nɪk.kʌ#dʌs.sɪ#mæz.zʌ#nɪk.k
ʌ#dʌs.sɪ#bæk.kɪ#mæz.zʌ#dʌs.sɪ#mæz.zʌ#nɪk.kʌ#dʌs.sɪ#mæz.zʌ#nɪk.kʌ#bæk.kɪ#tʌz.zæ#bæk.
kɪ#mæz.zʌ#nɪk.kʌ#bæk.kɪ#tʌz.zæ#pɪs.sæ#mæz.zʌ#nɪk.kʌ#dʌs.sɪ#nɪk.kʌ#pɪs.sæ#dʌs.sɪ#tʌz.zæ
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#pɪs.sæ#tʌz.zæ#pɪs.sæ#nɪk.kʌ#tʌz.zæ#mæz.zʌ#bæk.kɪ#nɪk.kʌ#mæz.zʌ#pɪs.sæ#bæk.kɪ#nɪk.kʌ

#pɪs.sæ#dʌs.sɪ#nɪk.kʌ#mæz.zʌ#bæk.kɪ#dʌs.sɪ#pɪs.sæ#nɪk.kʌ#bæk.kɪ#dʌs.sɪ#mæz.zʌ#tʌz.zæ#
mæz.zʌ#dʌs.sɪ#tʌz.zæ#mæz.zʌ#nɪk.kʌ#pɪs.sæ#tʌz.zæ#dʌs.sɪ#mæz.zʌ#nɪk.kʌ#pɪs.sæ#nɪk.kʌ#b
æk.kɪ#pɪs.sæ#dʌs.sɪ#pɪs.sæ#bæk.kɪ#nɪk.kʌ#pɪs.sæ#nɪk.kʌ#dʌs.sɪ#nɪk.kʌ#pɪs.sæ#dʌs.sɪ#pɪs.sæ
#bæk.kɪ#mæz.zʌ#tʌz.zæ#dʌs.sɪ#tʌz.zæ#dʌs.sɪ#nɪk.kʌ#pɪs.sæ#mæz.zʌ#bæk.kɪ#tʌz.zæ#bæk.kɪ
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k.kʌ#tʌz.zæ#bæk.kɪ#dʌs.sɪ#pɪs.sæ#nɪk.kʌ#bæk.kɪ#mæz.zʌ#bæk.kɪ#nɪk.kʌ#mæz.zʌ#tʌz.zæ#m
æz.zʌ#nɪk.kʌ#tʌz.zæ#pɪs.sæ#dʌs.sɪ#tʌz.zæ#bæk.kɪ#nɪk.kʌ#mæz.zʌ#bæk.kɪ#dʌs.sɪ#tʌz.zæ#pɪs.
sæ#dʌs.sɪ#pɪs.sæ#bæk.kɪ#pɪs.sæ#nɪk.kʌ#dʌs.sɪ#mæz.zʌ#bæk.kɪ#mæz.zʌ#bæk.kɪ#tʌz.zæ#bæk.
kɪ#tʌz.zæ#bæk.kɪ#tʌz.zæ#nɪk.kʌ#dʌs.sɪ#bæk.kɪ#pɪs.sæ#mæz.zʌ#pɪs.sæ#tʌz.zæ#pɪs.sæ#bæk.kɪ
#tʌz.zæ#bæk.kɪ#pɪs.sæ#dʌs.sɪ#nɪk.kʌ#bæk.kɪ#pɪs.sæ#nɪk.kʌ#mæz.zʌ#nɪk.kʌ#mæz.zʌ#pɪs.sæ#
dʌs.sɪ#pɪs.sæ#dʌs.sɪ#mæz.zʌ#bæk.kɪ#pɪs.sæ#nɪk.kʌ#pɪs.sæ#nɪk.kʌ#mæz.zʌ#dʌs.sɪ#pɪs.sæ#dʌ
s.sɪ#bæk.kɪ#dʌs.sɪ#mæz.zʌ#nɪk.kʌ#dʌs.sɪ#tʌz.zæ#mæz.zʌ#bæk.kɪ#pɪs.sæ#tʌz.zæ#pɪs.sæ#bæk.
kɪ#tʌz.zæ#mæz.zʌ#pɪs.sæ#nɪk.kʌ#dʌs.sɪ#tʌz.zæ#dʌs.sɪ#nɪk.kʌ#dʌs.sɪ#tʌz.zæ#bæk.kɪ#dʌs.sɪ#b
æk.kɪ#nɪk.kʌ#pɪs.sæ#nɪk.kʌ#bæk.kɪ#dʌs.sɪ#mæz.zʌ#bæk.kɪ#pɪs.sæ#nɪk.kʌ#bæk.kɪ#tʌz.zæ#m
æz.zʌ#dʌs.sɪ#tʌz.zæ#bæk.kɪ#tʌz.zæ#nɪk.kʌ#dʌs.sɪ#tʌz.zæ#mæz.zʌ#tʌz.zæ#mæz.zʌ#nɪk.kʌ#m
æz.zʌ#bæk.kɪ#pɪs.sæ#dʌs.sɪ#tʌz.zæ#dʌs.sɪ#mæz.zʌ#bæk.kɪ#tʌz.zæ#pɪs.sæ#mæz.zʌ#bæk.kɪ#nɪ
k.kʌ#mæz.zʌ#pɪs.sæ#tʌz.zæ#dʌs.sɪ#tʌz.zæ#pɪs.sæ#dʌs.sɪ#tʌz.zæ#mæz.zʌ#pɪs.sæ#dʌs.sɪ#bæk.
kɪ#tʌz.zæ#dʌs.sɪ#bæk.kɪ#pɪs.sæ#tʌz.zæ#nɪk.kʌ#pɪs.sæ#tʌz.zæ#dʌs.sɪ#mæz.zʌ#tʌz.zæ#dʌs.sɪ#
pɪs.sæ#bæk.kɪ#pɪs.sæ#mæz.zʌ#tʌz.zæ#dʌs.sɪ#nɪk.kʌ#pɪs.sæ#bæk.kɪ#pɪs.sæ#tʌz.zæ#dʌs.sɪ#bæ
k.kɪ#pɪs.sæ#mæz.zʌ#nɪk.kʌ#bæk.kɪ#dʌs.sɪ#nɪk.kʌ#bæk.kɪ#dʌs.sɪ#tʌz.zæ#nɪk.kʌ#mæz.zʌ#tʌz.
zæ#bæk.kɪ#tʌz.zæ#mæz.zʌ#tʌz.zæ#dʌs.sɪ#pɪs.sæ#mæz.zʌ#pɪs.sæ#mæz.zʌ#nɪk.kʌ#mæz.zʌ#b
æk.kɪ#pɪs.sæ#mæz.zʌ#nɪk.kʌ#bæk.kɪ#tʌz.zæ#bæk.kɪ#nɪk.kʌ#bæk.kɪ#mæz.zʌ#dʌs.sɪ#nɪk.kʌ#p
ɪs.sæ#bæk.kɪ#mæz.zʌ#dʌs.sɪ#bæk.kɪ#nɪk.kʌ#dʌs.sɪ#pɪs.sæ#nɪk.kʌ#dʌs.sɪ#mæz.zʌ#dʌs.sɪ#nɪk.
kʌ#dʌs.sɪ#bæk.kɪ#pɪs.sæ#nɪk.kʌ#dʌs.sɪ#tʌz.zæ#mæz.zʌ#pɪs.sæ#tʌz.zæ#dʌs.sɪ#pɪs.sæ#bæk.kɪ#
pɪs.sæ#tʌz.zæ#bæk.kɪ#dʌs.sɪ#bæk.kɪ#tʌz.zæ#mæz.zʌ#pɪs.sæ#dʌs.sɪ#mæz.zʌ#nɪk.kʌ#tʌz.zæ#b
æk.kɪ#tʌz.zæ#bæk.kɪ#tʌz.zæ#mæz.zʌ#bæk.kɪ#dʌs.sɪ#bæk.kɪ#dʌs.sɪ#tʌz.zæ#bæk.kɪ#dʌs.sɪ#m
æz.zʌ#dʌs.sɪ#bæk.kɪ#pɪs.sæ#dʌs.sɪ#bæk.kɪ#nɪk.kʌ#tʌz.zæ#mæz.zʌ#dʌs.sɪ#tʌz.zæ#mæz.zʌ#b
æk.kɪ#dʌs.sɪ#nɪk.kʌ#dʌs.sɪ#mæz.zʌ#bæk.kɪ#pɪs.sæ#mæz.zʌ#nɪk.kʌ#mæz.zʌ#dʌs.sɪ#mæz.zʌ#
pɪs.sæ#bæk.kɪ#tʌz.zæ#dʌs.sɪ#mæz.zʌ#tʌz.zæ#bæk.kɪ#nɪk.kʌ#dʌs.sɪ#tʌz.zæ#bæk.kɪ#tʌz.zæ#m
æz.zʌ#tʌz.zæ#pɪs.sæ#bæk.kɪ#pɪs.sæ#dʌs.sɪ#mæz.zʌ#pɪs.sæ#mæz.zʌ#nɪk.kʌ#tʌz.zæ#pɪs.sæ#dʌ
s.sɪ#tʌz.zæ#pɪs.sæ#bæk.kɪ#dʌs.sɪ#mæz.zʌ#tʌz.zæ#nɪk.kʌ#bæk.kɪ#dʌs.sɪ#bæk.kɪ#mæz.zʌ#tʌz.
zæ#mæz.zʌ#tʌz.zæ#nɪk.kʌ#dʌs.sɪ#mæz.zʌ#nɪk.kʌ#tʌz.zæ#dʌs.sɪ#mæz.zʌ#bæk.kɪ#mæz.zʌ#dʌ
s.sɪ#pɪs.sæ#mæz.zʌ#nɪk.kʌ#tʌz.zæ#mæz.zʌ#tʌz.zæ#mæz.zʌ#dʌs.sɪ#bæk.kɪ#mæz.zʌ#nɪk.kʌ#d
ʌs.sɪ#tʌz.zæ#mæz.zʌ#nɪk.kʌ#dʌs.sɪ#nɪk.kʌ#tʌz.zæ#dʌs.sɪ#nɪk.kʌ#mæz.zʌ#pɪs.sæ#mæz.zʌ#nɪ
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ʌ#dʌs.sɪ#nɪk.kʌ#pɪs.sæ#mæz.zʌ#pɪs.sæ#tʌz.zæ#mæz.zʌ#dʌs.sɪ#tʌz.zæ#mæz.zʌ#tʌz.zæ#bæk.k
ɪ#dʌs.sɪ#mæz.zʌ#nɪk.kʌ#bæk.kɪ#dʌs.sɪ#pɪs.sæ#bæk.kɪ#tʌz.zæ#pɪs.sæ#tʌz.zæ#pɪs.sæ#nɪk.kʌ#
mæz.zʌ#dʌs.sɪ#bæk.kɪ#nɪk.kʌ#pɪs.sæ#dʌs.sɪ#mæz.zʌ#dʌs.sɪ#bæk.kɪ#tʌz.zæ#bæk.kɪ#mæz.zʌ#
pɪs.sæ#nɪk.kʌ#dʌs.sɪ#mæz.zʌ#nɪk.kʌ#pɪs.sæ#tʌz.zæ#pɪs.sæ#bæk.kɪ#pɪs.sæ#mæz.zʌ#dʌs.sɪ#b
æk.kɪ#tʌz.zæ#pɪs.sæ#dʌs.sɪ#mæz.zʌ#pɪs.sæ#bæk.kɪ#tʌz.zæ#bæk.kɪ#dʌs.sɪ#mæz.zʌ#tʌz.zæ#m
æz.zʌ#dʌs.sɪ#pɪs.sæ#mæz.zʌ#nɪk.kʌ#bæk.kɪ#mæz.zʌ#bæk.kɪ#nɪk.kʌ#dʌs.sɪ#bæk.kɪ#dʌs.sɪ#tʌ
z.zæ#pɪs.sæ#bæk.kɪ#tʌz.zæ#dʌs.sɪ#nɪk.kʌ#mæz.zʌ#tʌz.zæ#mæz.zʌ#bæk.kɪ#tʌz.zæ#mæz.zʌ#p
ɪs.sæ#dʌs.sɪ#mæz.zʌ#tʌz.zæ#mæz.zʌ#tʌz.zæ#bæk.kɪ#nɪk.kʌ#dʌs.sɪ#nɪk.kʌ#tʌz.zæ#bæk.kɪ#m
æz.zʌ#pɪs.sæ#dʌs.sɪ#tʌz.zæ#mæz.zʌ#bæk.kɪ#nɪk.kʌ#tʌz.zæ#bæk.kɪ#dʌs.sɪ#mæz.zʌ#tʌz.zæ#b
æk.kɪ#mæz.zʌ#bæk.kɪ#tʌz.zæ#nɪk.kʌ#pɪs.sæ#mæz.zʌ#tʌz.zæ#nɪk.kʌ#mæz.zʌ#dʌs.sɪ#pɪs.sæ#
bæk.kɪ#dʌs.sɪ#bæk.kɪ#dʌs.sɪ#nɪk.kʌ#tʌz.zæ#dʌs.sɪ#nɪk.kʌ#dʌs.sɪ#bæk.kɪ#pɪs.sæ#bæk.kɪ#pɪs.s

æ#nɪk.kʌ#pɪs.sæ#tʌz.zæ#pɪs.sæ#dʌs.sɪ#tʌz.zæ#bæk.kɪ#tʌz.zæ#pɪs.sæ#dʌs.sɪ#tʌz.zæ#bæk.kɪ#d
ʌs.sɪ#bæk.kɪ#tʌz.zæ#pɪs.sæ#nɪk.kʌ#dʌs.sɪ#bæk.kɪ#mæz.zʌ#bæk.kɪ#tʌz.zæ#bæk.kɪ#mæz.zʌ#pɪ
s.sæ#bæk.kɪ#tʌz.zæ#nɪk.kʌ#pɪs.sæ#nɪk.kʌ#pɪs.sæ#mæz.zʌ#bæk.kɪ#dʌs.sɪ#bæk.kɪ#pɪs.sæ#bæk
.kɪ#dʌs.sɪ#nɪk.kʌ#bæk.kɪ#tʌz.zæ#pɪs.sæ#dʌs.sɪ#tʌz.zæ#bæk.kɪ#tʌz.zæ#mæz.zʌ#pɪs.sæ#nɪk.kʌ
#mæz.zʌ#tʌz.zæ#nɪk.kʌ#tʌz.zæ#mæz.zʌ#pɪs.sæ#tʌz.zæ#bæk.kɪ#mæz.zʌ#pɪs.sæ#mæz.zʌ#dʌs.
sɪ#tʌz.zæ#pɪs.sæ#mæz.zʌ#bæk.kɪ#dʌs.sɪ#mæz.zʌ#dʌs.sɪ#tʌz.zæ#nɪk.kʌ#pɪs.sæ#tʌz.zæ#bæk.kɪ
#tʌz.zæ#nɪk.kʌ#pɪs.sæ#bæk.kɪ#nɪk.kʌ#dʌs.sɪ#bæk.kɪ#nɪk.kʌ#mæz.zʌ#tʌz.zæ#mæz.zʌ#tʌz.zæ
#mæz.zʌ#pɪs.sæ#dʌs.sɪ#nɪk.kʌ#dʌs.sɪ#bæk.kɪ#pɪs.sæ#dʌs.sɪ#tʌz.zæ#mæz.zʌ#dʌs.sɪ#tʌz.zæ#b
æk.kɪ#mæz.zʌ#bæk.kɪ#pɪs.sæ#

APPENDIX F: Ordered list of stimuli in the speech string for Language 4 of Experiment 5 in Chapter 3.

The “.” indicates syllable breaks and “#” marks stimulus word breaks.

Language 4 (Experiment 5)
pæz.zɪ#tæs.sʌ#dʌk.kɪ#nɪz.zʌ#pæz.zɪ#bʌs.sæ#tæs.sʌ#mɪk.kæ#dʌk.kɪ#mɪk.kæ#pæz.zɪ#bʌs.sæ#p
æz.zɪ#mɪk.kæ#nɪz.zʌ#pæz.zɪ#nɪz.zʌ#tæs.sʌ#nɪz.zʌ#pæz.zɪ#tæs.sʌ#bʌs.sæ#dʌk.kɪ#pæz.zɪ#tæs.
sʌ#pæz.zɪ#mɪk.kæ#pæz.zɪ#tæs.sʌ#dʌk.kɪ#pæz.zɪ#mɪk.kæ#tæs.sʌ#bʌs.sæ#pæz.zɪ#dʌk.kɪ#nɪz.z
ʌ#mɪk.kæ#tæs.sʌ#pæz.zɪ#dʌk.kɪ#mɪk.kæ#nɪz.zʌ#mɪk.kæ#nɪz.zʌ#bʌs.sæ#nɪz.zʌ#tæs.sʌ#mɪk.k
æ#tæs.sʌ#dʌk.kɪ#nɪz.zʌ#dʌk.kɪ#nɪz.zʌ#mɪk.kæ#tæs.sʌ#nɪz.zʌ#bʌs.sæ#dʌk.kɪ#nɪz.zʌ#tæs.sʌ#n
ɪz.zʌ#mɪk.kæ#dʌk.kɪ#pæz.zɪ#bʌs.sæ#mɪk.kæ#dʌk.kɪ#tæs.sʌ#pæz.zɪ#tæs.sʌ#nɪz.zʌ#pæz.zɪ#mɪ
k.kæ#bʌs.sæ#mɪk.kæ#pæz.zɪ#dʌk.kɪ#tæs.sʌ#mɪk.kæ#dʌk.kɪ#mɪk.kæ#tæs.sʌ#bʌs.sæ#tæs.sʌ#d
ʌk.kɪ#mɪk.kæ#tæs.sʌ#pæz.zɪ#mɪk.kæ#nɪz.zʌ#pæz.zɪ#tæs.sʌ#nɪz.zʌ#tæs.sʌ#dʌk.kɪ#pæz.zɪ#dʌk
.kɪ#pæz.zɪ#dʌk.kɪ#mɪk.kæ#dʌk.kɪ#mɪk.kæ#pæz.zɪ#tæs.sʌ#dʌk.kɪ#mɪk.kæ#pæz.zɪ#bʌs.sæ#tæs.
sʌ#bʌs.sæ#mɪk.kæ#dʌk.kɪ#pæz.zɪ#nɪz.zʌ#bʌs.sæ#dʌk.kɪ#bʌs.sæ#mɪk.kæ#dʌk.kɪ#bʌs.sæ#dʌk.
kɪ#nɪz.zʌ#dʌk.kɪ#nɪz.zʌ#tæs.sʌ#mɪk.kæ#nɪz.zʌ#pæz.zɪ#bʌs.sæ#mɪk.kæ#dʌk.kɪ#bʌs.sæ#tæs.sʌ
#mɪk.kæ#tæs.sʌ#bʌs.sæ#dʌk.kɪ#tæs.sʌ#dʌk.kɪ#tæs.sʌ#dʌk.kɪ#pæz.zɪ#bʌs.sæ#tæs.sʌ#pæz.zɪ#n
ɪz.zʌ#pæz.zɪ#bʌs.sæ#pæz.zɪ#nɪz.zʌ#bʌs.sæ#dʌk.kɪ#bʌs.sæ#tæs.sʌ#pæz.zɪ#nɪz.zʌ#mɪk.kæ#pæ
z.zɪ#mɪk.kæ#pæz.zɪ#mɪk.kæ#dʌk.kɪ#bʌs.sæ#tæs.sʌ#mɪk.kæ#pæz.zɪ#dʌk.kɪ#pæz.zɪ#mɪk.kæ#t
æs.sʌ#pæz.zɪ#dʌk.kɪ#pæz.zɪ#tæs.sʌ#bʌs.sæ#dʌk.kɪ#bʌs.sæ#tæs.sʌ#dʌk.kɪ#bʌs.sæ#nɪz.zʌ#pæz
.zɪ#nɪz.zʌ#bʌs.sæ#tæs.sʌ#pæz.zɪ#mɪk.kæ#dʌk.kɪ#tæs.sʌ#nɪz.zʌ#dʌk.kɪ#pæz.zɪ#dʌk.kɪ#mɪk.k
æ#dʌk.kɪ#mɪk.kæ#pæz.zɪ#mɪk.kæ#tæs.sʌ#nɪz.zʌ#pæz.zɪ#mɪk.kæ#bʌs.sæ#dʌk.kɪ#pæz.zɪ#nɪz.z
ʌ#dʌk.kɪ#mɪk.kæ#pæz.zɪ#bʌs.sæ#nɪz.zʌ#bʌs.sæ#mɪk.kæ#dʌk.kɪ#pæz.zɪ#dʌk.kɪ#tæs.sʌ#nɪz.zʌ
#dʌk.kɪ#mɪk.kæ#tæs.sʌ#pæz.zɪ#tæs.sʌ#pæz.zɪ#dʌk.kɪ#pæz.zɪ#tæs.sʌ#bʌs.sæ#dʌk.kɪ#mɪk.kæ#
dʌk.kɪ#nɪz.zʌ#mɪk.kæ#pæz.zɪ#nɪz.zʌ#tæs.sʌ#dʌk.kɪ#nɪz.zʌ#bʌs.sæ#pæz.zɪ#nɪz.zʌ#mɪk.kæ#dʌ
k.kɪ#mɪk.kæ#dʌk.kɪ#nɪz.zʌ#dʌk.kɪ#bʌs.sæ#nɪz.zʌ#pæz.zɪ#tæs.sʌ#nɪz.zʌ#mɪk.kæ#dʌk.kɪ#pæz.
zɪ#bʌs.sæ#nɪz.zʌ#tæs.sʌ#pæz.zɪ#nɪz.zʌ#pæz.zɪ#mɪk.kæ#bʌs.sæ#mɪk.kæ#bʌs.sæ#mɪk.kæ#pæz.
zɪ#dʌk.kɪ#mɪk.kæ#bʌs.sæ#pæz.zɪ#dʌk.kɪ#nɪz.zʌ#mɪk.kæ#dʌk.kɪ#mɪk.kæ#dʌk.kɪ#mɪk.kæ#dʌk
.kɪ#tæs.sʌ#mɪk.kæ#tæs.sʌ#mɪk.kæ#tæs.sʌ#dʌk.kɪ#mɪk.kæ#nɪz.zʌ#dʌk.kɪ#mɪk.kæ#bʌs.sæ#mɪk
.kæ#nɪz.zʌ#dʌk.kɪ#bʌs.sæ#dʌk.kɪ#mɪk.kæ#pæz.zɪ#tæs.sʌ#pæz.zɪ#tæs.sʌ#dʌk.kɪ#nɪz.zʌ#pæz.z
ɪ#dʌk.kɪ#mɪk.kæ#nɪz.zʌ#dʌk.kɪ#bʌs.sæ#tæs.sʌ#bʌs.sæ#mɪk.kæ#nɪz.zʌ#bʌs.sæ#mɪk.kæ#bʌs.s
æ#nɪz.zʌ#mɪk.kæ#bʌs.sæ#mɪk.kæ#pæz.zɪ#tæs.sʌ#bʌs.sæ#pæz.zɪ#dʌk.kɪ#nɪz.zʌ#dʌk.kɪ#nɪz.zʌ
#mɪk.kæ#nɪz.zʌ#bʌs.sæ#nɪz.zʌ#pæz.zɪ#dʌk.kɪ#bʌs.sæ#tæs.sʌ#nɪz.zʌ#bʌs.sæ#pæz.zɪ#bʌs.sæ#
pæz.zɪ#nɪz.zʌ#bʌs.sæ#tæs.sʌ#mɪk.kæ#tæs.sʌ#bʌs.sæ#mɪk.kæ#nɪz.zʌ#pæz.zɪ#bʌs.sæ#dʌk.kɪ#b
ʌs.sæ#pæz.zɪ#bʌs.sæ#pæz.zɪ#nɪz.zʌ#tæs.sʌ#mɪk.kæ#tæs.sʌ#pæz.zɪ#tæs.sʌ#bʌs.sæ#dʌk.kɪ#mɪ
k.kæ#tæs.sʌ#nɪz.zʌ#dʌk.kɪ#pæz.zɪ#nɪz.zʌ#bʌs.sæ#pæz.zɪ#mɪk.kæ#bʌs.sæ#tæs.sʌ#mɪk.kæ#pæ
z.zɪ#mɪk.kæ#tæs.sʌ#dʌk.kɪ#nɪz.zʌ#bʌs.sæ#mɪk.kæ#tæs.sʌ#nɪz.zʌ#tæs.sʌ#pæz.zɪ#mɪk.kæ#bʌs.
sæ#dʌk.kɪ#mɪk.kæ#dʌk.kɪ#bʌs.sæ#tæs.sʌ#pæz.zɪ#tæs.sʌ#pæz.zɪ#dʌk.kɪ#bʌs.sæ#pæz.zɪ#nɪz.z
ʌ#tæs.sʌ#pæz.zɪ#bʌs.sæ#pæz.zɪ#bʌs.sæ#dʌk.kɪ#mɪk.kæ#tæs.sʌ#pæz.zɪ#bʌs.sæ#nɪz.zʌ#tæs.sʌ
#mɪk.kæ#dʌk.kɪ#pæz.zɪ#nɪz.zʌ#bʌs.sæ#nɪz.zʌ#tæs.sʌ#dʌk.kɪ#nɪz.zʌ#dʌk.kɪ#pæz.zɪ#bʌs.sæ#d
ʌk.kɪ#bʌs.sæ#pæz.zɪ#nɪz.zʌ#dʌk.kɪ#bʌs.sæ#nɪz.zʌ#tæs.sʌ#pæz.zɪ#nɪz.zʌ#bʌs.sæ#tæs.sʌ#dʌk.
kɪ#bʌs.sæ#pæz.zɪ#tæs.sʌ#pæz.zɪ#bʌs.sæ#dʌk.kɪ#tæs.sʌ#nɪz.zʌ#dʌk.kɪ#tæs.sʌ#bʌs.sæ#nɪz.zʌ#
pæz.zɪ#nɪz.zʌ#dʌk.kɪ#nɪz.zʌ#tæs.sʌ#mɪk.kæ#nɪz.zʌ#mɪk.kæ#pæz.zɪ#bʌs.sæ#pæz.zɪ#tæs.sʌ#d
ʌk.kɪ#pæz.zɪ#bʌs.sæ#nɪz.zʌ#tæs.sʌ#dʌk.kɪ#tæs.sʌ#bʌs.sæ#tæs.sʌ#nɪz.zʌ#dʌk.kɪ#tæs.sʌ#bʌs.s

æ#mɪk.kæ#dʌk.kɪ#mɪk.kæ#tæs.sʌ#pæz.zɪ#bʌs.sæ#tæs.sʌ#dʌk.kɪ#bʌs.sæ#tæs.sʌ#nɪz.zʌ#mɪk.k
æ#dʌk.kɪ#bʌs.sæ#nɪz.zʌ#pæz.zɪ#tæs.sʌ#mɪk.kæ#dʌk.kɪ#mɪk.kæ#dʌk.kɪ#mɪk.kæ#bʌs.sæ#nɪz.z
ʌ#tæs.sʌ#dʌk.kɪ#nɪz.zʌ#dʌk.kɪ#nɪz.zʌ#dʌk.kɪ#mɪk.kæ#pæz.zɪ#mɪk.kæ#dʌk.kɪ#mɪk.kæ#bʌs.s
æ#mɪk.kæ#bʌs.sæ#mɪk.kæ#tæs.sʌ#pæz.zɪ#nɪz.zʌ#dʌk.kɪ#bʌs.sæ#tæs.sʌ#pæz.zɪ#dʌk.kɪ#bʌs.s
æ#dʌk.kɪ#pæz.zɪ#tæs.sʌ#pæz.zɪ#nɪz.zʌ#bʌs.sæ#dʌk.kɪ#nɪz.zʌ#bʌs.sæ#mɪk.kæ#pæz.zɪ#dʌk.kɪ
#pæz.zɪ#bʌs.sæ#nɪz.zʌ#mɪk.kæ#bʌs.sæ#pæz.zɪ#nɪz.zʌ#mɪk.kæ#nɪz.zʌ#pæz.zɪ#bʌs.sæ#dʌk.kɪ#
mɪk.kæ#pæz.zɪ#nɪz.zʌ#bʌs.sæ#mɪk.kæ#pæz.zɪ#mɪk.kæ#nɪz.zʌ#dʌk.kɪ#bʌs.sæ#mɪk.kæ#tæs.sʌ
#dʌk.kɪ#pæz.zɪ#dʌk.kɪ#tæs.sʌ#nɪz.zʌ#tæs.sʌ#mɪk.kæ#tæs.sʌ#dʌk.kɪ#pæz.zɪ#tæs.sʌ#mɪk.kæ#b
ʌs.sæ#tæs.sʌ#mɪk.kæ#tæs.sʌ#dʌk.kɪ#tæs.sʌ#mɪk.kæ#nɪz.zʌ#mɪk.kæ#pæz.zɪ#dʌk.kɪ#bʌs.sæ#p
æz.zɪ#tæs.sʌ#nɪz.zʌ#dʌk.kɪ#tæs.sʌ#mɪk.kæ#dʌk.kɪ#tæs.sʌ#pæz.zɪ#mɪk.kæ#nɪz.zʌ#mɪk.kæ#tæ
s.sʌ#bʌs.sæ#dʌk.kɪ#tæs.sʌ#bʌs.sæ#tæs.sʌ#mɪk.kæ#nɪz.zʌ#tæs.sʌ#mɪk.kæ#tæs.sʌ#bʌs.sæ#pæz
.zɪ#mɪk.kæ#nɪz.zʌ#mɪk.kæ#nɪz.zʌ#mɪk.kæ#nɪz.zʌ#dʌk.kɪ#pæz.zɪ#tæs.sʌ#nɪz.zʌ#dʌk.kɪ#mɪk.k
æ#tæs.sʌ#dʌk.kɪ#bʌs.sæ#pæz.zɪ#tæs.sʌ#dʌk.kɪ#tæs.sʌ#mɪk.kæ#dʌk.kɪ#mɪk.kæ#bʌs.sæ#nɪz.zʌ
#bʌs.sæ#mɪk.kæ#bʌs.sæ#nɪz.zʌ#dʌk.kɪ#tæs.sʌ#nɪz.zʌ#dʌk.kɪ#mɪk.kæ#dʌk.kɪ#tæs.sʌ#mɪk.kæ
#nɪz.zʌ#dʌk.kɪ#bʌs.sæ#nɪz.zʌ#bʌs.sæ#pæz.zɪ#tæs.sʌ#pæz.zɪ#dʌk.kɪ#bʌs.sæ#tæs.sʌ#dʌk.kɪ#b
ʌs.sæ#pæz.zɪ#dʌk.kɪ#bʌs.sæ#tæs.sʌ#pæz.zɪ#mɪk.kæ#tæs.sʌ#dʌk.kɪ#pæz.zɪ#nɪz.zʌ#pæz.zɪ#dʌ
k.kɪ#pæz.zɪ#nɪz.zʌ#dʌk.kɪ#nɪz.zʌ#pæz.zɪ#tæs.sʌ#dʌk.kɪ#bʌs.sæ#nɪz.zʌ#bʌs.sæ#pæz.zɪ#tæs.sʌ
#bʌs.sæ#nɪz.zʌ#tæs.sʌ#pæz.zɪ#tæs.sʌ#nɪz.zʌ#pæz.zɪ#mɪk.kæ#dʌk.kɪ#mɪk.kæ#tæs.sʌ#nɪz.zʌ#
mɪk.kæ#dʌk.kɪ#pæz.zɪ#nɪz.zʌ#dʌk.kɪ#mɪk.kæ#nɪz.zʌ#bʌs.sæ#dʌk.kɪ#nɪz.zʌ#bʌs.sæ#tæs.sʌ#m
ɪk.kæ#tæs.sʌ#dʌk.kɪ#pæz.zɪ#nɪz.zʌ#bʌs.sæ#mɪk.kæ#nɪz.zʌ#pæz.zɪ#tæs.sʌ#pæz.zɪ#tæs.sʌ#pæz
.zɪ#bʌs.sæ#tæs.sʌ#dʌk.kɪ#mɪk.kæ#pæz.zɪ#mɪk.kæ#nɪz.zʌ#pæz.zɪ#nɪz.zʌ#dʌk.kɪ#pæz.zɪ#tæs.s
ʌ#mɪk.kæ#bʌs.sæ#tæs.sʌ#mɪk.kæ#pæz.zɪ#bʌs.sæ#mɪk.kæ#pæz.zɪ#tæs.sʌ#bʌs.sæ#tæs.sʌ#nɪz.z
ʌ#mɪk.kæ#bʌs.sæ#pæz.zɪ#dʌk.kɪ#mɪk.kæ#tæs.sʌ#dʌk.kɪ#mɪk.kæ#nɪz.zʌ#tæs.sʌ#nɪz.zʌ#tæs.sʌ
#mɪk.kæ#tæs.sʌ#mɪk.kæ#pæz.zɪ#mɪk.kæ#bʌs.sæ#pæz.zɪ#dʌk.kɪ#tæs.sʌ#nɪz.zʌ#bʌs.sæ#pæz.zɪ
#mɪk.kæ#dʌk.kɪ#tæs.sʌ#bʌs.sæ#tæs.sʌ#pæz.zɪ#nɪz.zʌ#tæs.sʌ#bʌs.sæ#tæs.sʌ#bʌs.sæ#dʌk.kɪ#t
æs.sʌ#bʌs.sæ#pæz.zɪ#tæs.sʌ#nɪz.zʌ#pæz.zɪ#mɪk.kæ#bʌs.sæ#mɪk.kæ#dʌk.kɪ#mɪk.kæ#nɪz.zʌ#b
ʌs.sæ#tæs.sʌ#nɪz.zʌ#tæs.sʌ#pæz.zɪ#bʌs.sæ#dʌk.kɪ#pæz.zɪ#mɪk.kæ#nɪz.zʌ#bʌs.sæ#tæs.sʌ#dʌk
.kɪ#tæs.sʌ#nɪz.zʌ#tæs.sʌ#bʌs.sæ#mɪk.kæ#pæz.zɪ#bʌs.sæ#nɪz.zʌ#mɪk.kæ#bʌs.sæ#dʌk.kɪ#bʌs.s
æ#pæz.zɪ#tæs.sʌ#mɪk.kæ#tæs.sʌ#bʌs.sæ#pæz.zɪ#dʌk.kɪ#nɪz.zʌ#pæz.zɪ#bʌs.sæ#tæs.sʌ#pæz.zɪ
#dʌk.kɪ#tæs.sʌ#nɪz.zʌ#mɪk.kæ#bʌs.sæ#nɪz.zʌ#bʌs.sæ#mɪk.kæ#nɪz.zʌ#mɪk.kæ#dʌk.kɪ#bʌs.sæ
#dʌk.kɪ#nɪz.zʌ#bʌs.sæ#pæz.zɪ#nɪz.zʌ#bʌs.sæ#tæs.sʌ#pæz.zɪ#mɪk.kæ#nɪz.zʌ#pæz.zɪ#dʌk.kɪ#
mɪk.kæ#dʌk.kɪ#bʌs.sæ#dʌk.kɪ#tæs.sʌ#bʌs.sæ#dʌk.kɪ#bʌs.sæ#nɪz.zʌ#tæs.sʌ#dʌk.kɪ#pæz.zɪ#d
ʌk.kɪ#bʌs.sæ#pæz.zɪ#bʌs.sæ#mɪk.kæ#bʌs.sæ#mɪk.kæ#pæz.zɪ#tæs.sʌ#nɪz.zʌ#pæz.zɪ#nɪz.zʌ#d
ʌk.kɪ#bʌs.sæ#dʌk.kɪ#mɪk.kæ#pæz.zɪ#tæs.sʌ#bʌs.sæ#tæs.sʌ#bʌs.sæ#dʌk.kɪ#bʌs.sæ#nɪz.zʌ#mɪ
k.kæ#dʌk.kɪ#pæz.zɪ#mɪk.kæ#dʌk.kɪ#pæz.zɪ#mɪk.kæ#bʌs.sæ#mɪk.kæ#pæz.zɪ#mɪk.kæ#pæz.zɪ#
dʌk.kɪ#nɪz.zʌ#pæz.zɪ#dʌk.kɪ#pæz.zɪ#dʌk.kɪ#bʌs.sæ#mɪk.kæ#tæs.sʌ#dʌk.kɪ#bʌs.sæ#mɪk.kæ#t
æs.sʌ#bʌs.sæ#pæz.zɪ#nɪz.zʌ#tæs.sʌ#bʌs.sæ#tæs.sʌ#nɪz.zʌ#mɪk.kæ#dʌk.kɪ#nɪz.zʌ#bʌs.sæ#dʌk
.kɪ#mɪk.kæ#dʌk.kɪ#pæz.zɪ#tæs.sʌ#bʌs.sæ#tæs.sʌ#mɪk.kæ#nɪz.zʌ#tæs.sʌ#dʌk.kɪ#tæs.sʌ#mɪk.k
æ#nɪz.zʌ#bʌs.sæ#pæz.zɪ#dʌk.kɪ#tæs.sʌ#pæz.zɪ#tæs.sʌ#dʌk.kɪ#bʌs.sæ#dʌk.kɪ#pæz.zɪ#bʌs.sæ#
dʌk.kɪ#mɪk.kæ#tæs.sʌ#bʌs.sæ#tæs.sʌ#dʌk.kɪ#mɪk.kæ#bʌs.sæ#dʌk.kɪ#tæs.sʌ#pæz.zɪ#mɪk.kæ#
bʌs.sæ#pæz.zɪ#nɪz.zʌ#pæz.zɪ#bʌs.sæ#pæz.zɪ#bʌs.sæ#nɪz.zʌ#mɪk.kæ#tæs.sʌ#dʌk.kɪ#bʌs.sæ#p
æz.zɪ#bʌs.sæ#tæs.sʌ#mɪk.kæ#pæz.zɪ#bʌs.sæ#dʌk.kɪ#tæs.sʌ#pæz.zɪ#mɪk.kæ#dʌk.kɪ#bʌs.sæ#m
ɪk.kæ#dʌk.kɪ#mɪk.kæ#pæz.zɪ#tæs.sʌ#pæz.zɪ#dʌk.kɪ#mɪk.kæ#nɪz.zʌ#dʌk.kɪ#nɪz.zʌ#dʌk.kɪ#nɪz
.zʌ#pæz.zɪ#nɪz.zʌ#pæz.zɪ#mɪk.kæ#tæs.sʌ#bʌs.sæ#dʌk.kɪ#tæs.sʌ#nɪz.zʌ#mɪk.kæ#pæz.zɪ#tæs.s
ʌ#nɪz.zʌ#pæz.zɪ#dʌk.kɪ#pæz.zɪ#bʌs.sæ#tæs.sʌ#nɪz.zʌ#bʌs.sæ#tæs.sʌ#mɪk.kæ#dʌk.kɪ#tæs.sʌ#
mɪk.kæ#dʌk.kɪ#bʌs.sæ#nɪz.zʌ#pæz.zɪ#mɪk.kæ#nɪz.zʌ#mɪk.kæ#tæs.sʌ#dʌk.kɪ#pæz.zɪ#tæs.sʌ#

nɪz.zʌ#dʌk.kɪ#mɪk.kæ#nɪz.zʌ#tæs.sʌ#nɪz.zʌ#dʌk.kɪ#pæz.zɪ#nɪz.zʌ#dʌk.kɪ#pæz.zɪ#mɪk.kæ#tæs.sʌ#dʌk.kɪ#tæs.sʌ#pæz.zɪ#mɪk.kæ#bʌs.sæ#dʌk.kɪ#nɪz.zʌ#bʌs.sæ#dʌk.kɪ#mɪk.kæ#nɪz.zʌ#pæz.zɪ#bʌs.sæ#mɪk.kæ#dʌk.kɪ#bʌs.sæ#tæs.sʌ#nɪz.zʌ#pæz.zɪ#tæs.sʌ#bʌs.sæ#tæs.sʌ#dʌk.kɪ#pæz.zɪ#tæs.sʌ#bʌs.sæ#tæs.sʌ#nɪz.zʌ#dʌk.kɪ#tæs.sʌ#bʌs.sæ#pæz.zɪ#nɪz.zʌ#mɪk.kæ#tæs.sʌ#pæz.zɪ#bʌs.sæ#dʌk.kɪ#tæs.sʌ#mɪk.kæ#bʌs.sæ#tæs.sʌ#nɪz.zʌ#pæz.zɪ#tæs.sʌ#mɪk.kæ#bʌs.sæ#nɪz.zʌ#pæz.zɪ#dʌk.kɪ#pæz.zɪ#mɪk.kæ#tæs.sʌ#mɪk.kæ#nɪz.zʌ#pæz.zɪ#mɪk.kæ#tæs.sʌ#bʌs.sæ#nɪz.zʌ#bʌs.sæ#tæs.sʌ#nɪz.zʌ#mɪk.kæ#nɪz.zʌ#pæz.zɪ#dʌk.kɪ#pæz.zɪ#mɪk.kæ#nɪz.zʌ#tæs.sʌ#dʌk.kɪ#bʌs.sæ#tæs.sʌ#mɪk.kæ#dʌk.kɪ#mɪk.kæ#bʌs.sæ#dʌk.kɪ#bʌs.sæ#tæs.sʌ#nɪz.zʌ#mɪk.kæ#nɪz.zʌ#mɪk.kæ#tæs.sʌ#dʌk.kɪ#pæz.zɪ#tæs.sʌ#bʌs.sæ#dʌk.kɪ#pæz.zɪ#tæs.sʌ#mɪk.kæ#tæs.sʌ#pæz.zɪ#bʌs.sæ#pæz.zɪ#

APPENDIX G: Transitional probabilities for Experiment 2

Language 1

TP Type	Transition		Count	TP
Syllable TP	bni	fe	228	1
	dgu	sɑ	243	1
	kfɑ	mi	214	1
	lzo	tʃu	229	1
	vte	ko	257	1
	tʃu	vte	100	0.437
	mi	bni	85	0.397
	fe	dgu	85	0.373
	sɑ	kfɑ	85	0.35
	fe	lzo	71	0.311
	ko	dgu	71	0.277
	ko	kfɑ	71	0.277
	fe	vte	57	0.25
	sɑ	vte	58	0.239
	sɑ	lzo	57	0.235
	ko	lzo	58	0.227
	ko	bni	56	0.219
	mi	dgu	44	0.206
	mi	lzo	43	0.201
	mi	vte	42	0.196
	tʃu	bni	43	0.188
	tʃu	dgu	43	0.188
	tʃu	kfɑ	43	0.188
	sɑ	bni	43	0.177
	fe	kfɑ	15	0.066
Word TP	lzotʃu	vteko	100	0.437
	kfɑmi	bnife	85	0.397
	bnife	dgusɑ	85	0.373
	dgusɑ	kfɑmi	85	0.35
	bnife	lzotʃu	71	0.311
	vteko	dgusɑ	71	0.277
	vteko	kfɑmi	71	0.277
	bnife	vteko	57	0.25
	dgusɑ	vteko	58	0.239
	dgusɑ	lzotʃu	57	0.235
	vteko	lzotʃu	58	0.227
	vteko	bnife	56	0.219
	kfɑmi	dgusɑ	44	0.206

	kfɑmi	lzotʃu	43	0.201
	kfɑmi	vteko	42	0.196
	lzotʃu	bnife	43	0.188
	lzotʃu	dgusɑ	43	0.188
	lzotʃu	kfɑmi	43	0.188
	dgusɑ	bnife	43	0.177
	bnife	kfɑmi	15	0.066

Language 2

TP Type	Transition		Count	TP
Syllable TP	fkɑ	mi	226	1
	nbi	fe	211	1
	tve	ko	241	1
	zlo	tʃu	241	1
	gdu	sɑ	271	1
	mi	zlo	90	0.398
	ko	gdu	91	0.378
	tʃu	fkɑ	90	0.332
	fe	tve	75	0.312
	sɑ	nbi	60	0.284
	tʃu	nbi	60	0.284
	tʃu	tve	76	0.28
	ko	zlo	75	0.277
	fe	fkɑ	61	0.253
	fe	zlo	60	0.25
	ko	nbi	60	0.25
	sɑ	fkɑ	59	0.245
	sɑ	tve	46	0.218
	sɑ	zlo	45	0.213
	mi	tve	46	0.204
	mi	gdu	45	0.199
	mi	nbi	45	0.199
	fe	gdu	45	0.188
	ko	fkɑ	30	0.124
	tʃu	gdu	30	0.111
Word TP	fkɑmi	zlotʃu	90	0.398
	zlotʃu	fkɑmi	91	0.378
	tveko	gdusɑ	90	0.332
	nbife	tveko	75	0.312
	gdusɑ	nbife	60	0.284
	zlotʃu	nbife	60	0.284

	zlotʃu	tveko	76	0.28
	tveko	zlotʃu	75	0.277
	nbife	fkɑmi	61	0.253
	nbife	zlotʃu	60	0.25
	tveko	nbife	60	0.25
	gdusɑ	fkɑmi	59	0.245
	gdusɑ	tveko	46	0.218
	gdusɑ	zlotʃu	45	0.213
	fkɑmi	tveko	46	0.204
	fkɑmi	gdusɑ	45	0.199
	fkɑmi	nbife	45	0.199
	nbife	gdusɑ	45	0.188
	tveko	fkɑmi	30	0.124
	zlotʃu	gdusɑ	30	0.111

APPENDIX H: Transitional probabilities for Experiment 4

Language 1

TP Type	Transition		Count	TP
Syllable TP	bɛk	kɛ	198	1
	dɛs	sɛ	216	1
	mɛz	zɛ	220	1
	nɛk	kɛ	202	1
	pɛs	sɛ	196	1
	tɛz	zɛ	214	1
	kɛ	mɛz	96	0.24
	sɛ	tɛz	90	0.218
	zɛ	dɛs	94	0.217
	zɛ	pɛs	90	0.208
	kɛ	dɛs	82	0.205
	sɛ	mɛz	84	0.204
	zɛ	nɛk	84	0.194
	sɛ	bɛk	76	0.184
	sɛ	nɛk	74	0.18
	kɛ	tɛz	70	0.175
	zɛ	bɛk	71	0.164
	kɛ	pɛs	58	0.145
	kɛ	bɛk	50	0.125
	zɛ	tɛz	54	0.125
	sɛ	pɛs	48	0.117
	kɛ	nɛk	44	0.11
	sɛ	dɛs	40	0.097
	zɛ	mɛz	40	0.092
Word TP	pɛssɛ	tɛzzɛ	50	0.255
	bɛkkɛ	mɛzzɛ	50	0.253
	tɛzzɛ	dɛssɛ	54	0.252
	nɛkkɛ	bɛkkɛ	50	0.248
	mɛzzɛ	tɛzzɛ	54	0.247
	dɛssɛ	bɛkkɛ	50	0.231
	nɛkkɛ	mɛzzɛ	46	0.228
	pɛssɛ	nɛkkɛ	44	0.224
	tɛzzɛ	nɛkkɛ	48	0.224
	bɛkkɛ	nɛkkɛ	44	0.222
	dɛssɛ	mɛzzɛ	48	0.222
	dɛssɛ	pɛssɛ	48	0.222
	tɛzzɛ	pɛssɛ	46	0.215
	bɛkkɛ	dɛssɛ	42	0.212

	mɛzzɛ	bɛkkɛ	45	0.205
	pɛssɛ	dɛssɛ	40	0.204
	mɛzzɛ	pɛssɛ	44	0.201
	nɛkkɛ	dɛssɛ	40	0.198
	tɛzzɛ	mɛzzɛ	40	0.187
	dɛssɛ	tɛzzɛ	40	0.185
	pɛssɛ	mɛzzɛ	36	0.184
	mɛzzɛ	dɛssɛ	40	0.183
	nɛkkɛ	tɛzzɛ	36	0.178
	bɛkkɛ	tɛzzɛ	34	0.172
	mɛzzɛ	nɛkkɛ	36	0.164
	nɛkkɛ	pɛssɛ	30	0.149
	bɛkkɛ	pɛssɛ	28	0.141
	dɛssɛ	nɛkkɛ	30	0.139
	pɛssɛ	bɛkkɛ	26	0.133
	tɛzzɛ	bɛkkɛ	26	0.121

Language 2

TP Type	Transition		Count	TP
Syllable TP	bʌs	sʌ	196	1
	dʌk	kʌ	184	1
	mʌk	kʌ	198	1
	nʌz	zʌ	198	1
	pʌz	zʌ	222	1
	tʌs	sʌ	202	1
	kʌ	pʌz	92	0.241
	sʌ	pʌz	95	0.239
	zʌ	mʌk	100	0.238
	kʌ	tʌs	80	0.209
	zʌ	bʌs	82	0.195
	zʌ	tʌs	80	0.19
	kʌ	nʌz	72	0.188
	sʌ	mʌk	74	0.186
	kʌ	bʌs	70	0.183
	sʌ	nʌz	72	0.181
	sʌ	dʌk	70	0.176
	zʌ	dʌk	70	0.167
	zʌ	nʌz	54	0.129
	kʌ	dʌk	44	0.115
	sʌ	bʌs	44	0.111
	sʌ	tʌs	42	0.106

	zʌ	pʌz	34	0.081
	kʌ	mʌk	24	0.063
Word	nʌzzʌ	mʌkkʌ	54	0.273
	bʌssʌ	pʌzzʌ	53	0.272
	dʌkkʌ	pʌzzʌ	50	0.272
	pʌzzʌ	nʌzzʌ	54	0.243
	mʌkkʌ	tʌssʌ	46	0.232
	nʌzzʌ	bʌssʌ	46	0.232
	mʌkkʌ	dʌkkʌ	44	0.222
	tʌssʌ	bʌssʌ	44	0.218
	dʌkkʌ	nʌzzʌ	40	0.217
	pʌzzʌ	tʌssʌ	48	0.216
	bʌssʌ	tʌssʌ	42	0.215
	mʌkkʌ	pʌzzʌ	42	0.212
	tʌssʌ	nʌzzʌ	42	0.208
	tʌssʌ	pʌzzʌ	42	0.208
	pʌzzʌ	mʌkkʌ	46	0.207
	bʌssʌ	mʌkkʌ	40	0.205
	tʌssʌ	dʌkkʌ	40	0.198
	dʌkkʌ	bʌssʌ	36	0.196
	dʌkkʌ	tʌssʌ	34	0.185
	mʌkkʌ	bʌssʌ	34	0.172
	nʌzzʌ	pʌzzʌ	34	0.172
	pʌzzʌ	dʌkkʌ	38	0.171
	tʌssʌ	mʌkkʌ	34	0.168
	mʌkkʌ	nʌzzʌ	32	0.162
	nʌzzʌ	dʌkkʌ	32	0.162
	nʌzzʌ	tʌssʌ	32	0.162
	pʌzzʌ	bʌssʌ	36	0.162
	bʌssʌ	dʌkkʌ	30	0.154
	bʌssʌ	nʌzzʌ	30	0.154
	dʌkkʌ	mʌkkʌ	24	0.13

APPENDIX I: Transitional probabilities for Experiment 5

Language 3

TP Type	Transition		Count	TP
Syllable TP	bæk	kɪ	206	1
	dʌs	sɪ	200	1
	mæz	zʌ	189	1
	nɪk	kʌ	172	1
	pɪs	sæ	184	1
	tʌz	zæ	184	1
	kʌ	dʌs	46	0.267
	zæ	bæk	47	0.255
	kɪ	dʌs	50	0.243
	sæ	bæk	44	0.24
	zæ	mæz	44	0.239
	sɪ	tʌz	47	0.235
	sɪ	bæk	46	0.23
	zʌ	nɪk	43	0.228
	kʌ	pɪs	37	0.215
	kɪ	tʌz	44	0.214
	sɪ	mæz	42	0.21
	sæ	dʌs	38	0.208
	kɪ	pɪs	42	0.204
	sæ	mæz	37	0.202
	zʌ	pɪs	37	0.196
	zʌ	tʌz	37	0.196
	zæ	pɪs	35	0.19
	zʌ	bæk	36	0.19
	zʌ	dʌs	36	0.19
	kʌ	bæk	32	0.186
	kʌ	mæz	32	0.186
	sæ	nɪk	33	0.18
	kɪ	nɪk	36	0.175
	sæ	tʌz	31	0.169
	kɪ	mæz	34	0.165
	sɪ	pɪs	33	0.165
	zæ	dʌs	30	0.163
	sɪ	nɪk	32	0.16
	zæ	nɪk	28	0.152
	kʌ	tʌz	25	0.145
Word TP	nɪkkʌ	dʌssɪ	46	0.267
	tʌzzæ	bækkɪ	47	0.255

	bækkɪ	dʌssɪ	50	0.243
	pɪssæ	bækkɪ	44	0.24
	tʌzzæ	mæzzʌ	44	0.239
	dʌssɪ	tʌzzæ	47	0.235
	dʌssɪ	bækkɪ	46	0.23
	mæzzʌ	nɪkkʌ	43	0.228
	nɪkkʌ	pɪssæ	37	0.215
	bækkɪ	tʌzzæ	44	0.214
	dʌssɪ	mæzzʌ	42	0.21
	pɪssæ	dʌssɪ	38	0.208
	bækkɪ	pɪssæ	42	0.204
	pɪssæ	mæzzʌ	37	0.202
	mæzzʌ	pɪssæ	37	0.196
	mæzzʌ	tʌzzæ	37	0.196
	mæzzʌ	bækkɪ	36	0.19
	mæzzʌ	dʌssɪ	36	0.19
	tʌzzæ	pɪssæ	35	0.19
	nɪkkʌ	bækkɪ	32	0.186
	nɪkkʌ	mæzzʌ	32	0.186
	pɪssæ	nɪkkʌ	33	0.18
	bækkɪ	nɪkkʌ	36	0.175
	pɪssæ	tʌzzæ	31	0.169
	bækkɪ	mæzzʌ	34	0.165
	dʌssɪ	pɪssæ	33	0.165
	tʌzzæ	dʌssɪ	30	0.163
	dʌssɪ	nɪkkʌ	32	0.16
	tʌzzæ	nɪkkʌ	28	0.152
	nɪkkʌ	tʌzzæ	25	0.145

Language 4

TP Type	**Transition**		**Count**	**TP**
Syllable TP	bʌs	sæ	186	1
	dʌk	kɪ	200	1
	mɪk	kæ	192	1
	nɪz	zʌ	171	1
	pæz	zɪ	195	1
	tæs	sʌ	200	1
	sæ	tæs	47	0.253
	kɪ	mɪk	48	0.24
	zɪ	tæs	46	0.237
	kæ	dʌk	45	0.234

	kæ	tæs	44	0.229
	kɪ	bʌs	45	0.225
	zʌ	pæz	38	0.222
	kɪ	pæz	44	0.22
	sæ	dʌk	40	0.215
	zʌ	dʌk	36	0.211
	sʌ	dʌk	42	0.21
	sʌ	pæz	41	0.205
	zʌ	bʌs	35	0.205
	sæ	pæz	38	0.204
	kæ	nɪz	39	0.203
	zɪ	mɪk	39	0.201
	sʌ	nɪz	40	0.2
	sʌ	mɪk	39	0.195
	zʌ	mɪk	33	0.193
	zɪ	bʌs	37	0.191
	zɪ	dʌk	37	0.191
	sʌ	bʌs	38	0.19
	zɪ	nɪz	35	0.18
	sæ	mɪk	33	0.177
	kæ	pæz	33	0.172
	kɪ	tæs	34	0.17
	zʌ	tæs	29	0.17
	kæ	bʌs	31	0.161
	sæ	nɪz	28	0.151
	kɪ	nɪz	29	0.145
Word TP	bʌssæ	tæssʌ	47	0.253
	dʌkkɪ	mɪkkæ	48	0.24
	pæzzɪ	tæssʌ	46	0.237
	mɪkkæ	dʌkkɪ	45	0.234
	mɪkkæ	tæssʌ	44	0.229
	dʌkkɪ	bʌssæ	45	0.225
	nɪzzʌ	pæzzɪ	38	0.222
	dʌkkɪ	pæzzɪ	44	0.22
	bʌssæ	dʌkkɪ	40	0.215
	nɪzzʌ	dʌkkɪ	36	0.211
	tæssʌ	dʌkkɪ	42	0.21
	nɪzzʌ	bʌssæ	35	0.205
	tæssʌ	pæzzɪ	41	0.205
	bʌssæ	pæzzɪ	38	0.204
	mɪkkæ	nɪzzʌ	39	0.203
	pæzzɪ	mɪkkæ	39	0.201
	tæssʌ	nɪzzʌ	40	0.2

	tæssʌ	mɪkkæ	39	0.195
	nɪzzʌ	mɪkkæ	33	0.193
	pæzzɪ	bʌssæ	37	0.191
	pæzzɪ	dʌkkɪ	37	0.191
	tæssʌ	bʌssæ	38	0.19
	pæzzɪ	nɪzzʌ	35	0.18
	bʌssæ	mɪkkæ	33	0.177
	mɪkkæ	pæzzɪ	33	0.172
	dʌkkɪ	tæssʌ	34	0.17
	nɪzzʌ	tæssʌ	29	0.17
	mɪkkæ	bʌssæ	31	0.161
	bʌssæ	nɪzzʌ	28	0.151
	dʌkkɪ	nɪzzʌ	29	0.145

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