THE PHONOLOGICAL REPRESENTATION OF /S/ VERSUS /SH/ IN JAPANESE

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CONTENTS

0. NOTATION

I will follow the practice of using square brackets [] for Auditory Forms, slashes // for prelexical Surface Forms and vertical lines || for lexical Underlying Forms. Chapter 3 discusses these terms in more detail.

Further, I use /sh/ for the IPA notations /ʃ/ (English phoneme) and /ç/ (Japanese phoneme), while /ch/ stands for the IPA notations /tʃ/ (English affricate) and /cç/ (Japanese affricate). Also, /j/ refers to the IPA notations /ʤ/ (English affricate) and /ɟʑ/ (Japanese affricate). The notations /sh/, /ch/ and /j/ are based on the Hepburn way of transcribing Japanese, which most Japanese-English dictionaries have adopted.

In Japanese words both vowels and consonants may be lengthened. Long vowels are represented by a macron (for instance: ā or ō). Only in Auditory Forms I will follow the practice of using a colon (for example: [a:] or [o:]). Long consonants (geminates) appear as double letters (for instance: kk or tt). Finally, an asterisk * indicates an impossible sound (combination).

1. INTRODUCTION

This study is an attempt to gain insight in the phonological representation of /s/ versus /sh/ in Japanese. Due to the introduction of (mainly English) loanwords, /s/ and /sh/ may be developing into phonemes that can combine with all vowels rather than being phonemes before /u/, /o/ and /a/ and complements before /i/ and /e/. In order to clarify the status of /s/ and /sh/, two Japanese participants were tested in an auditory lexical decision task, in which I measured repetition priming effects.

The structure of this paper is as follows. In the first part I will explain why I picked the contrast between /s/ and /sh/ as the central subject of this paper. Also, I will discuss the theoretical framework. Taking Boersma's model of bidirectional phonology and phonetics (2005 as in 2006b) as a starting point, I will describe the experiment in part II. Part III contains the results, a discussion and some suggestions for future research.

PART I: THEORY

2. THE RELEVANCE OF STUDYING /S/ AND /SH/

2.1 Introduction

This chapter illustrates why it is relevant to look into /s/ and /sh/ in Japanese. The expectation is that /si/ (a non-existent sound in Japanese so far) will eventually be adopted into standard Japanese[1], leading to a full phonemic status of /s/ and /sh/. This expectation is based on a similar and more developed pattern of change for the opposition between /t/ and /ch/. The drive behind the changes seems to be the influence of English contrasts.

2.2 Japanese consonants

Japanese consonants have palatized and non-palatized forms. They are palatized (and /t/ is also affricated) before the high front vowel /i/, while the palatized forms cannot occur before the mid front vowel /e/ (Akamatsu, 1997; Tsujimura, 2007). Table 1 shows this complementary distribution for /k/, /r/, /s/ and /t/ and their palatized (for /t/ also affricated) counterparts.[2]

Table 1: Indigenous syllables beginning with /k/, /r/, /s/ and /t/ and their palatized (and for /t/ also affricated) counterparts

ku	k'u	ru	r'u	su	shu	tsu	chu
ko	k'o	ro	r'o	so	sho	to	cho
ka	k'a	ra	r'a	sa	sha	ta	cha
ke	*k'e	re	*r'e	se	*she	te	*che
*ki	k'i	*ri	r'i	*si	shi	*ti	chi

Since the non-palatized and the palatized forms appear in complementary positions before front vowels, the question arises if both of these forms may be considered 'true phonemes'. For the consonants appearing before /u/, /o/ and /a/, the two forms seem to be phonemic and not mere allophonic variations: both may occur, resulting in minimal pairs such

[1] Following Akamatsu (1997), 'standard Japanese' refers to "what the Japanese hear – and expect to hear – from the mouths of radio and television newsreaders anywhere in Japan" (Akamatsu, 1997, 5). Although it is "generally used in the Tokyo-Yokohama conurbation", in "adjoining areas" (id.) as well as in the northern island of Hokkaido, it is not considered a particular regional dialect.

[2] For palatized consonants other than /sh/ and /ch/ I deviate from the Hepburn notation (mentioned in chapter 0 of this paper), since it does not reveal the similarity between them. For example, /k'i/, /k'u/, /k'o/ and /k'a/ would be written as /ki/ versus /kyu/, /kyo/ and kya/.

as *kaku* 'to lack' versus *k'aku* 'guest', *sakai* 'boundary' versus *shakai* 'society' and *chūshin* 'centre' versus *tsūshin* 'correspondence', 'communication'.

2.3 The influence of English

For /t/ versus /ch/ and for /s/ versus /sh/ new sounds in English loanwords have challenged the complementary distribution of (non)-palatized forms before front vowels. The adoption of English loanwords started in the second half of the 19th century and has accelerated in the last decades. Consequently, the influence of English on the Japanese vocabulary (and, as a concomitant, the sound system) has been substantial, even though it is difficult to pinpoint it in numbers.[3]

In English /t/ and /ch/ combine with all vowels, including /i/ and /e/, to form minimal pairs. The same goes for the voiced counterparts /d/ and /j/ and for /s/ and /sh/. Examples include *tease* versus *cheese*, *Terry* versus *cherry*, *deep* versus *jeep*, *debt* versus *jet*, *sea* (or *see*) versus *she* and *self* versus *shelf*. As a result the Japanese sound system has been confronted with the new sounds [ti] versus [chi], [che] versus [te], [di] versus [ji], [je] versus [de], [si] versus [shi] and [she] versus [se]. Because English does not have minimal pairs based on palatized and non-palatized versions of other consonants, the other consonants have not exerted a similar pressure on the phonemic inventory.

As I will discuss in more detail in chapter 3, listeners tend to categorize new sounds on the basis of the sound system that they are familiar with (Polivanov, 1931/translation 1974). Therefore we expect the [ti] in English loanwords to appear in the Japanese vocabulary as [chi]. Examples of English loanwords with [ti] confirm this pattern: 'ticket' has appeared as *chiketto*, 'tip' as *chippu* and 'team' as *chīmu*.[4]

In the last decades, however, [ti] has shown up as well. Whereas Lovins mentions in 1975 that "In recent borrowings /ti di/ are pronounced with 'plain' consonants in exceptional cases" (Lovins, 1975: 144), Akamatsu reports about twenty years later that the choice for pronouncing [ti] or [chi] depends "on individual items and also on individual Japanese

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[3] I could not find numerical data on the amount of adopted words and the pace of adoption. The following data might give an indication. Estimates that were documented before the Second World War mention 1400 words discovered in 1928 by a Japanese scholar "in a few months reading newspapers and magazines" (Miller, 1967, 249). In 1930 "another Japanese researcher claimed to be able to list 5000 words." (Id.) The newest "Encyclopedia of Contemporary Words" (Gendai Yogo no Kiso Chishiki, 2007), which appears every year, lists more than 10.000 new (mainly English) loanwords.

[4] In a few loanwords [ti] is adopted as [te]. That is: the adjustment boiled down to "lowering the vowel and saving the stop" rather than "affricating the consonant while preserving the high vowel" (both quotes from Lovins, 1975: 55-56). Examples are *sutekki* ('walking stick') and *sutekkā* ('sticker') (examples from Kenkyūsha, 1974 and Lovins, 1975, 56).

speakers" (Akamatsu, 1997: 80). He also mentions that loanwords containing [ti] "occur frequently in everyday discourse of any Japanese speakers, young and old, and are therefore not rare items" (id.: 81).

This change is reflected in several loanwords. Examples are *tī* 'tea' (plus combinations such as *tī pātī* 'tea party') and *tī shatsu* 'T-shirt'. In addition, we encounter loanwords with [di] (such as *disuku* 'disc'), [je] (such as *jetto* 'jet'), [che] (such as *chesu* 'chess') and [she] (such as *sherī* 'sherry')[5]. At the same time loanwords with [si] do not appear: all instances of [si] appear as [shi] in Japanese words (Itō & Mester, 1999, 2006). Examples include *shī* 'sea' (and combinations such as *shī fūdo* 'seafood') and *shirubā* 'silver'.

Table 2 illustrates the new syllable inventory for palatized and non-palatized forms of /s/ and /t/. For /t/ versus /ch/ (as for the voiced counterparts) the complementary nature before front vowels has disappeared, resulting in complete phonemic paradigms without the empty spaces that we saw in Table 1. As for /s/ versus /sh/ however, the inventory seems unstable: the complementary distribution before /i/ and /e/ has vanished without leading to a complete phonemization of /s/.

Table 2: Indigenous syllables beginning with /s/-/sh/ and /t/-/ch/ and the new syllables /she/, /che/ and /ti/

su	shu	tsu	chu
so	sho	to	cho
sa	sha	ta	cha
se	***she***	te	***che***
*si	shi	***ti***	chi

2.4 Hypothesis and research questions

Given that the phonemic inventory seems unstable, the hypothesis is that /si/ will eventually be adopted into standard Japanese.[6] It seems worthwhile to look into the perception of [si], since we expect the change to appear in perception before production: speakers will not

[5] I could not find examples of loanwords in which [che] was adopted as [te]. As for [she], there is an example of a loanword in which this sound was adopted as [se]: originally the word 'shepherd' (for 'shepherd dog') was taken up as *sepādo*, but now *shepādo* seems to be more common. (Gakushū Kenyūsha, 1967; Kenkyūsha, 1974 and Shogakukan, 1988). The data suggest that the difference between palatized and non-palatized forms is more difficult to perceive (1) before the highest vowel [i] than before [e] and (2) for fricatives than for plosives.
[6] See note 1.

produce phonemic distinctions between sounds without being able to hear them apart, while they may perceive new sounds without being able to produce them correctly.

I will focus on the following three research questions (which will be formulated in more detail at the end of the next chapter). Do Japanese people perceive a difference between the English syllables [si] (which does not occur in Japanese words) and [shi]? Are there differences in their perception of the English [s] and [sh] before other vowels? And can we pinpoint a pattern of change comparable to the adoption of the English sound [ti] as /ti/ rather than as /chi/?

3. THE THEORETICAL FRAMEWORK

3.1 Some controversies

In the literature we find different models that account for speech perception and the way words and their sounds are stored in the human brain. There appear to be at least three points of controversy. (The following brief description of the first two points is based on several authors among whom Lahiri and Reetz, 2002; McLennan et. al. 2003; Nguyen, 2005 and Pallier et. al. 2001. The third point is discussed in Carroll, 2004).

One question is the 'level of abstraction' that occurs in storing words. Are words stored directly as concrete exemplars or do we form more abstract phonological entities as we learn them? And if we form abstractions, do we do so rigorously or do we retain some acoustic detail in the lexical representations?

A second issue, relating to the comprehension of words, is whether we hypothesize one or more intermediate levels between the acoustic signal and the lexical representation. All models seem to "assume that sensory information is initially recoded in some manner" (McLennan et.al., 2003, 539). At the same time, some models specify several intermediate levels (containing for example feature, phoneme and syllable levels), while other ones claim a more direct mapping of acoustic material onto lexical forms.

A third point of discussion, which pertains to mediated access models is whether the levels are activated sequentially (i.e. one by one, in neat steps), in a parallel fashion (so that the levels may be activated at the same time) or interactively (so that in addition to parallel activation, the activation may also spread in both directions, i.e. from lower levels to higher ones or the other way around). A famous example of an interactive speech perception model is McClelland and Elman's TRACE model (1986. See for instance Carroll, 2004).

3.2 Boersma's model

In this paper I will take Boersma's model of parallel bidirectional phonology and phonetics (Boersma 2005, Apoussidou 2006; as in Boersma 2006b) as a starting point. Figure 1 illustrates the model.

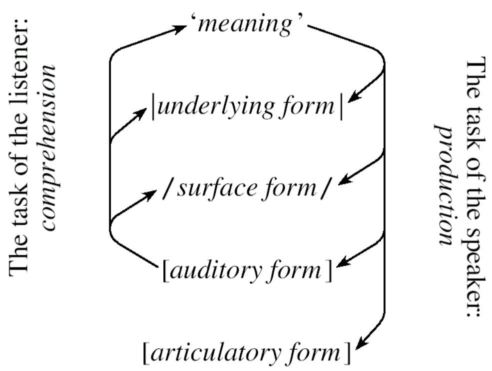

Figure 1: Grammar model
(Boersma 2005, Apoussidou 2006. Source: Boersma, 2006b)

The model is bidirectional in that it describes the processes of both comprehension and production. As we will study the perception of /s/ and /sh/, we will focus on the comprehension part. In the figure comprehension starts with hearing an Auditory Form (almost at the bottom) and ends with grasping a meaning (at the top).

Articulatory and Auditory Forms (at the bottom) are phonetic representations. The former represents articulatory gestures, the latter auditory information such as pitches and formants. In the model the Auditory Form rather than the Articulatory Form is the starting point for comprehension and the connection with the two phonological representations: the Surface Form and the Underlying Form. In this paper I will follow this assumption, although the reverse option (that the Articulatory Form is the main link) seems possible as well (Boersma, 2006a).

When someone hears an Auditory Form, he will first categorize it as a Surface Form, which consists of "abstract phonological elements such as features, segments, syllables and feet" (Boersma, 2006a, 2). This step involves partitioning a continuous stream of information into discrete known elements and may also be called *prelexical perception*. The second step from Surface Form to Underlying Form is the *recognition* of a sound form available in the lexicon. The Underlying Form, therefore, is the lexical representation: it symbolizes the sound forms of morphemes and words.

Polivanov observed that the first step is language-specific: when a listener hears "a foreign, unfamiliar word" he will try "to break it down into his own phonemes, and even in conformity with his own laws of combining phonemes (i.e. inherent to the listener's native language)" (Polivanov, 1931/ translation 1974, 223). This does not imply that Surface Forms may never change. As we saw, in Japanese /t/ and /ch/ may have developed into full phonemes due to the availability of English minimal pairs with the Auditory Forms [ti] versus [chi] and [che] versus [te]. Therefore, a crucial element in a process of change like this appears to be the interaction of phonology with both phonetics (i.e. the Auditory Forms should be available) *and* semantics (i.e. separating homophones into words with different Underlying Forms improves comprehension) (Boersma, 2006a).

Although I will not pursue the theoretical implications of a parallel model versus a sequential or an interactive one, I should mention that on the basis of the description of these terms in section 3.1, the model could be labelled as parallel for perception[7] and interactive for production (Boersma, 2007a).

3.3 The recognition of [shi:] and [si:]

Let us consider an example pertaining to the topic of this paper: how will a Japanese native speaker perceive and recognize the Auditory Forms [shi:] ('she') and [si:] ('sea' or 'see'), as pronounced by a native speaker of English? Figure 2 lists the options. The top row corresponds to the meaning. The upper middle row stands for the Underlying Forms, the lower middle row for the Surface Forms and the row at the bottom for the Auditory Forms.

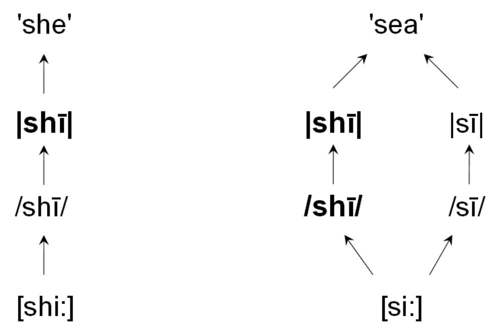

Figure 2: Options for the recognition of [shi:] and [si:] by a Japanese native speaker

First we will reflect on the recognition of [shi:]. Since the English [sh] is very similar to a Japanese [sh], the odds are high that a Japanese listener will categorize the first sound as /sh/. Consequently, the Surface Form /shī/ will activate the lexical form |shī|. Higher up in the model the listener may retrieve the meaning ('she') associated with this sound form.

For [si:] there are two scenarios. We may expect a Japanese-specific categorization as

[7] In figure 1 parallel (rather than sequential) activation is represented by connected (rather than separate) arrows (Boersma, 2006a). To keep the explanation simple, the model was described as sequential for perception.

/shī/, since /si/ is not a possible combination in the Japanese lexicon. If this happens, the Japanese listener will activate an underlying |shī| rather than |sī|. Because this form is identical to the one constructed upon hearing [shī], the two English words *she* and *sea* will be homophones in the listener's lexicon.

The second possibility is that [si:] is categorized as /sī/, leading to the underlying word form |sī|. In this case the two English words *she* and *sea* will not be homophones in the listener's lexicon. If this scenario occurs, it could indicate a potential change in the Japanese phonemic (and/or syllabic) inventory,[8] which could be comparable to the introduction of /ti/ versus /chi/.

3.4 Speculations on the absence of [si]

The model may also serve as a basis for explaining potential reasons for the absence of [si] in loanwords as opposed to the presence of [ti]. One option is that the *perception* of [si] (i.e. the first step from Auditory Form to Surface Form) is more difficult for [si] than for [ti]. A complicating factor might be that the English phonemes /th/[9] and /s/ assimilate to a single category[10] /s/ (Tsujimura, 2007). As a result Japanese listeners will categorize [thi] and [si] as the same sound, which is probably /shi/. As figure 3 shows, this would mean that they would have to learn to split the single syllable /shi/ into three rather than 'just' two sounds.

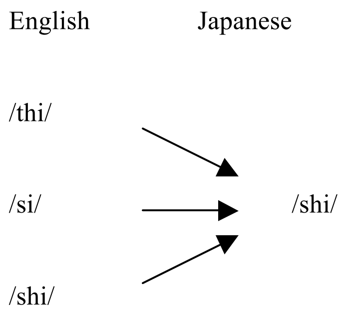

Figure 3: Potential assimilation of /si/, /shi/ and /thi/

[8] Proponents of exemplar-based models could argue that the activation of |si:| supports their claim of a direct mapping of acoustic information to memorized elements. In this view the recognition of |si:| would not necessarily be due to a change in the sound system.
[9] The IPA-notation is [▯].
[10] Best et.al. define Single Category assimilation as the situation that two "non-native phones (…) assimilate equally well or poorly to a single native phoneme" (Best et.al., 2001, 777). Another possibility is that "both might assimilate to a single native phoneme, but one may fit better than the other, termed a Category Goodness difference" (id.). The latter option could also apply to /s/ and /th/.

A second option is that the *articulation* is the main obstacle against the appearance of [si]. In this scenario [si] would be perceived as /si/ and taken up as |si| in words. It would just not appear as such in production due to articulatory constraints, i.e. in figure 1 the last step in production (to the Articulatory Form) would be hampered.

Finally, there may be factors that complicate both the comprehension and the production of [si]. An example is the fact that [shi] appears to be one of the most frequent sounds in the Japanese vocabulary. To obtain a rough indication of the difference with [chi], I counted the number of pages with words beginning with [shi] and [chi] in the well-known Japanese dictionary Shōgakukan (edition 1988). For [shi] the number mounted up to 133 pages, compared to just 19 pages for [chi]. The potential impact of this difference becomes clear, if we consider the adoption process again. If this process is based on the interaction of phonology with both phonetics and semantics (as was referred to above), then it might be that /si/ does not exist due to an abundance of (1) Auditory Forms [shi] and (2) Underlying Forms with |shi|.

3.5 Once more: the research questions

We may exploit the possibility that [si:] and [shi:] may both be categorized as /shī/, resulting in homophones in the lexicon (as figure 2 showed). To this end, we need to reformulate the research questions. Rather than asking if Japanese people would perceive a difference between the *syllables* [si] and [shi], we should ask whether they recognize a difference between *words* with [si] and [shi], i.e. will they hear English minimal pairs with [si] and [shi] as homophones or not? Further, are there differences in their recognition of English words containing [s] versus [sh] before other vowels? And can we pinpoint a pattern of change, based on the recognition of English words with [ti] as opposed to [chi]? The next chapter converts these questions into an experimental design.

PART II: THE EXPERIMENT

4. DESIGN

4.1 Two requirements

Since the research questions centre on words, we cannot use a discrimination task or an identification task. In terms of the model outlined in the last chapter discrimination tasks focus on Auditory Forms: they determine whether a listener can hear a difference between sounds. Identification tasks relate to Surface Forms: they measure how a listener categorizes sounds. Instead, we need a task that (1) taps Underlying Forms and (2) exploits the fact that minimal pairs pronounced with [si] versus [shi] may be recognized as homophones.

A task that meets both requirements is an auditory lexical decision task that is used to measure repetition priming effects. The idea to use this task is based on experiments that have been conducted with early Catalan-Spanish bilinguals by Pallier et.al. (1999, 2001) and with native speakers of standard French and southern French by Dufour et.al. (2005 as in Nguyen, 2005; 2007). First I will explain why a lexical decision task seems suitable. A few drawbacks will also be discussed. Next, I will illustrate the purpose of measuring repetition priming effects.

4.2 A lexical decision task

In lexical decision tasks participants see or hear words and non-words and must quickly decide for each item whether it is a word (or not). Depending on the purpose different variables may be measured. In this study I measured reaction times (the reason will become clear in the next section) for auditory stimuli. The two buttons of a computer mouse were used to record reaction times for words and non-words separately. A Japanese participant heard a list of English stimuli and was asked to push the left button upon hearing a word and the right button upon hearing a non-word.

Since the task relates to the processing of *words*, it will tap lexical representations (which was the first requirement). The reaction times on the non-words may support this: if these differ reliably from the reaction times for words, the difference may be caused by the fact that words are part of the listener's lexicon and non-words are not.

Considering the suitability of the task in more detail, it may well be that the task taps *phonological* lexical representations in particular. Although in many lexical decision tasks there is an "implicit requirement of full lexical processing" (Goldinger, 1996, 559), we cannot be sure that a participant will retrieve semantic representations. At any rate, presenting a list of words and non-words, stripped off context, does not encourage participants to retrieve meanings.

Some potential drawbacks of the task should also be pointed out. The first shortcoming is that it is 'unnatural'. This holds true for all experiments, but even more so for this one. In a spontaneous conversation listeners will assume that the speaker's contribution is meaningful. Consequently, they will concentrate on unmasking the speaker's words as quickly as possible and most words will be identified before the speaker finishes pronouncing them. In a lexical decision task, however, the listener is forced to block this natural behaviour and to wait until the speaker finishes reading out the item. After all, final sound elements may determine whether an item is a word or not. For example, *drump* can be mislabelled as a word, if the listener expects *drum* and makes his decision before the end of the item.

Secondly, it is important to realize that reaction times are not clear-cut indications of lexical access. There are many variables influencing them. Some of these may be controlled for, but other ones are hard to exclude. For instance, part of the reaction times may reflect a 'decision stage' apart from the perceptual process of lexical retrieval (Goldinger, 1996; McLennan, 2003).[11] Also, time is needed for pushing the right button.

4.3 Measuring repetition priming effects

The second requirement was that the task exploits the fact that minimal pairs pronounced with [si] versus [shi] may be recognized as homophones. This can be accommodated by measuring repetition priming effects. "The repetition priming effect describes facilitation in the speed or accuracy with which a word is read (or heard), produced by prior presentation of that word" (Lainé et.al., 1998, 2; comma added). In other words, if we present words in *same* pairs (i.e. the first and the second items are identical), we expect the reaction time for the second item to be shorter. This effect has been demonstrated in several tasks, among which lexical decision tasks. For this study the crucial point is that we may expect a similar facilitating effect, if we present *minimal* pairs that the participant perceives as homophones. Let me illustrate this on the basis of the example of [si:] and [shi:] again.

Suppose that we use the scenario pictured in figure 4. A Japanese participant hears the word [shi:] (the 'prime') for the first time in the experiment. Lexical retrieval will cost a certain amount of time (which we will call reaction time 1 or RT1). After several other items, he will encounter the same word again (the 'target'). Because the word has been activated

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[11] In lexical decision tasks "additional processing [in addition to perceptual processing, kw] is required to make a lexical decision" (McLennan et.al., 2003, 546; see also Goldinger, 1996), i.e. it is as if the listener needs time to weigh the pros and cons of his decision. Empirical evidence for a 'decision stage' is that shadowing tasks, for which no lexical decision is required, yield smaller reaction times, under conditions which are similar otherwise. (In shadowing tasks participants are asked to repeat a stimulus as quickly and accurately as possible).

before, lexical retrieval may be facilitated and we expect a shorter reaction time (RT2). The repetition priming effect is defined as the difference between the first and the second reaction times (RT1-RT2). Therefore, if priming occurs, the effect will be positive (RT1-RT2>0).

she → **RT1** quar mipe voice quail … **she** → **RT2**	***Priming:*** ***RT1 – RT2 > 0***

Figure 4: repetition priming with *same* pairs

Now imagine the situation presented in figure 5: instead of an identical [shi:] we use [si:] as a target item. As we saw before, [shi:] and [si:] may be perceived as homophones. If this happens, [shi:] may prime [si:], resulting in a positive effect (RT1-RT2>0). If the two words are not perceived as homophones, we expect a 'neutral' priming effect (RT1-RT2≈0).

she → **RT1** quar mipe voice quail … **<u>sea</u>** → **RT2**	***No priming:*** ***RT1 – RT2 ≈ 0*** ***Priming:*** ***RT1 – RT2 > 0***

Figure 5: repetition priming with *minimal* pairs

Reaction times were measured as follows. Each time the participant pushed the 'yes'-button, a 450 Hz sinus wave was added to the original sound file. For each 'no' a 900 Hz sinus wave was inserted. Reaction times were extracted from the sound files by running a script (Boersma, 2007b) in the computer program Praat. They were measured from stimulus onset to the onset of the added sinus waves.

Measuring reaction times from stimulus onset is a common practice (see for instance Dufour et.al., 2007; Goldinger, 1996; McLennan et.al., 2003; Pallier et.al., 1999; Radeau et.al., 1998; Sebastián-Gallés et.al., 2005). After all, perception for spoken stimuli starts at the beginning of the item.

Other authors advise to (also) measure from 'uniqueness points' or 'deviation points' (which are based on the Cohort Model by Marslen-Wilson and Welsh, 1978; see also Goldinger, 1992, 1996; Goodman and Huttenlocher, 1988). The uniqueness point of a word is the point where the input deviates from all other words. In the same way the deviation point for a non-word is the point where the input deviates from all possible words. However, measuring from these points was not necessary, since only reaction times of items in minimal pairs were compared. Differences in duration between these items were controlled for (see section 6.3.2).

4.4 Conclusion

To recapitulate: the task settled upon was an auditory lexical decision task, conducted with English words and non-words. The list contained same pairs and minimal pairs. Reaction times for the items in each pair should be compared and the priming effects (RT1 – RT2) computed. If a Japanese participant hears words with [si] and [shi] as homophones, we expect the effect to be positive.

5. MATERIALS

5.1 Words

Appendix A lists all stimuli. The main test words were eight minimal word pairs with /si/-/shi/, such as *she-sea*. Their priming effects were compared to those of other sound contrasts.

The first group comprised the difficult contrasts /l/-/r/[12] and /si/-/thi/. The expectation for these pairs was that priming would occur. The same goes for all same pairs, i.e. pairs of two identical words (such as *six-six* and *check-check*), which were included for each sound. If priming would not occur for same pairs, the validity of the experiment would have to be questioned.

The second group contained the contrasts that were introduced by English loanwords: /se/-/she/, /ti/-/chi/ and /te-che/. These pairs were included to detect a potential graduality in the priming effects: if priming would occur, it was expected that the priming effect would be larger for /si/-/shi/-pairs than for /se/-she/-pairs and larger for these pairs than for the other pairs.

Common contrasts, for which no priming was expected, were included in the third group. There were related contrasts (combinations of /s/-/sh/ with /a/ and /o/) and contrasts that were not related to /s/-/sh/ (namely /k/-/t/ and /m/-/n/). Minimal pairs combining /t/-/ch/ with /a/ and /o/ were added, in case priming would also occur with /ti/-/chi/ (and /te/-/che/). If priming would occur for minimal pairs in this group, it could not be based on an identical categorization of phonemes. In that case the experiment could not be considered valid.

In order to detect potentially asymmetric priming effects, half of the minimal pairs for each group were presented in one order (for example /si/-/shi/ in *seat-sheet*), the other half in the reverse order (for example /shi/-/si/ in *sheep-seep*).

5.2 Non-words

Apart from word pairs, the list contains pairs of non-words (i.e. phonotactically legal English pseudo-words) for the sound pairs that were most likely to demonstrate priming effects: /si/-/shi/, /si/-/thi/ and /l/-/r/. Non-word pairs for /ti/-/chi/ were added, in case priming would also occur with /ti/-/chi/. The expectation was that non-word pairs would not yield priming effects, not even for the same pairs, since they do not reside in the lexicon. If priming would occur with non-words, we could not claim to be measuring priming effects on the lexical level.

[12] The fact that this contrast is difficult for native speakers of Japanese is well known. There are several articles on the topic. (See for example Yamada, 1995).

5.3 Fillers

Fillers (i.e. words and non-words that were not analyzed) were added to the pairs described above. They were included to fill up positions between primes and targets and to reduce potential phonological priming effects (which will be explained in section 6.3.4). Their numbers were adjusted in such a way that about half of all stimuli were words (233 or 55%) and the other half pseudo-words (192 or 45%). All items added up to 425 stimuli. Table 3 shows how many test items and fillers were words and how many of them were non-words.

Table 3: The number of words and non-words for test and filler items

	Test items	**Fillers**	**Total**
Words	166	67	***233***
Non-words	75	117	***192***
Total	241	184	425

5.4 Recording the stimuli

The recording took place in the sound-attenuated studio of the Linguistics Department at the University of Amsterdam. A male native speaker of a Midwestern dialect of American English read out the stimuli.

6. CONTROLS

6.1 Stimuli

In chapter 5 I mentioned three control groups of sounds: (1) same pairs (for which we had to find priming), (2) common contrasts (which should not prime) and (3) non-words (which should not prime either). If the results would be contrary to these expectations, we could not claim the validity of the experiment.

6.2 Control person

To make sure that the results would account for a Japanese way of categorizing sounds the experiment was also conducted with a non-native speaker of Japanese, who would categorize /si/ and /shi/ as separate sounds. A female Dutch student of English, who studied English in the Netherlands and in the United Kingdom, was asked to play this role of 'control person'.

6.3 Influences on reaction times

Other controls served to exclude the influence of other factors than repetition priming on reaction times. The factors taken into account were word frequency, item duration, the 'distance' between items in a pair, phonological priming, semantic priming and 'physical and psychological factors'. I will now discuss each of them.

6.3.1 The word frequency effect

The word frequency effect "might be considered as a very long term product of repetition priming" (Lainé et.al., 1998, 2). It refers to the finding that the time needed for lexical retrieval is shorter for statistically frequent words than for less frequent words. The effect is well known and had to be taken into account, especially since it has been demonstrated in several studies using lexical decision tasks (see for example in Carroll, 2004).

Since there were not enough minimal pairs to match the words on frequency, the pairs were presented in the order Higher Frequency (and therefore shorter expected Reaction Time) – Lower Frequency (and therefore longer expected Reaction Time). Using this order, we expect the difference in reaction times to be negative (RT1-RT2<0) when priming does not occur. If it does, the priming effect may be positive (RT1-RT2>0) regardless of the frequencies. The reverse order would result in uncertainty as to the cause of the effect: repetition priming or word frequency priming. Word frequencies were based on CELEX.

Unfortunately some pairs had to be presented in the reverse order Lower Frequency – Higher Frequency. As was mentioned in section 5.1, the minimal pairs in each sound group were presented in two orders, so as to detect potentially asymmetric priming effects. For example, for half of the minimal pairs in the sound group /si/-/shi/ words starting with /si/ preceded those beginning with /shi/, while for the remaining pairs words starting with /shi/ were the primes and those starting with /si/ the targets. To create comparable sets of equal size for each sound group, it was necessary to present 6 pairs (out of 47) in the undesirable order Lower Frequency – Higher Frequency.[13]

6.3.2 Item duration

Speech is variable enough to result in substantial duration differences between sounds in minimal pairs. The differences in the list rose up to more than 120 milliseconds. Since repetition effects could turn out to be as small as 60 milliseconds (Pallier et.al., 2001; Dufour et.al., 2007), differences in duration of more than 20 milliseconds were adapted with PSOLA in the computer program Praat. To minimize the effect of manipulation, both items in minimal pairs were adapted: the longer items were shortened and shorter ones lengthened. The differences between the original stimuli and the manipulated sounds were inaudible, as confirmed by two persons (not including me). Eighty items (40 minimal pairs) out of 126 items (63 minimal pairs) were adjusted in this way.

Using the Cohort Model of spoken word recognition (Marslen-Wilson and Welsh, 1978) as a guideline, item duration was measured up to the 'decision point', that is: the point where a participant in the test can be certain about the decision 'word or non-word'. For non-words this is the point where "the input diverges from all possible words" (Goodman and Huttenlocher, 1988, 686). The decision point for the non-word *shig*, for example, is the burst of the plosive. For most items the decision point lies at the end (since, for example, *drum* may turn into the non-word *drump*).

6.3.3 The distance between items in a pair

As figure 4 and 5 (in section 4.3) showed, other stimuli appeared between primes and targets. The number of positions (i.e. the number of intervening stimuli or the 'distance') between items in minimal or same pairs was 8 to 17, comparable to the range of 8 to 20 positions used in a similar experiment by Pallier et.al. (2001) and 8 to 17 positions used by Dufour et.al. (2007).

[13] As a patch-up measure, for all words in these pairs three words with similar frequencies were taken up in the list, so that reaction times could be compared (and possibly corrected) on the basis of reaction times for these stimuli. However (as will be discussed in chapter 8) this solution proved to be inadequate.

The authors mentioned did not clarify why they chose this number of intervening positions.[14] Apparently differences within the specified range were assumed not to affect reaction times. To be on the safe side, I tried to reduce a potential influence by matching sound groups to be compared on the average distance between primes and targets. Table 4 lists the sound groups (which were explained in sections 5.1 and 5.2) and the average number of positions between primes and targets for each of them. The groups in the left column are to be compared to those that appear to the right of them. As the table shows, the average distances for sound groups to be compared did not differ more than 1 position. For example, the average number of positions was 12 for words presented in the order /si/-/shi/ en also 12 for words presented in the reverse order /shi/-/si/ (resulting in a difference of 0 positions).

[14] It is difficult to find guidelines in the literature. Also, terms for the 'distance' between primes and targets (expressed in either the number of intervening stimuli or the duration or both) are ambiguous. Pallier et.al. speak of "medium-term (…) priming" (Pallier et.al., 2001, 445), presumably as opposed to 'short-term priming' (when targets follow primes immediately, without intervening stimuli) and 'long-term priming', an expression which is equally vague. It may refer to what Pallier et.al call "medium-term priming" (as in Dufour et.al., 2007) or to effects which persist over 'longer periods', extending from a few minutes (for example Mclennan et.al., 2003) to days or longer (for example Lainé et.al, 1998).

Table 4: Average number of stimuli between primes and targets for sound groups to be compared (Groups in the left column should be compared to those in the right column)

Sound group	Distance	Sound group	Distance
Words		**Words**	
/si/-/shi/ and /shi/-/si/	12.0	/l/-/r/ and /r/-/l/	12.9
		/si/-/thi/ and /thi/-/si/	11.7
		/se-/she/ and /she/-/se/	12.5
		/ti/-/chi/ and /chi/-/ti/	12.8
		/te/-/che/ and /che/-/te/	12.3
		/sa/-/sha/ and /sha/-/sa/	12.3
		/so/-/sho/ and /sho/-/so/	
		/k/-/t/ and /t/-/k/	12.0
		/m/-/b/ and /b/-/m/	
/ti/-/chi/ and /chi/-/ti/	12.8	/te/-/che/ and /che/-/te/	12.3
		/ta/-/cha/ and /cha/-/ta/	13.0
		/to/-/cho/ and /cho/-/to/	
/si/-/shi/	12.0	/shi/-/si/	12.0
/si/-/thi/	11.7	/thi/-/si/	11.7
/l/-/r/	13.0	/r/-/l/	12.7
/se/-/she/	12.5	/she/-/se/	12.5
/ti/-/chi/	12.5	/chi/-/ti/	13.0
/te/-/che/	12.0	/che/-/te/	12.5
Words		**Non-words**	
/si/-/shi/	12.0	/si/-/shi/	12.5
/shi/-/si/	12.0	/shi/-/si/	12.5
/si/-/thi/	11.7	/si/-/thi/	11.5
/thi/-/si/	11.7	/thi/-/si/	11.5
/l/-/r/	13.0	/l/-/r/	13.0
/r/-/l/	12.7	/r/-/l/	13.0
/ti/-/chi/	12.5	/ti/-/chi/	13.5
/chi/-/ti/	13.0	/chi/-/ti/	12.5

6.3.4 Phonological priming

Phonological priming may occur when an item facilitates the identification of another item due to phonological overlap. The effect can be found when final overlap (rime priming) is used, but seems debatable for initial phonological overlap of spoken words: studies show divergent results, ranging from facilitation to inhibition and to no effect at all (Radeau et.al., 1998; Goldinger et.al., 1992). Since in this study the focus was on initial sounds (such as /s/-/sh/), phonological priming did not seem a main concern. To be on the safe side, test words with the same initial syllables were spread over the different tracks. In addition, the fillers contained different (initial) sounds.

6.3.5 Semantic priming

It is well known, that words may prime semantically related words (e.g. Meyer and Schaneveldt, 1971; in Carroll, 2004). The fact that presenting items in a long list does not encourage the participant to retrieve the lexical meanings, is not sufficient to discard the possibility of semantic priming: there is at least one example of a study showing the effect in an auditory lexical decision task (Radeau, 1983. In: Radeau et.al.,1998). Since "a single intervening trial can eliminate the effect" (Cronk, 2001, 366), every word was only compared to the item immediately following it. Only the combination "say cheese" (which reminds of taking photographs) had to be separated.

6.3.6 'Physical and psychological factors'

Finally, the test contained safeguards against some 'physical and psychological factors', which might influence the reaction times. As will be discussed in the next chapter, the participant practised before the real test started. The training was added to make sure that she would understand the task and to make her familiar with pushing the two mouse buttons.

To prevent the participant from lapsing into a rhythmic pushing pattern rather than staying alert, the interstimulus interval of 3 seconds was lengthened at random for each item. Further, the list was divided into two longer tracks (of about a 100 stimuli each) and four shorter ones (of about 55 stimuli each) to minimize the risk of weariness. The participant could pause in between tracks. The first three items (and the last one) of any track were not analyzed.[15]

[15] Therefore 401 out of 425 items were included in the analysis.

7. PARTICIPANTS AND PROCEDURE

7.1 Participants

The participants in the experiment were selected on the basis of four criteria: (1) they had to be native speakers of Japanese (2) without hearing problems (3) who had been using Japanese daily all their lives and (4) who had a 'reasonable' proficiency in understanding spoken English. The first two criteria are obvious. The third one was important, since phonological representations might change when speakers do not use their mother tongues for a long time.

The fourth criterion posed difficulties. The proficiency level of English should have been determined by an auditory test measuring vocabulary. However, it turned out to be hard to find suitable candidates in the Netherlands, even without developing such a test and defining the proficiency level more vaguely in terms of the time spent learning English. As a consequence of the difficulty of finding appropriate candidates, it was also impossible to select them randomly.

Both participants were female and had studied English in school for at least six years. Participant 1 had also studied English in a language school (comparable to university). She has lived in Europe for almost five years, using English daily in her work and privately when talking to her husband and friends. Participant 2 has lived in Europe for 18-odd years and used to communicate in English in her work for about 5 years. She has a good command of Dutch as well.

The participants were told that they would receive compensation for their travel expenses, but only participant 2 accepted a partial repayment. Both participants accepted a gift voucher.

7.2 Procedure

The experimental sessions for the two participants proceeded as follows. First about ten to fifteen minutes were spent on clarifying the task. The participant read a one-page explanation written in Japanese. Then the instructions were discussed (in Japanese as well) and she could ask questions.

The participant was instructed to push the left mouse button upon hearing an English word and the right mouse button upon hearing an English nonsense-word. She was warned that about half of the items would be nonsense-words, which would sound very similar to English words. Special emphasis was put on the importance of responding as quickly as possible after making the decision 'word or nonsense-word'. In addition it was stressed that the goal of the experiment was not to test vocabulary.

After the instructions, the participant practised the test with 30 filler items for about 10 minutes. The stimuli were presented binaurally over headphones. The participant could ask questions and adjust the volume. Also, she could repeat the test if necessary. Participant 1 practised once and participant 2 twice.

Next, the experiment started. Appendix B lists all stimuli in the order of presentation. The participant could take breaks in between the six tracks. Neither one of the participants rested for a long time. The longest pause was about one minute. The experiment including the breaks took about 30 minutes.

PART III: RESULTS AND DISCUSSION

8. RESULTS

8.1 Introduction

Appendix C contains the reaction times for all items in same and minimal pairs for both participants and for the control person. In this chapter I summarize the results and comment on them. Unfortunately the data do not justify a conclusion on the phonological representations of /s/ and /sh/ in Japanese. They do contain, however, evidence for (1) a repetition priming effect for words that were presented in same pairs and (2) a reliable difference between words and non-words.

8.2 Minimal pairs

As a natural consequence of testing just one or two participants on a small number of available minimal pairs, there were not enough data per sound group to draw a conclusion on priming effects. This problem was exacerbated by the loss of a substantial part of these pairs (32% for participant 1 and 25% for participant 2) due to a lack of lexical knowledge (so that the participant responded "yes" for non-words or "no" for words) or accidental technical obstacles (resulting in a failure to present part of the stimuli to the participant).

Also, pairs that were presented in the order Low Frequency – High Frequency had to be excluded from the analysis. The original intention was to correct the reaction times on these words by comparing them to the reaction times of words with similar frequencies. However, this turned out to be tricky, for reaction times on these control words differed considerably.

8.3 Other outcomes for participant 1

Even though it was emphasized that about half of the items would be non-words, participant 1 showed a strong tendency to push the 'yes'-button: she did so for 72 percent of the items (290 out of 401), whereas a flawless score would have yielded 56 percent of 'yes'-es. Upon closer examination it turned out that she labelled almost half (47 percent) of all non-words as words. Consequently, more than 60 percent of non-word pairs (23 in number; see table 5, which shows the number of used and discarded pairs) had to be discarded and conclusions on these pairs were not possible, neither for minimal pairs nor for same pairs.

As for the words, the error rate was relatively low (8 percent). Fourteen percent (12 in number) of the word pairs had to be discarded. However, the actual percentage of errors could be higher, since the participant showed a bias towards responding "yes". In other words, it was possible that she had answered "yes" for words she did not know.

Table 5: Number of used and discarded pairs for participant 1, for words and non-words

Pairs of:	Minimal pairs		Same pairs		Total	
	Used	Discarded	Used	Discarded	Total	Discarded
Words	36	11	35	1	83 (100%)	12 (14%)
Non-words	6	9	8	14	37 (100%)	23 (62%)
Total	42	20	43	15	120 (100%)	35 (29%)

Fortunately the same-paired words provided some 'encouraging' data. All but one of these pairs could be used in the analysis. For the remaining 35 pairs a positive effect (i.e. RT1-RT2>0, see section 4.3) occurred reliably more often than a negative effect (30 versus 5 times; one-tailed sign test, p=0.000011). If we could validate a reliable difference with non-words, these data would support the explanation that priming occurs for words but not for non-words (since non-words do not reside in the lexicon). However, since participant 1 was inclined to push "yes" for non-words, it is not surprising that her data do not justify this claim.

8.4 Other outcomes for participant 2

Contrary to participant 1, the second participant did not show a bias towards answering "yes" or "no": she judged 56 percent of the presented items to be words, while the correct rate was 57 percent. The overall error rate was also lower, but still mounted up to 15 percent for words and 17 percent for non-words.

As a result 21 percent of the presented word pairs (15 in number) and 28 percent of the non-word pairs (9 in number) had to be discarded (see table 6, which shows the number of used and discarded pairs for participant 2). Further, 11 word pairs and 5 non-word pairs were not presented over the headphones accidentally.[16] The remaining numbers of minimal pairs (30 for words and 8 for non-words, both spread over the different sound groups) were too small to yield significant data on priming effects.

[16] Therefore the stated percentage of words as opposed to non-words (57%) differed from the percentage mentioned for participant 1 (56%).

Table 6: Number of used and discarded pairs for participant 2, for words and non-words

Pairs of:	Minimal pairs		Same pairs		Total	
	Used	Discarded	Used	Discarded	Total	Discarded
Words	30	9	27	6	72 (100%)	15 (21%)
Non-words	8	4	15	5	32 (100%)	9 (28%)
Total	38	13	42	11	104 (100%)	24 (23%)

As for the same-paired words, just as for participant one's data, positive effects occurred reliably more often than negative effects (see table 7: 21 versus 6 times; one-tailed sign test, p=0.000296). In addition, there was evidence for a reliable difference between same-paired words and same-paired non-words, thus supporting the claim that the test measures effects on a lexical level. (As table 7 shows, there was a positive effect for 21 versus 6 pairs for words and 6 versus 9 pairs for non-words; two-tailed chi-squared test, p=0.035).

Table 7: Positive and negative priming effects (i.e. RT1-RT2) for same-paired (non-)words, for participant 2

Same pairs of:	RT1-RT2>0	RT1-RT2<0	Total
Words	21	6	27
Non-words	6	9	15
Total	27	15	42

8.5 Outcomes for the control person

The control person had an error rate of only 2.8% (5 out of 177) for non-words and 6% (13 out of 224) for words. For same word pairs positive effects occurred reliably more often than negative effects again (26 versus 10 times; one-tailed sign test, p = 0.0057), once more sustaining the assumption underlying the test that words prime identical words. However, we cannot claim a reliable difference with non-words on the basis of the control person's data (which show a positive effect for 26 versus 10 pairs for words and 12 versus 10 pairs for non-words; two-tailed chi-squared test, p = 0.275).

As for the minimal word pairs, we expected positive priming effects for pairs presented in the order Low Frequency – High Frequency (7 in number) and negative priming effects for all pairs that were presented in the reverse order (40 in number), since it was not likely that the Dutch control person would categorize the chosen contrasting phones as identical sounds. However, the word frequency effect could not be substantiated, since expected effects did not occur more often reliably than non-expected effects (25 expected effects versus 17 non-expected effects; one-tailed sign test, $p = 0.14$).

8.6 Conclusion

The results leave the main question open: we do not have an answer on the phonological representations of /s/ and /sh/. This is due to a lack of minimal pairs, triggered by a combination of little availability of these pairs and few participants. High error rates and technical misfortunes further reduced the number of these pairs available for analysis.

In addition, there were substantial individual differences both in the mistakes made and in the reaction times on individual items. An obvious reason (apart from the fact that individuals can never be the same) seems an inadequate selection of participants, who had insufficient knowledge of English and who had different backgrounds.

The use of few participants could also be an important reason for the failure to pinpoint the word frequency effect. CELEX scores are meant to represent common scores for frequency of use. It is very well possible that individual reaction times diverge from this score pattern, particularly since English is a second language for the persons tested (including the control person).

All factors mentioned above imply that we do not have clarity as to the quality of the test either. Fortunately same pairs provided support for the principal assumption that words prime copies: word pairs for all three persons showed significant positive priming effects. Moreover, outcomes for participant 2 confirmed a reliable difference with non-words, thus endorsing the claim that the test measures effects on a lexical level.

9. CONCLUDING REMARKS AND FUTURE RESEARCH

The results of this study are ambivalent. Even though we did not find an answer on the question how /s/ and /sh/ are represented in Japanese, we can confirm the potential of repetition priming experiments for testing lexical phonological representations. The results show significant positive priming effects for identical words and validate a reliable difference with non-words.

For future experiments many lessons were learned. The main lesson seems that tests aiming for demonstrating repetition priming effects with minimal pairs in a second language cannot yield significant results on the basis of a case study. There are insufficient minimal pairs for a particular sound. Having many participants permits efficient use of these pairs. If we intend to study the possibility of asymmetric priming, for example, we could use one minimal pair in different orders for different participants (so that one group would hear a certain minimal pair in the order 1-2, the other in the order 2-1).

Employing many participants would also level out individual differences in reaction times due to different build-ups of lexicons (resulting in different word frequency effects) and accidental mistakes. The effect of even small differences will be inflated in a small data set.

A second lesson pertains to the choice of participants. Apart from the fact that they should have been selected at random, they should have been fully proficient in the second language for two reasons: we would not lose many minimal pairs due to a lack of knowledge and we would not be confronted by biases in answers due to a participant's uncertainty about his or her ability to do the task. Candidates should feel confident that they can perform the task and the experiment should not evoke bad memories about vocabulary tests in high school. It is not without reason that other studies comparable to this one have used people who have been bilinguals from birth.

There may be a further reason for preferring people who have been raised in two languages from an early age. This reason is a possible effect of orthography, which does not play a role in discrimination or identification tasks. People who study second languages when they are older (i.e. not from birth), often learn the words by reading them, rather than hearing them. As a consequence, the way a word is written may influence the phonological representation. In this study the control person, who made very few errors, marked the common word "talk" as a non-word, potentially because she identified the pronunciation [ta:k] as "tock" (and would expect an [l] in the pronunciation of the word "talk").

Instead of selecting fluent bilinguals, an alternative prevention against a shortage of lexical knowledge may be a focus on loanwords in the first language, rather than appealing to lexical knowledge of a second language. In Japanese there are quite many loanwords with /si/ (or /shi/) and /ti/, which could be presented to participants as [si] - [shi] and [ti] - [chi]. In this respect it may be of importance that the languages used in similar studies (Spanish and Catalan for Pallier et.al. 1999, 2001 and northern and standard French for Dufour et.al., 2005, 2007) were much more related to one another than Japanese and English are.

It seems worthwhile to make an effort at reconstructing the test along the lines suggested above, for it is clear that the potential of repetition priming experiments for deepening our understanding of phonological representations has not been explored to the full yet.

10. APPENDICES

APPENDIX A: OVERVIEW OF ALL STIMULI

Table A1: Word pairs and expected priming results

Sound groups	Conditions[1]				Expectations for minimal pairs (= conditions 1-2 and 2-1)
	1-1	**1-2**	**2-1**	**2-2**	
/si/-/shi/	1. seize – seize 2. six – six	3. seat – sheet 4. seek – chic 5. sit – shit 6. single – shingle	7. she – sea/see 8. sheep – seep 9. ship – sip 10. shield – sealed	11. sheer – sheer 12. shift – shift	Priming (Minimal pairs contain difficult contrasts).
/si/-/thi/ /l/-/r/	Zie 1 en 2 (en 55 en 56) 21. lam – lam 22. louse – louse	13. seem – theme 14. sick – thick 15. (sigh – thigh)[2] 23. late – rate 24. let – rat 25. low – row	16. think – sink 17. thing – sing 18. thin – sin 26. road – load 27. rock – lock 28. right – light	19. thief – thief 20. (thumb – thumb)[2] 29. room – room 30. red – red	Priming (Minimal pairs contain difficult contrasts).
/se/-/she/ /ti/-/chi/ /te/-che/	31. say – say 32. send – send 39. tea – tea 40. team – team 47. tell – tell 48. tax – tax	33. same – shame 34. self – shelf 41. tease – cheese 42. tin – chin 49. test – chest 50. taste – chaste	35. shake – sake 36. shell – sell 43. cheek – teak 44. chip – tip 51. chap – tap 52. (cherry – Terry)[2]	37. shape – shape 38. share – share 45. chief – chief 46. cheap – cheap 53. change – change 54. check – check	If priming occurs, the effect will be smaller than for /si/-/shi/. (Minimal pairs contain 'recently' introduced contrasts). Otherwise: no priming. (Minimal pairs contain common contrasts).

1 and 2: see next page

Table A1 (continued): Word pairs and expected priming results

Sound groups	Conditions[1]				Expectations for minimal pairs (= conditions 1-2 and 2-1)
	1-1	**1-2**	**2-1**	**2-2**	
/so/-/sho/ /sa/-/sha/	55. soap – soap 56. size – size	57. sort – short 58. sigh – shy	59. shock – sock 60. shine – sign	61. shop – shop 62. shout – shout	No priming (Minimal pairs contain common contrasts).
/to/-/cho/ /ta/-/cha/	63. tone – tone 64. tight – tight	65. talk – chalk 66. top – chop	67. chart – tart	68. charm – charm 69. choice – choice	
/k/-/t/	70. come – come 71. cool - cool	72. call – tall 73. cape – tape	74. toast – coast 75. take – cake	Zie 63 en 64	
/m/-/b/	76. mess – mess 77. moon – moon	78. man – ban 79. may/May – bay	80. bad – mad 81. ball – mall	82. bell – bell 83. book – book	

1: *Same pairs* are listed under the conditions 1-1 (for example words with /si/-/si/) and 2-2 (for example words with /shi/-/shi/).
All same pairs are expected to yield priming effects.
Conditions 1-2 en 2-1 refer to *minimal pairs*. The numbers indicate the order of presenting the sounds to the Japanese participant, for example /si/-/shi/ in *seat-sheet* (condition 1-2) and /shi/-/si/ in *sheep-seep* (condition 2-1). Priming expectations are listed in the table.
2: Three pairs deviate from the other words, but were included to fill up empty spaces due to a lack of minimal pairs. The pairs *sigh-thigh* and *thumb-thumb* contain the 'wrong' vowels. *Cherry-Terry* includes a name.

Table A2: Non-word pairs and expected priming results (with intended pronunciation between parentheses)

Sound groups	Conditions[3] 1-1	1-2	2-1	2-2	Expectations for all pairs (= all conditions)
/si/-/shi/	98. seach – seach (reach) 99. sitch – sitch (pitch)	100. seague – sheague (league) 101. sig – shig (pig)	102. sheird – seird (weird) 103. shib – sib (rib)	104. shim – shim (dim) 105. shive – shive (live)	No priming. (Task with words taps *lexical* information).
/si/-/thi/ /l/-/r/	Zie 98 en 99. 112. lown – lown (down) 113. lact – lact (pact)	106. siggle – thiggle (giggle) 107. soun – thoun (down) 114. loke – roke (smoke) 115. liss – riss (miss)	108. thist – sist (fist) 109. thart – sart (dart) 116. roise – loise (noise) 117. rix – lix (mix)[4]	110. thamp – thamp (damp) 111. thoom – thoom (boom) 118. rond – rond (pond) 119. runk – runk (chunk)	
/ti/-/chi/	120. teave – teave (leave) 121. teag – teag (league)	122. tilm – chilm (film) 123. tib – chib (rib)	124. chiz – tiz (Liz) 125. chid – tid (mid)	126. cheal – cheal (deal) 127. chead – chead (read)	
/s/-/sh/ (without /si/-shi/) /k/-/t/	128. sime – sime (time) 129. samp – samp (lamp) 132. coom – coom (room) 133. kig – kig (pig)			130. shorm – shorm (norm) 131. shoop – shoop(loop) 134. toaf – toaf (loaf) 135. tarm – tarm (farm)	

3: Same pairs are listed under conditions 1-1 and 2-2. Minimal pairs refer to conditions 1-2 and 2-1.
4: This pair was excluded from the analysis later, since *lix* corresponds to the word *licks*.

Table A3 Fillers (words) and the reasons for including them

Reasons for including: - Filling the spaces between primes and targets - Reduction of potential phonological priming effects				
1. boat	14. fire	27. heal	40. numb*	52. truck*
2. bold	15. fly	28. high	41. old	53. tool
3. bow	16. free	29. home	42. play	54. toy
4. blue	17. fun	30. horse	43. pope	55. voice
5. bull	18. game	31. hue*	44. port	56. warm
6. crown	19. go	32. hum*	45. pub	57. west
7. dance	20. good	33. jump	46. quo*	58. wing
8. doled*	21. grow	34. job	47. ring	59. work
9. dog	22. Gump*	35. kine*	48. ski	60. world
10. drug	23. guess	36. kiss	49. song	61. y'all*
11. drum	24. guide	37. next	50. storm	62. young
12. earth	25. hand	38. night	51. thank	63. zoo
13. field	26. hay	39. nose		

*: These stimuli were recorded as the non-words dold (old), gump (jump), hew (few), hom (come), kine (fine), quo (so), nome (come), trock (rock) and yall (call). (The pronunciation is indicated between parentheses). However, since the pronunciation was identical to that of existing words, they had to be analyzed as such.

Table A4 Fillers (non-words) and the reasons for including them (with intended pronunciation between parentheses)

Reasons for including:
- Filling the spaces between primes and targets
- Reduction of potential phonological priming effects

1. oon (moon)	24. feam (beam)	46. hoice (voice)	68. mirst (first)	90. stipe (pipe)
2. oot (foot)	25. fick (stick)	47. hong (song)	69. masp (gasp)	91. tase (case)
3. ain (vain)	26. fift (lift)	48. yoot (foot)	70. moun (noun)	92. tate (late)
4. ock (knock)	27. fim (dim)	49. yague (vague)	71. mipe (hype)	93. tash (cash)
5. unt (stunt)	28. fingle (mingle)	50. yorn (born)	72. neach (reach)	94. tass (pass)
6. aun (down)	29. fass (pass)	51. yike (like)	73. noot (put)	95. tife (life)
7. bave (brave)	30. fike (like)	52. cail (tail)	74. nust (dust)	96. tob (rob)
8. baff (staff)	31. goop (loop)	53. cang (hang)	75. nirst (first)	97. toint (point)
9. bome (home)	32. goint (point)	54. ko (go)	76. nam (dam)	98. trimp (imp)
10. boft (soft)	33. gus (bus)	55. cust (dust)	77. noaf (loaf)	99. trine (line)
11. bipe (pipe)	34. garm (farm)	56. kirm (firm)	78. nall (call)	100. cheave (leave)
12. bluck (luck)	35. glute (flute)	57. kire (fire)	79. noft (soft)	101. chive (give)
13. blay (play)	36. glab (lab)	58. coun (noun)	80. noil (soil)	102. viss (kiss)
14. blout (out)	37. heaf (leaf)	59. quee (queen/fee)	81. poon (moon)	103. voak (oak)
15. doot (foot)	38. heak (leak)	60. quim (quint/dim)	82. pust (dust)	104. vime (rhyme)
16. doint (point)	39. heam (beam)	61. quar (quark/bar)	83. poat (boat)	105. wust (dust)
17. dorn (corn)	40. hib (rib)	62. lunk (funk)	84. poun (noun)	106. welf (elf/whelp)
18. dost (lost)	41. hift (lift)	63. mave (brave)	85. paff (staff)	107. wang (hang)
19. dunt (stunt)	42. hin (bin)	64. meft (left)	86. plean (clean)	108. woss (loss)
20. dus (bus)	43. hingle (mingle)	65. mang (hang)	87. pluff (bluff)	109. whaff (staff)
21. dasp (gasp)	44. hoon (moon)	66. moaf (loaf)	88. sife (life)	110. zam (dam)
22. foap (soap)	45. hote (vote)	67. mus (bus)	89. spim (dim)	111. zasp (gasp)
23. feaf (leaf)				

APPENDIX B: STIMULI IN PRESENTATION ORDER

Explanation of letter styles used in the list

Letter style	**Example**	**Category**
Bold	**change**	word pairs
Italics (pronunciation between parentheses)	*shim (dim)*	non-word pairs
Standard	crown	word fillers
Standard (pronunciation between parentheses)	Moun (noun)	non-word fillers

Track 1 (98 items)

1.	voice	**34.**	**top**	67.	whaff (staff)
2.	cang (hang)	35.	pope	68.	glab (lab)
3.	grow	**36.**	**light**	**69.**	**shit**
4.	**change**	*37.*	*tarm (farm)*	70.	guide
5.	**cape**	**38.**	**cheese**	**71.**	**cool**
6.	fift (lift)	**39.**	**sea (/see)**	*72.*	*teave (leave)*
7.	**toast**	*40.*	*sheague (league)*	*73.*	*runk (chunk)*
8.	crown	*41.*	*shoop (loop)*	74.	hue
9.	*shim (dim)*	*42.*	*thist (fist)*	**75.**	**soap**
10.	glute (flute)	**43.**	**call**	76.	baff (staff)
11.	nose	**44.**	**chop**	*77.*	*chib (rib)*
12.	*lown (down)*	45.	bave (brave)	**78.**	**think**
13.	**tape**	**46.**	**seem**	**79.**	**sealed**
14.	**change**	*47.*	*tarm (farm)*	**80.**	**may**
15.	hoon (moon)	**48.**	**say**	*81.*	*chilm (film)*
16.	doled	49.	woss (loss)	**82.**	**cheek**
17.	**talk**	*50.*	*roise (noise)*	83.	spim (dim)
18.	cail (tail)	*51.*	*shoop (loop)*	**84.**	**road**
19.	quo	*52.*	*sist (fist)*	85.	bome (home)
20.	**sick**	53.	quar (quark/bar)	*86.*	*teave (leave)*
21.	**coast**	54.	mipe (hype)	87.	ski
22.	*lown (down)*	55.	noil (soil)	88.	dost (lost)
23.	noft (soft)	**56.**	**tall**	**89.**	**soap**
24.	moun (noun)	**57.**	**say**	**90.**	**bay**
25.	*seague (league)*	**58.**	**sit**	91.	fingle (mingle)
26.	*shim (dim)*	**59.**	**cool**	92.	heaf (leaf)
27.	**right**	*60.*	*runk (chunk)*	93.	ko (go)
28.	**tease**	**61.**	**theme**	**94.**	**sink**
29.	**she**	62.	stipe (pipe)	**95.**	**teak**
30.	wing	*63.*	*loise (noise)*	96.	hote (vote)
31.	**thick**	**64.**	**shield**	97.	**load**
32.	tife (life)	*65.*	*tilm (film)*	98.	dorn (corn)
33.	**chalk**	*66.*	*tib (rib)*		

Track 2 (104 items)

99. fim (dim)
100. kiss
101. kine (fine)
102. west
103. cheap
104. shell
105. heal
106. lunk (funk)
107. sort
108. neach (reach)
109. poon (moon)
110. bad
111. cheap
112. tob (rob)
113. sheer
114. sell
115. short
116. hay
117. hoice (voice)
118. fire
119. chart
120. zam (dam)
121. chap
122. boft (soft)
123. hand
124. book
125. mad
126. rix (mix)
127. sheer
128. bold
129. dunt (stunt)
130. charm
131. lact (pact)
132. tart
133. fass (pass)
134. room
135. tap
136. chiz (Liz)
137. heak (leak)
138. seize
139. licks*
140. thing
141. book
142. dog
143. charm
144. cust (dust)
145. mave (brave)
146. viss (kiss)
147. tiz (Liz)
148. lact (pact)
149. room
150. sing
151. shive (give)
152. warm
153. seize
154. zasp (gasp)
155. noot (put)
156. port
157. sigh
158. sheep
159. man
160. shive (give)
161. night
162. pust (dust)
163. toint (point)
164. fly
165. boat
166. thigh
167. aun (down)
168. hingle (mingle)
169. seep
170. thin
171. wang (hang)
172. cheave (leave)
173. tass (pass)
174. shy
175. home
176. ban
177. ship
178. quim (quint/dim)
179. sin
180. samp (lamp)
181. garm (farm)
182. coom (room)
183. doint (point)
184. thief
185. late
186. shake
187. unt (stunt)
188. test
189. sip
190. guess
191. yike (like)
192. samp (lamp)
193. numb
194. masp (gasp)
195. thief
196. fick (stick)
197. work
198. rate
199. coom (room)
200. chest
201. sake
202. drug

*: See note 4 on page 40

Track 3 (57 items)

203. pluff (bluff)	222. earth	**241. louse**
204. voice	**223. take**	**242. shine**
205. zam (dam)	**224. rat**	*243. thamp (damp)*
206. sig (pig)	*225. teag (league)*	244. plean (clean)
207. thart (dart)	**226. check**	**245. shift**
208. size	**227. taste**	246. feam (beam)
209. free	**228. tone**	247. y'all
210. let	229. horse	*248. siggle (giggle)*
211. tash (cash)	**230. chin**	249. welf (elf)
212. check	**231. come**	250. trine (line)
213. tone	**232. cake**	**251. louse**
214. song	233. ock (knock)	252. noaf (loaf)
215. tin	234. quee (queen)	253. world
216. shig (pig)	235. mirst (first)	254. bow
217. come	*236. teag (league)*	**255. sign**
218. size	237. ain (vain)	**256. shift**
219. sife (life)	238. bipe (pipe)	*257. thiggle (giggle)*
220. sart (dart)	**239. chaste**	*258. thamp (damp)*
221. dance	240. gus (bus)	259. spim (dim)

Track 4 (58 items)

260. grow	**280. self**	*299. seird (weird)*
261. kirm (firm)	**281. seek**	300. storm
262. hote (vote)	282. old	**301. send**
263. sime (time)	283. nall (call)	*302. chid (mid)*
264. choice	284. high	303. zoo
265. seach (reach)	285. mus (bus)	304. wust (dust)
266. good	286. doot (foot)	*305. loke (smoke)*
267. Gump	287. drum	306. mang (hang)
268. tea	**288. lock**	307. pub
269. job	289. vime (rhyme)	308. blout (out)
270. feaf (leaf)	**290. lam**	309. game
271. hin (bin)	*291. sheird (weird)*	**310. shape**
272. rock	**292. moon**	**311. tip**
273. lam	293. meft (left)	312. goint (point)
274. sime (time)	**294. shape**	313. oon (moon)
275. choice	**295. shelf**	**314. send**
276. moon	296. yague (vague)	*315. roke (smoke)*
277. oot (foot)	**297. chic**	*316. tid (mid)*
278. seach (reach)	**298. chip**	317. glute (flute)
279. tea		

Track 5 (53 items)

318. bluck (luck)	336. blay (play)	354. hib (rib)
319. hift (lift)	337. field	355. hum
320. dorn (corn)	338. fike (like)	356. play
321. kig (pig)	339. nam (dam)	*357. chead (read)*
322. coun (noun)	**340. red**	**358. tax**
323. red	341. voak (oak)	359. kire (fire)
324. seat	**342. sock**	**360. team**
325. young	*343. rond (pond)*	361. yorn (born)
326. rond (pond)	**344. tell**	**362. bell**
327. tell	345. trimp (imp)	363. truck
328. poat (boat)	**346. six**	364. tate (late)
329. paff (staff)	**347. team**	365. nirst (first)
330. kig (pig)	**348. mess**	366. bull
331. shock	**349. bell**	367. kine
332. sheet	350. nust (dust)	**368. tax**
333. mess	351. tase (case)	*369. chead (read)*
334. dus (bus)	352. poun (noun)	370. nose
335. six	353. foap (soap)	

Track 6 (55 items)

371. moaf (loaf)	*390. sitch (pitch)*	*408. cheal (deal)*
372. hoon (moon)	*391. toaf (loaf)*	**409. ball**
373. heaf (leaf)	**392. share**	**410. same**
374. soun (down)	**393. tight**	*411. riss (miss)*
375. cherry	394. next	**412. thumb**
376. sitch (pitch)	*395. liss (miss)*	**413. shingle**
377. yoot (foot)	*396. shorm (norm)*	**414. shop**
378. goop (loop)	**397. chief**	415. fun
379. dasp (gasp)	*398. thoom (boom)*	416. toy
380. jump	**399. row**	**417. shout**
381. chief	**400. single**	418. heam (beam)
382. blue	**401. tight**	**419. mall**
383. hong (song)	*402. sib (rib)*	**420. shame**
384. shorm (norm)	**403. shout**	*421. cheal (deal)*
385. shib (rib)	404. tool	**422. thumb**
386. Terry	*405. toaf (loaf)*	423. ring
387. low	**406. share**	**424. shop**
388. thoun (down)	407. go	425. thank
389. thoom (boom)		

APPENDIX C: RESULTS

Results for participant 1 (page 1)

<u>**Same pairs**</u>	**RT1**	**RT2**	**RT1-RT2**	**RT1-RT2**
	in s	*in s*	*in s*	*in ms*
Words				
seize	1.392	1.329	0.063	63
six	1.088	0.756	0.332	332
sheer	2.202	0.913	1.289	1289
shift	0.867	0.759	0.108	108
thief	0.938	0.821	0.117	117
thumb	1.039	0.890	0.149	149
lam	0.848	0.759	0.089	89
louse	-	-	-	-
room	0.816	0.715	0.101	101
red	1.177	1.040	0.137	137
say	1.247	0.978	0.269	269
send	1.143	0.818	0.325	325
shape	0.850	0.929	-0.079	-79
share	1.097	0.829	0.268	268
tea	0.989	0.743	0.246	246
team	0.881	0.676	0.205	205
chief	1.759	1.008	0.751	751
cheap	0.877	0.898	-0.021	-21
tell	1.029	0.997	0.032	32
tax	2.126	2.254	-0.128	-128
change	0.834	0.791	0.043	43
check	0.921	0.724	0.197	197
soap	0.902	0.766	0.136	136
size	1.046	0.919	0.127	127
shop	1.008	0.893	0.115	115
shout	1.282	0.956	0.326	326
tone	0.636	0.638	-0.002	-2
tight	0.989	0.848	0.141	141
charm	1.621	2.229	-0.608	-608
choice	0.705	0.628	0.077	77
come	0.881	0.593	0.288	288
cool	0.704	0.648	0.056	56
mess	0.829	0.788	0.041	41
moon	0.804	0.723	0.081	81
bell	1.070	0.888	0.182	182
book	1.018	0.797	0.221	221

Nr of pairs	36
Nr of used pairs	35
Nr of discarded pairs	1
Nr of "RT1-RT2=pos"	30
Nr of "RT1-RT2=neg"	5

Results for participant 1 (page 2)

<u>**Same pairs**</u>	**RT1**	**RT2**	**RT1-RT2**	**RT1-RT2**
	in s	*in s*	*in s*	*in ms*
Non-words				
seach	2.421	1.754	0.667	667
sitch	-	-	-	-
shim	-	-	-	-
shive	-	-	-	-
thamp	-	-	-	-
thoom	-	-	-	-
lown	-	-	-	-
lact	-	-	-	-
rond	-	-	-	-
runk	-	-	-	-
teave	-	-	-	-
teag	1.260	1.241	0.019	19
cheal	1.601	1.857	-0.256	-256
chead	-	-	-	-
sime	1.898	1.819	0.079	79
samp	-	-	-	-
shorm	1.299	1.302	-0.003	-3
shoop	1.412	1.041	0.371	371
coom	1.110	1.140	-0.030	-30
kig	-	-	-	-
toaf	1.693	1.259	0.434	434
tarm	-	-	-	-

Nr of pairs	22
Nr of used pairs	8
Nr of discarded pairs	14
Nr of "RT1-RT2=pos"	5
Nr of "RT1-RT2=neg"	3

Results for participant 1 (page 3)

<u>Minimal pairs</u>	**RT1**	**RT2**	**RT1-RT2**	**RT1-RT2**
	in s	*in s*	*in s*	*in ms*
Words				
seat - sheet	1.165	1.076	0.089	89
seek - chic	2.286	1.763	0.523	523
she - sea	1.223	1.090	0.133	133
sheep - seep	-	-	-	-
shield - sealed	*1.163*	*1.169*	*-0.006*	*-6*
sit - shit	-	-	-	-
single-shingle	0.908	1.081	-0.173	-173
ship - sip	0.733	1.065	-0.332	-332
seem - theme	1.347	1.058	0.289	289
sick - thick	-	-	-	-
sigh - thigh	-	-	-	-
think - sink	1.006	0.941	0.065	65
thing - sing	-	-	-	-
thin - sin	0.830	1.079	-0.249	-249
late - rate	1.044	1.227	-0.183	-183
let - rat	1.823	1.607	0.216	216
low - row	1.503	1.634	-0.131	-131
road - load	0.780	0.826	-0.046	-46
rock - lock	0.824	0.833	-0.009	-9
right - light	0.858	0.792	0.066	66
same - shame	1.207	1.112	0.095	95
self - shelf	-	-	-	-
shake - sake	-	-	-	-
shell - sell	*0.965*	*1.132*	*-0.167*	*-167*
tease - cheese	*1.872*	*0.891*	*0.981*	*981*
tin - chin	0.680	0.877	-0.197	-197
cheek - teak	0.724	1.263	-0.539	-539
chip - tip	*0.763*	*0.645*	*0.118*	*118*
test - chest	0.824	0.858	-0.034	-34
taste - chaste	0.878	1.125	-0.247	-247
chap - tap	-	-	-	-
cherry - Terry	1.205	1.204	0.001	1
sort - short	1.202	0.984	0.218	218
sigh - shy	2.021	1.081	0.940	940
shock - sock	1.091	1.083	0.008	8
shine - sign	0.780	0.757	0.023	23
talk - chalk	0.866	1.238	-0.372	-372
top - chop	0.962	0.798	0.164	164
chart - tart	-	-	-	-

Nr of pairs	47
Nr of used pairs	36
Nr of discarded pairs	11
***Italics* =**	
Low-High frequency	

Results for participant 1 (page 4)

<u>**Minimal pairs**</u>	**RT1**	**RT2**	**RT1-RT2**	**RT1-RT2**	
	in s	*in s*	*in s*	*in ms*	
Words (continued)					
call - tall	1.140	1.227	-0.087	-87	
cape - tape	-	-	-	-	
toast - coast	0.813	1.478	-0.665	-665	
take - cake	0.741	0.568	0.173	173	
man - ban	0.855	0.788	0.067	67	
may - bay	1.082	1.247	-0.165	-165	
bad - mad	1.057	1.139	-0.082	-82	
ball - mall	-	-	-	-	
Non-words					
seague - sheague	2.068	1.480	0.588	588	
sig - shig	1.923	2.453	-0.530	-530	
sheird- seird	-	-	-	-	
shib - sib	-	-	-	-	
siggle - thiggle	-	-	-	-	
soun - thoun	-	-	-	-	
thist - sist	-	-	-	-	
thart - sart	1.919	1.547	0.372	372	
loke - roke	-	-	-	-	
liss - riss	-	-	-	-	
roise - loise	-	-	-	-	
rix - lix	-	-	-	-	ex
tilm - chilm	1.344	1.533	-0.189	-189	
tib - chib	2.009	1.306	0.703	703	
chiz - tiz	1.857	1.486	0.371	371	
chid - tid	-	-	-	-	

Nr of pairs	15
Nr of used pairs	6
Nr of discarded pairs	9
Nr of "RT1-RT2=pos"	4
Nr of "RT1-RT2=neg"	2
ex = excluded from analysis (since 'lix' corresponds to the word 'licks')	

Results for participant 2 (page 1)

Same pairs	RT1	RT2	RT1-RT2	RT1-RT2	
	in s	*in s*	*in s*	*in ms*	
Words					
seize	1.285	1.499	-0.214	-214	
six	1.327	1.052	0.275	275	
sheer	-	-	-	-	
shift	0.949	0.766	0.183	183	
thief	0.896	0.859	0.037	37	
thumb	-	-	-	-	
lam	-	-	-	-	
louse	-	-	-	-	
room	0.967	0.768	0.199	199	
red	0.681	0.722	-0.041	-41	
say	-	-	-	-	nr
send	1.031	0.836	0.195	195	
shape	0.797	0.834	-0.037	-37	
share	0.828	0.750	0.078	78	
tea	0.778	0.682	0.096	96	
team	0.680	0.743	-0.063	-63	
chief	-	-	-	-	
cheap	0.835	0.687	0.148	148	
tell	0.956	0.838	0.118	118	
tax	2.871	2.814	0.057	57	
change	1.000	1.021	-0.021	-21	
check	0.861	0.776	0.085	85	
soap	-	-	-	-	nr
size	1.546	1.173	0.373	373	
shop	1.215	0.842	0.373	373	
shout	1.015	1.008	0.007	7	
tone	-	-	-	-	
tight	1.006	0.962	0.044	44	
charm	0.859	0.748	0.111	111	
choice	0.835	0.732	0.103	103	
come	1.858	0.765	1.093	1093	
cool	-	-	-	-	nr
mess	2.018	1.047	0.971	971	
moon	0.945	0.765	0.180	180	
bell	0.985	1.093	-0.108	-108	
book	0.811	0.712	0.099	99	

Nr of pairs	33
Nr of used pairs	27
Nr of discarded pairs	6
Nr of "RT1-RT2=pos"	21
Nr of "RT1-RT2=neg"	6
nr = no recording	

Results for participant 2 (page 2)

Same pairs	**RT1**	**RT2**	**RT1-RT2**	**RT1-RT2**	
	in s	*in s*	*in s*	*in ms*	
Non-words					
seach	1.104	1.410	-0.306	-306	
sitch	1.052	1.431	-0.379	-379	
shim	1.231	1.317	-0.086	-86	
shive	1.051	1.168	-0.117	-117	
thamp	-	-	-	-	
thoom	1.200	1.261	-0.061	-61	
lown	1.378	1.837	-0.459	-459	
lact	-	-	-	-	
rond	1.274	1.324	-0.050	-50	
runk	-	-	-	-	nr
teave	-	-	-	-	nr
teag	-	-	-	-	
cheal	0.953	0.902	0.051	51	
chead	1.025	1.162	-0.137	-137	
sime	1.223	1.489	-0.266	-266	
samp	-	-	-	-	
shorm	1.109	0.973	0.136	136	
shoop	1.641	1.481	0.160	160	
coom	1.073	0.949	0.124	124	
kig	1.373	1.175	0.198	198	
toaf	1.208	1.193	0.015	15	
tarm	-	-	-	-	

Nr of pairs	20
Nr of used pairs	15
Nr of discarded pairs	5
Nr of "RT1-RT2=pos"	6
Nr of "RT1-RT2=neg"	9

Results for participant 2 (page 3)

Minimal pairs	**RT1**	**RT2**	**RT1-RT2**	**RT1-RT2**	
	in s	*in s*	*in s*	*in ms*	
Words					
seat - sheet	1.411	0.969	0.442	442	
seek - chic	1.259	1.238	0.021	21	
she - sea	1.430	0.903	0.527	527	
sheep - seep	1.068	1.025	0.043	43	
shield - sealed	-	-	-	-	nr
sit - shit	-	-	-	-	nr
single-shingle	-	-	-	-	
ship - sip	0.899	0.816	0.083	83	
seem - theme	-	-	-	-	nr
sick - thick	0.935	0.950	-0.015	-15	
sigh - thigh	-	-	-	-	
think - sink	-	-	-	-	nr
thing - sing	1.025	1.055	-0.030	-30	
thin - sin	0.929	0.870	0.059	59	
late - rate	1.836	1.330	0.506	506	
let - rat	-	-	-	-	
low - row	0.887	1.102	-0.215	-215	
road - load	-	-	-	-	nr
rock - lock	1.103	0.934	0.169	169	
right - light	0.924	0.988	-0.064	-64	
same - shame	1.081	0.917	0.164	164	
self - shelf	-	-	-	-	
shake - sake	0.991	1.372	-0.381	-381	
shell - sell	*1.504*	*1.084*	*0.420*	*420*	
tease - cheese	*1.960*	*1.089*	*0.871*	*871*	
tin - chin	-	-	-	-	
cheek - teak	-	-	-	-	nr
chip - tip	*0.811*	*0.747*	0.064	64	
test - chest	1.301	1.079	0.222	222	
taste - chaste	0.832	1.166	-0.334	-334	
chap - tap	*0.965*	*1.171*	*-0.206*	*-206*	
cherry - Terry	0.900	0.900	0.000	0	
sort - short	1.149	1.176	-0.027	-27	
sigh - shy	-	-	-	-	
shock - sock	0.961	2.817	-1.856	-1856	
shine - sign	*0.986*	*0.948*	*0.038*	*38*	
talk - chalk	-	-	-	-	
top - chop	1.448	1.533	-0.085	-85	
chart - tart	-	-	-	-	

Nr of pairs	39
Nr of used pairs	30
Nr of discarded pairs	9
nr = no recording	
Italics = Low-High frequency	

Results for participant 2 (page 4)

<u>**Minimal pairs**</u>	**RT1**	**RT2**	**RT1-RT2**	**RT1-RT2**	
	in s	*in s*	*in s*	*in ms*	
Words (continued)					
call - tall	-	-	-	-	nr
cape - tape	*2.198*	*1.049*	*1.149*	*1149*	
toast - coast	0.970	1.418	-0.448	-448	
take - cake	0.743	0.717	0.026	26	
man - ban	1.183	1.820	-0.637	-637	
may - bay	-	-	-	-	nr
bad - mad	0.991	0.953	0.038	38	
ball - mall	-	-	-	-	
Non-words					
seague - sheague	2.435	1.351	1.084	1084	
sig - shig	1.953	1.155	0.798	798	
sheird- seird	-	-	-	-	
shib - sib	1.105	1.009	0.096	96	
siggle - thiggle	1.442	1.011	0.431	431	
soun - thoun	1.559	1.234	0.325	325	
thist - sist	-	-	-	-	
thart - sart	-	-	-	-	
loke - roke	1.094	0.988	0.106	106	
liss - riss	1.152	1.078	0.074	74	
roise - loise	-	-	-	-	nr
rix - lix	-	-	-	-	ex
tilm - chilm	-	-	-	-	nr
tib - chib	-	-	-	-	nr
chiz - tiz	-	-	-	-	
chid - tid	1.001	1.321	-0.320	-320	

Nr of pairs	12
Nr of used pairs	8
Nr of discarded pairs	4
Nr of "RT1-RT2=pos"	7
Nr of "RT1-RT2=neg"	1
ex = excluded from analysis	
(since 'lix' corresponds to the word 'licks')	

Results for the control person (page 1)

Same pairs	RT1	RT2	RT1-RT2	RT1-RT2
	in s	*in s*	*in s*	*in ms*
Words				
seize	1.142	1.539	-0.397	-397
six	1.087	1.023	0.064	64
sheer	0.935	1.025	-0.090	-90
shift	0.910	0.859	0.051	51
thief	1.089	0.927	0.162	162
thumb	1.064	0.866	0.198	198
lam	0.901	1.067	-0.166	-166
louse	1.194	0.942	0.252	252
room	0.885	0.685	0.200	200
red	0.877	0.773	0.104	104
say	1.141	0.946	0.195	195
send	1.133	1.043	0.090	90
shape	0.878	1.001	-0.123	-123
share	0.983	0.919	0.064	64
tea	0.995	0.696	0.299	299
team	0.944	0.795	0.149	149
chief	1.488	1.175	0.313	313
cheap	0.832	1.182	-0.350	-350
tell	0.770	1.188	-0.418	-418
tax	1.205	0.688	0.517	517
change	1.249	1.083	0.166	166
check	0.795	0.785	0.010	10
soap	0.983	0.879	0.104	104
size	1.328	0.899	0.429	429
shop	1.331	0.973	0.358	358
shout	1.123	0.833	0.290	290
tone	1.001	1.142	-0.141	-141
tight	0.894	0.808	0.086	86
charm	0.970	0.914	0.056	56
choice	0.860	0.729	0.131	131
come	0.892	1.016	-0.124	-124
cool	0.851	0.668	0.183	183
mess	1.588	0.760	0.828	828
moon	1.017	0.702	0.315	315
bell	1.054	1.279	-0.225	-225
book	0.754	1.056	-0.302	-302

Nr of pairs	36
Nr of used pairs	36
Nr of discarded pairs	0
Nr of "RT1-RT2=pos"	26
Nr of "RT1-RT2=neg"	10

Results for the control person (page 2)

<u>**Same pairs**</u>	**RT1**	**RT2**	**RT1-RT2**	**RT1-RT2**
	in s	*in s*	*in s*	*in ms*
Non-words				
seach	1.299	1.601	-0.302	-302
sitch	1.248	1.135	0.113	113
shim	1.313	1.065	0.248	248
shive	0.990	1.325	-0.335	-335
thamp	0.946	1.333	-0.387	-387
thoom	1.238	0.964	0.274	274
lown	1.578	1.200	0.378	378
lact	1.689	1.355	0.334	334
rond	1.521	1.231	0.290	290
runk	1.214	1.093	0.121	121
teave	0.893	1.109	-0.216	-216
teag	2.143	1.029	1.114	1114
cheal	1.519	1.100	0.419	419
chead	1.692	1.067	0.625	625
sime	1.342	1.211	0.131	131
samp	1.031	1.043	-0.012	-12
shorm	1.051	1.144	-0.093	-93
shoop	1.134	1.177	-0.043	-43
coom	0.872	1.084	-0.212	-212
kig	1.343	1.166	0.177	177
toaf	0.796	0.931	-0.135	-135
tarm	0.941	1.225	-0.284	-284

Nr of pairs	22
Nr of used pairs	22
Nr of discarded pairs	0
Nr of "RT1-RT2=pos"	12
Nr of "RT1-RT2=neg"	10

Results for the control person (page 3)

<u>**Minimal pairs**</u>	**RT1**	**RT2**	**RT1-RT2**	**RT1-RT2**	
	in s	*in s*	*in s*	*in ms*	
Words					
seat - sheet	1.587	1.135	0.452	452	
seek - chic	-	-	-	-	
she - sea	1.015	0.989	0.026	26	
sheep - seep	0.821	1.444	-0.623	-623	
shield - sealed	1.222	2.183	-0.961	-961	x
sit - shit	0.889	1.172	-0.283	-283	
single-shingle	-	-	-	-	
ship - sip	0.827	1.265	-0.438	-438	
seem - theme	1.083	1.348	-0.265	-265	
sick - thick	0.855	1.452	-0.597	-597	
sigh - thigh	1.572	1.071	0.501	501	
think - sink	0.868	1.127	-0.259	-259	
thing - sing	1.087	1.097	-0.010	-10	
thin - sin	0.950	0.963	-0.013	-13	
late - rate	0.844	1.066	-0.222	-222	
let - rat	1.314	0.961	0.353	353	
low - row	0.894	1.108	-0.214	-214	
road - load	0.896	1.003	-0.107	-107	
rock - lock	0.984	0.748	0.236	236	
right - light	1.000	0.930	0.070	70	
same - shame	0.941	1.178	-0.237	-237	
self - shelf	-	-	-	-	
shake - sake	0.973	0.975	-0.002	-2	
shell - sell	*0.902*	*0.830*	0.072	72	x
tease - cheese	*0.938*	*1.131*	-0.193	-193	x
tin - chin	0.884	1.205	-0.321	-321	
cheek - teak	1.174	1.032	0.142	142	
chip - tip	*1.073*	*1.063*	0.010	10	x
test - chest	1.441	1.077	0.364	364	
taste - chaste	0.997	1.244	-0.247	-247	
chap - tap	0.941	0.909	0.032	32	x
cherry - Terry	1.007	1.205	-0.198	-198	
sort - short	1.172	0.772	0.400	400	
sigh - shy	1.572	1.378	0.194	194	
shock - sock	0.915	0.984	-0.069	-69	
shine - sign	0.951	0.922	0.029	29	x
talk - chalk	-	-	-	-	
top - chop	1.281	1.062	0.219	219	
chart - tart	0.962	1.431	-0.469	-469	

Nr of pairs	47
Nr of used pairs	42
Nr of discarded pairs	5
Nr of "RT1-RT2=pos"	20
expected	5
unexpected	15
Nr of "RT1-RT2=neg"	22
expected	20
unexpected	2
Italics = x =	
Low-High Frequency	

Results for the control person (page 4)

<u>**Minimal pairs**</u>	**RT1**	**RT2**	**RT1-RT2**	**RT1-RT2**	
	in s	*in s*	*in s*	*in ms*	
Words (continued)					
call - tall	0.889	0.747	0.142	142	
cape - tape	1.105	0.863	0.242	242	x
toast - coast	1.393	0.785	0.608	608	
take - cake	1.381	0.889	0.492	492	
man - ban	-	-	-	-	
may - bay	1.059	1.545	-0.486	-486	
bad - mad	1.061	0.973	0.088	88	
ball - mall	0.907	1.100	-0.193	-193	
Non-words					
seague - sheague	1.497	1.192	0.305	305	
sig - shig	1.796	1.146	0.650	650	
sheird- seird	1.354	1.132	0.222	222	
shib - sib	1.077	1.215	-0.138	-138	
siggle - thiggle	0.994	0.914	0.080	80	
soun - thoun	1.227	1.581	-0.354	-354	
thist - sist	1.139	1.388	-0.249	-249	
thart - sart	2.185	0.960	1.225	1225	
loke - roke	1.193	1.591	-0.398	-398	
liss - riss	1.094	0.989	0.105	105	
roise - loise	1.119	1.001	0.118	118	
rix - lix	-	-	-	-	
tilm - chilm	1.074	1.513	-0.439	-439	
tib - chib	1.192	1.349	-0.157	-157	
chiz - tiz	1.156	0.999	0.157	157	
chid - tid	0.754	0.931	-0.177	-177	

Nr of pairs	15
Nr of used pairs	15
Nr of discarded pairs	0
Nr of "RT1-RT2=pos"	8
Nr of "RT1-RT2=neg"	7
ex = excluded from analysis	
(since 'lix' corresponds to the word 'licks')	

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