Effect of L1 Japanese Phonology in Silent Reading of L2 English by Japanese Speakers

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Abstract

母語において、音韻的に類似する語を黙読で処理する際に記憶率が低下したり、符号化時の処理負担が増大したりすると報告されている。一方で、第二言語の黙読文処理における音韻的類似の影響についての研究は乏しく、第二言語と母語のいずれの音韻規則によって音韻的類似が判断されるのか不明である。そこで本研究では自己ペース文黙読実験を実施し、音素の対立が失われ日本語で同音となる track、truck のような語と日本語でも対立を残す cat、cart のような語とでの読み時間を比較することで、日本語母語話者は第二言語としての英語の黙読時に、日本語の音韻規則の影響を受けるという仮説を検証した。結果については、同音となる語の方が対立を残す語よりも符号化時の処理負担が増大すると予測した。分析結果は、弱い証拠ではあるが、同音となる語の方が対立を残す語よりも符号化での処理負担をより増大させる可能性、対立を残す語が想起の処理負担を軽減する可能性を示唆した。したがって、日本語母語話者による第二言語としての英語の黙読文処理において、日本語の音韻規則が影響している可能性は否定できないといえる。

Key Words: sentence processing, L2 phonology, phonological interference

1. Introduction

1.1 L1 phonological transfer to L2 phonological realization

It has been reported that L2 late learners produce L2 phones differently from native speakers. For instance, acoustic analysis of Japanese speakers' production of English vowels revealed their confusion of English neighboring vowels, especially the /ɑ/–/ʌ/ contrast was mapped into Japanese /a/, and the /u/–/ʊ/ contrast into Japanese /u/ (Tsukada, 1999). Japanese speakers are also reported to produce both /æ/ and /ʌ/ as /a/ (Thompson, 2001), disabling the phonological differentiation of the English words *truck* and *track*, for instance. Such mispronunciations have been attributed to L1 phonological transfer into L2 production: learners cannot differentiate non-native contrast that the L1 phonology does not have. In this case, in Japanese, there is no phonological contrast between /æ/, /ʌ/, and /ɑ/, all of which are categorized as /a/. On the other hand, some phonological contrasts in L2 English are retained in L1 Japanese phonology, although they are in a different form from the original. For example, the vowels /æ/ and /ɑ:r/ are realized as /a/ and /a:/ respectively by native Japanese speakers: the vowels are differentiated by their length, not by their quality.

In sum, there are two patterns of L2 English phonological realization by L1 Japanese speakers: the L2 contrasts that are totally lost in L1 Japanese phonology, such as /æ/–/ʌ/ into /a/, and the L2 contrasts that are kept in L1 Japanese phonology, such as /æ/–/ɑ:r/ into /a/–/a:/.

1.2 Effect of phonological overlap on memory or sentence processing in L1

Some previous studies on L1 processing have suggested that phonological overlap interferes with memory or sentence processing even if the input is written words, not just audio stimuli. For example, when a group of participants memorized phonologically similar written words such as *mad*, *man*, or *map*, the recall accuracy of the words was significantly lower compared to when another group of participants memorized and recalled words which do not phonologically overlap, such as *pen*, *rig*, or *day* (Baddeley, 1966)[1]. He concluded that the phonological overlap disturbs the correct memorization into the short-term memory (STM), even if the words are presented in a written form.

The interference by phonologically similar words is reported to also occur at the sentence level. In a study by Kush et al. (2015), the participants memorized three load words sharing the same rhyme with the target word in the sentence: for instance, *coat–vote–note* for *boat*. After memorizing the load words, they silently read the sentences chunk by chunk such as *It was the boat/ that the guy/ who/ drank/ some hot coffee/ sailed/ on two sunny days* (the parts divided by a slash '/'). One of the aims of the study was to observe the phonological interference in encoding and retrieval. Encoding is the process where the information of the word is stored in the STM. On the other hand, retrieval is the process where information of the stored word is extracted from the memory. In this case, encoding is equivalent to *It was the boat* where the participants first encounter the word *boat* and memorize its information. Retrieval is equivalent to the transitive verb *sailed* where they need to recall the memorized word *boat* to fill the object of *sailed*. The results revealed that the reading time significantly increased immediately after *It was the boat*, compared to the condition when the participants memorized phonologically dissimilar words, such as *table–sink–truck* or the condition in which they did not memorize any words before reading the sentence. In contrast, no significant increase in the reading time was found at or after *sailed*. They concluded that the phonological similarity between the load words *coat–vote–note* and the word *boat* in the sentence interfered with the encoding, but not with the retrieval.

The reported interference can be considered to be phonological, rather than orthographic, even though the stimuli were written words. Phonological information is thought to play a central role in STM storage (Baddeley & Hitch, 1974)[2], and since an acoustic form is preferred to a visual form to store in the STM, the information of the visual form is converted into an acoustic one through covert or overt articulation (Murray, 1967: Sperling, 1967: Levy, 1971). Moreover, the activation of phonological information against written stimuli has been reported to automatically occur before lexical processing (Perfetti et al., 1988). Though it is possible to attribute the confusion to the orthographic similarity rather than the phonological one, phonological similarity has a stronger influence than orthographic similarity. For example, Van Orden (1987) revealed that ROWS, a homophone of ROSE, is more likely to be mistakenly categorized as a category of A FLOWER than ROBS, an orthographically similar word. These suggest that being affected by phonological similarity during the processing of written words is almost inevitable.

The existence of covert articulation is also physiologically evident. Magrassi et al. (2015) observed cortical activity and found that it is significantly correlated with the sound envelope of the utterance either in reading mentally or reading aloud. The results imply that both by the covert articulation and overt articulation, sentences are processed in similar ways and further suggesting the possibility that a pattern of covert articulation can be an extension of overt articulation.

1.3 Possible L1 phonological interference in L2 sentence processing

As explained in Chapter 1.1, there are two patterns of phonological similarity in L2 English words judged by L1 Japanese phonology: one is a totally same-sounding pair and the other is a contrastive but similar-sounding pair. If the phonological transfer to L2 production occurs also during silent reading of L2 English, words with contrasts that are lost in Japanese phonological rules, such as *track* vs. *truck*, will be regarded as phonologically the same words and a dramatic slowdown of processing is expected. On the other hand, L2 English words that retain phonological contrast also in the Japanese phonological rules, such as *cat* vs. *cart*, will be regarded as less similar compared to the *track–truck* pair, but still more similar than words which have little phonological similarity such as the *track–path* pair (/æ/ is overlapping).

We conducted a silent reading experiment to answer the following four research questions: 1) whether native Japanese speakers apply L1 Japanese phonological rules in processing of L2 English silent reading, as well as production of L2 English, 2) whether the degree of the increase of the processing cost differs between neutralized words and non-neutralized words in Japanese phonological rules, 3) at which point the phonological similarity of English words judged by Japanese phonological rules interferes with the processing, and 4) how English proficiency in general is related to the vulnerability to the phonological similarity judged by L1 Japanese phonology during the L2 English sentence processing.

2. Experiment

2.1 Participants

Thirty students from the University of Tokyo participated in the experiment. As four of the participants did not fill out the language background questionnaire, there are 26 out of the 30 participants' language background data including their age and English education experience available. Their age ranged from 19 to 25 (M = 20.27, SD = 1.37) and the length of their English experience ranged from 8 to 19 years (M: 11.3, SD = 3.27). The mean score of Oxford Quick Placement Test (OQPT) was 42.33/60 (SD = 4.11).

2.2 Stimuli

The target sentences were 48 relative clause sentences, 12 of which were presented per participant. They were of 2 factors × 2 standards as in Table 1 and randomized by Latin Square.

Table 1. Examples of the target sentences

	region 1	region 2	region 3	region 4	region 5	region 6	region 7	region 8	region 9	region 10
a. same/ overlap	The track	that	the truck	is	accidentally	running	toward (gap)	is	very	outstanding.
b. same/ no_overlap	The path	that	the truck	is	accidentally	running	toward (gap)	is	very	outstanding.
c. different/ overlap	The cart	that	the cat	is	accidentally	running	toward (gap)	is	very	outstanding.
d. different/ no_overlap	The box	that	the cat	is	accidentally	running	toward (gap)	is	very	outstanding.

The first factor is NE (Neutralization). As the /æ/–/ʌ/ contrast does not exist in Japanese phonology, the sound of words at region 1 and region 3 is totally neutralized in L1 Japanese phonology. This was set as SAME standard (see (1a) in Table 1). On the other hand, as in (1c), *cat* and *cart* are not neutralized into the same sound in Japanese phonology, with the first CV resulting in /kja/ and /ka:/ respectively, the sounds of which are similar. This was set as DIFFERENT standard. The second factor is OV (Overlap), which consists of the two standards of OVERLAP and NO_OVERLAP. As mentioned above, the sound of the words at region 1 and region 3 are similar in the condition a and c, which was set as OVERLAP standard. As a baseline for the OVERLAP standard, NO_OVERLAP standard was set. The word at region 1 is semantically similar or related between condition a and condition b, and also between condition c and condition d: *track* (a)–*path* (b), and *cart* (c)–*box* (d). On the other hand, the word at region 1 is phonologically dissimilar with the word at region 3 in condition b and condition d: *path*–*truck* (b) and *box*–*cat* (d). Therefore, though condition b is labeled as 'same', it does not mean that the words in region 1 and region 3 in condition b share the same phonological representation in L1 Japanese phonology.

In other target sentences, consonantal contrasts which are lost in Japanese speakers' production were also used, such as *writer* /ɹ̠aɪtɚ/ vs. *lighter* /l̠aɪtɚ/, whose initial consonants are both neutralized into /r/ due to the lack of a /r/-/l/ contrast in Japanese (see the Appendix for all examples). After reading the whole sentence, a comprehension question such as *Is the truck running toward the track?* was presented to the participants for each sentence and they were required to answer, by pressing the f key for *Yes* and the j key for *No* on the keyboard.

2.3 Fillers

After eight practice sentences, 90 filler sentences were presented to the participants in addition to the target sentences. The filler sentences included sentences with an island such as *He respects the princess that the musician who composed eagerly admired in her heart* or polarity licensing sentences such as *None of the students recognized the singer at all during the trip*. The number of sentences presented to each participant in the session therefore totaled to 102.

2.4 Procedure

Participants visited the computer room at the University of Tokyo and completed the silent reading task and OQPT in a row. The silent reading task was run on a desktop PC using the linger software (Rohde, 2003).

Before the experiment, they were told to read the sentences at the same pace as they usually read English. The silent reading task started with a practice session of eight sentences so that the participants could get used to the manipulation. On the screen, multiple hyphen characters '-----' whose length was corresponding to the length of each word or phrase in a sentence was first displayed. The first dash characters changed into a plus '+' when the participant pressed the space bar and the first word or phrase appeared when the space bar was pressed again. The multiple dash characters were replaced with a word or a phrase from left to right each time a participant pressed the space bar. After the silent reading task, the participants accessed the URL of OQPT transformed into a Google form via the Chrome browser and answered the questions there. The whole task took them 1.5 hours and they were paid 1,500 yen.

2.5 Analysis

The analysis was done for both the data of only the correct answers and the data that included wrong answers for the comprehension questions, as the two analyses offer different merits. The data of only correct answers represent the data of participants who understood the meaning of the sentences correctly, which means the analysis can omit the data of those who did not recognize the similar sounding words as different words. On the other hand, as phonological similarity is thought to confuse comprehension, the merit in observing the data including wrongly answered ones is that it can include the data of those who are more strongly influenced by the interfering effect of the phonological similarity.

2.5.1 Formula and Analysis Method

For the statistical analysis, Linear Mixed Effect Model (LME) was used, with the lmer package in the R software (version 3.5.0). The reading time (rt) was set as dependent variables, NE and OV as fixed factors, and individual differences among the participants and items as random factors. For NE, SAME was coded as 1 and DIFFERENT as 2. For OV, OVERLAP was coded as 1 and NO_OVERLAP as 2. The coded standards were then centralized. Using Backward Selection (Bates, 2015), which eliminates statistically less significant elements of the random factors, the formula below was simplified.

lmer(rt~ NE+OV+NE:OV+(1+NE+OV+NE:OV|subj)+(1+NE+OV+NE:OV|item))

To investigate whether low English proficiency is related to an increase in the processing cost at encoding, the interaction between the OQPT score and OV at region 3 was also analyzed through the LME. The reading time was set as dependent variables, OV and STA (the standardized OQPT score) as fixed factors, and individual differences among the participants and items were set as random factors. The formula is as follows.

lmer(rt~ STA+OV+STA:OV+(1+STA+OV+STA:OV|subj)+(1+STA+OV+STA:OV|item))

2.5.2 Data trimming

To omit the outliers, data trimming was done for both the data of correct answers and the data including wrong answers, taking two processes. The first process was to omit the data with too short or too long reading time arbitrarily judged by a histogram of each region (trimming 1). The data with less than 150ms and more than 1,500ms or 3,000ms were excluded in the trimming 1 (see Table 2). After the trimming 1 and the formula calculation, data that exceeded the range of $SD = \pm 2.5$ was excluded (trimming 2). The percentage of the remaining data is shown in Table 2 as well.

Table 2. The percentage of remaining data after each data trimming (correct answer only)

	correct answers only			including wrong answers		
	reading time	after trimming 1	after trimming 2	reading time	after trimming 1	after trimming 2
region 3	3000ms	96.60%	97.20%	3000ms	96.70%	97.70%
region 4	1500ms	97.00%	97.20%	1500ms	95.60%	96.50%
region 7	1500ms	97.60%	95.20%	1500ms	97.80%	95.70%
region 8	1500ms	96.30%	95.80%	1500ms	96.90%	96.30%
region 9	1500ms	95.60%	96.10%	1500ms	95.80%	95.70%

Regarding the analysis of OV × STA at region 3, the percentage of the remaining data after trimming 2 is 97.9% in correct answers only and 98.3% in including wrong answers.

2.6 Hypotheses and expected results

We set two hypotheses regarding the processing cost of the sentence, based on the premise that the processing cost will increase when the words are phonologically similar, as shown in the earlier studies. The first is that, based on the idea of L1 phonological transfer and the idea of covert articulation, native Japanese speakers will be subject to Japanese phonological rules even in silent reading of L2 English, as well as the production of L2 English sounds (transfer hypothesis). For instance, *track* and *truck* will be processed as the same words phonologically due to the loss of the /æ/–/ʌ/ contrast and *cart* and *cat* will be as phonologically contrastive words with the vowel contrast of /(j)a:/–/a/, the former of which is more onerous to process due to the higher degree of phonological similarity. The second is that, based on the results of the experiment by Kush et al. (2015), the phonological interference will be influential at encoding (encoding hypothesis).

The transfer hypothesis therefore expects the largest increase in reading time in SAME/OVERLAP (e.g., *track–truck*), followed by DIFFERENT/OVERLAP (e.g., *cart–cat*), and NO_OVERLAP baseline (e.g., *path–truck*, *box–cat*). The encoding hypothesis combined with the transfer hypothesis leads to the expectations that, at region 3, where the participants encounter the phonologically overlapping word with the one at region 1 and store the information of it in their STM (encoding), the reading time will be SAME/OVERLAP > DIFFERENT/OVERLAP > NO_OVERLAP. Though there is no strong evidence to support the phonological interference at retrieval, the transfer hypothesis can expect the same pattern of the increase in the reading time SAME/OVERLAP > DIFFERENT/OVERLAP > NO_OVERLAP also at region 7 or 8, where the participants need to remember the object that follows the preposition (retrieval), if the phonological interference occurs also at retrieval. The gap of the reading time at region 3, or possibly region 7 or 8 between the conditions, will appear as the significant interaction effect of NE × OV.

With regards to the relationship between the degree of vulnerability to the phonological similarity judged by L1 Japanese and English proficiency, we tested the hypothesis that less English proficiency related to more vulnerability to L1 Japanese phonology during processing of L2 English based on the results of the study on English production by Japanese speakers by Yazawa et al. (2018), which suggested that Japanese learners of English with high proficiency are likely to acquire native-like pronunciation while low proficiency learners' pronunciation being affected by their L1 Japanese. It is therefore expected that the lower the OQPT score is, the greater increase in the reading time at region 3 in OVERLAP standard will be: there will be a significant interaction effect of OV × STA.

3. Results

The critical region for encoding is at region 3 as the participants needed to memorize the phonologically overlapping words that they encountered into their STM (e.g., memorizing *truck* after encountering *track*). Region 4, the following region, is a spillover region where the effect that should have appeared in the critical region may appear delayed. The two regions were therefore analyzed for the observation of encoding. On the other hand, the participants need to extract the antecedent they encountered at region 1, to follow the preposition at region 7 (e.g., *the track* after *toward*), from their memory. Region 7 is therefore the critical region and the following region 8 is the spillover region for retrieval. It is also possible to set region 8 as the critical region for retrieval, as it becomes clear that the preposition at region 7 is in a relative clause. In this case, region 9 is the spillover region. Therefore, for the observation of retrieval, the reading time at the three regions was analyzed.

3.1 Region 3 and region 4: encoding

The results of the LME analysis of the reading time at region 3 and region 4 (correct answers only) are presented in Figure 1 and Table 3.

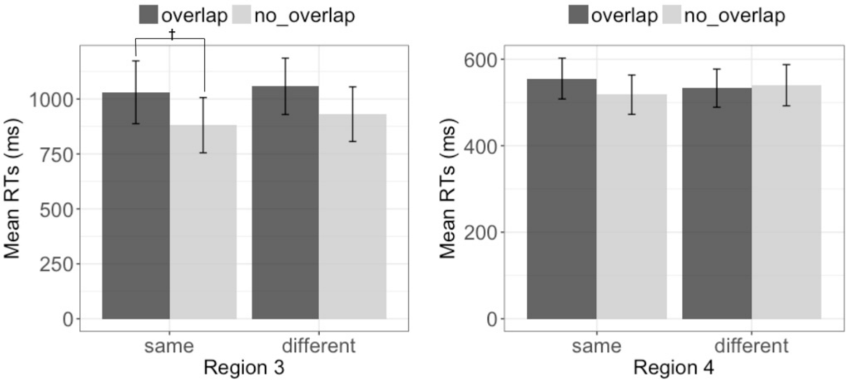

Figure 1. The reading time at region 3 and region 4 (correct answers only).
The error bars in the bar graph represent 95% confidence interval.

Table 3. LME results at region 3 and region 4 (correct answers only)[3].

	β	*SE*	*df*	*t*	*p*	
	region 3					
(Intercept)	981.390	62.620	28.970	15.672	<.001	***
NE	40.840	55.780	247.000	0.732	0.464	
OV	−145.050	55.560	244.260	−2.611	0.009	**
NE:OV	32.100	111.350	244.670	0.288	0.773	
	region 4					
(Intercept)	541.188	17.804	28.851	30.396	<.001	***
NE	4.898	21.258	254.113	0.230	0.818	
OV	−14.058	21.197	251.115	−0.663	0.508	
NE:OV	42.036	42.384	250.959	0.992	0.322	

The LME analysis revealed that the main effect of OV (Overlap) is significant at region 3, as in Table 3. As Figure 1 shows, the reading time seems to be longer in OVERLAP standard than in NO_OVERLAP standard at region 3. However, the simple main effect analysis indicated the marginally significant main effect of OV only at SAME standard. As in Figure 2, the results of the data including wrong answers at region 3 also show a similar pattern and simple main effect analysis revealed the significant main effect of OV only at SAME standard. No significant difference was found at region 4 in either the data with correct answers or the data including wrong answers, as in Table 3 and Table 4.

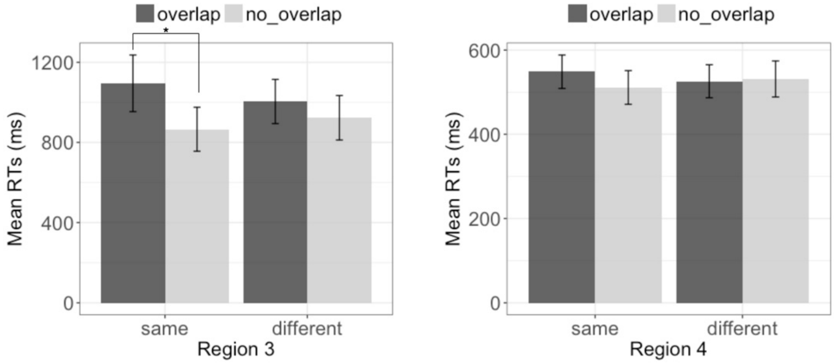

Figure 2. The reading time at region 3 and region 4 (including wrong answers).
The error bars in the bar graph represent 95% confidence interval.

Table 4. LME results at region 3 and region 4 (including wrong answers).

	β	*SE*	*df*	*t*	*p*	
	region 3					
(Intercept)	973.610	59.310	29.380	16.417	<.001	***
NE	−20.320	50.390	279.780	−0.403	0.687	
OV	−151.920	50.380	278.070	−3.015	0.002	**
NE:OV	143.310	124.330	29.200	1.153	0.258	
	region 4					
(Intercept)	531.066	16.762	29.003	31.682	<.001	***
NE	2.877	18.498	302.731	0.156	0.877	
OV	−14.108	18.480	302.133	−0.763	0.446	
NE:OV	38.584	36.981	302.458	1.043	0.298	

3.2 Region 7, region 8, and region 9: retrieval

For the analysis of correct answers only, the results of the LME analysis of the reading time at region 7 and region 8 are presented in Figure 3 and Table 5.

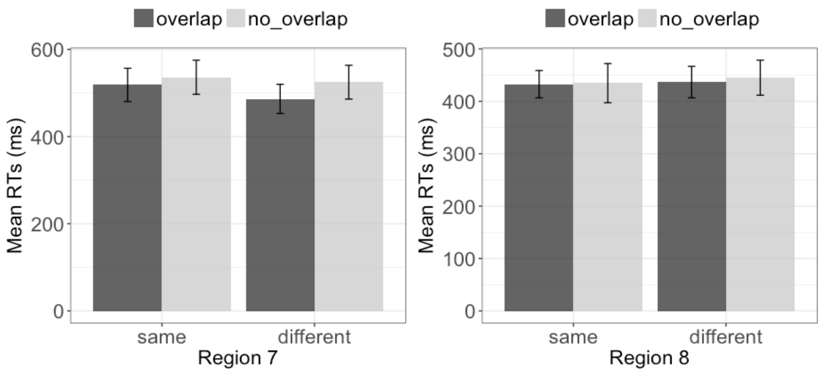

Figure 3. The reading time at region 7 and region 8 (correct answers only).
The error bars in the bar graph represent 95% confidence interval.

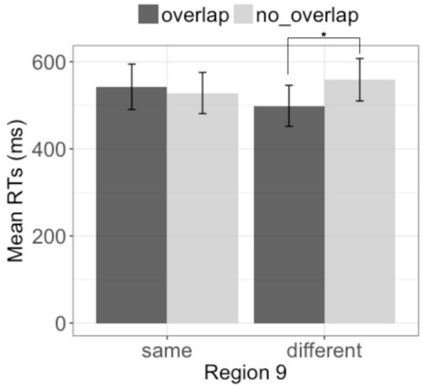

Figure 4. The reading time at region 9 (correct answers only).

The error bars represent 95% confidence interval.

Table 5. LME results at region 7, region 8, and region 9 (correct answers only)

	β	*SE*	*df*	*t*	*p*	
	region 7					
(Intercept)	521.030	20.720	21.220	25.148	<.001	***
NE	−24.790	15.600	216.950	−1.589	0.113	
OV	27.540	20.800	30.310	1.324	0.195	
NE:OV	20.510	30.980	216.150	0.662	0.509	
	region 8					
(Intercept)	437.599	16.121	28.919	27.143	<.001	***
NE	5.806	13.019	245.716	0.446	0.656	
OV	10.370	12.958	244.043	0.800	0.424	
NE:OV	−0.787	25.789	242.928	−0.031	0.976	
	region 9					
(Intercept)	537.403	27.885	19.504	19.272	<.001	***
NE	−2.379	20.974	237.279	−0.113	0.909	
OV	25.877	20.975	235.450	1.234	0.218	
NE:OV	76.238	41.709	232.939	1.828	0.068	.

As Figure 4 shows, the reading time in OVERLAP standard is shorter than that of NO_OVERLAP at DIFFERENT standard at region 9, while there is little difference in the reading time between OVERLAP and NO_OVERLAP at SAME standard. The LME analysis revealed that the interaction effect of NE × OV is marginally significant, as in Table 5. The simple main effect analysis in the DIFFERENT standard indicated that the main effect of OV is significant. No significant difference was found at either region 7 or region 8 in the data of only correct answers. In the analysis of the data including wrong answers, no significant effect was found in the three regions related to retrieval as in Table 6. However, as Figure 5 shows, the reading time at region 7 is the shortest in DIFFERENT/OVERLAP and the simple main effect analysis found a significant main effect of OV in the DIFFERENT standard. The pattern is close to the NE × OV interaction.

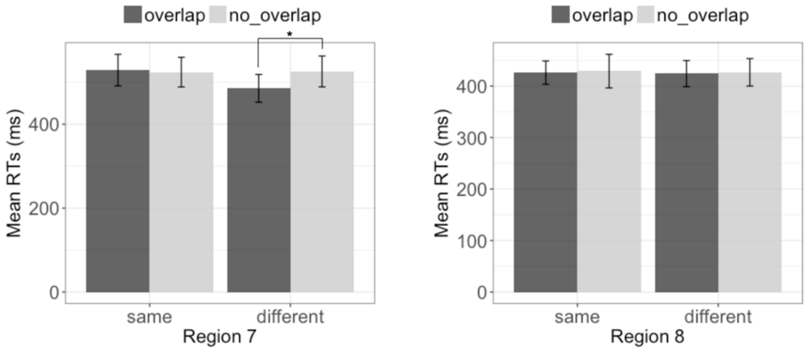

Figure 5. The reading time at region 7 and region 8 (including wrong answers)

The error bars represent 95% confidence interval.

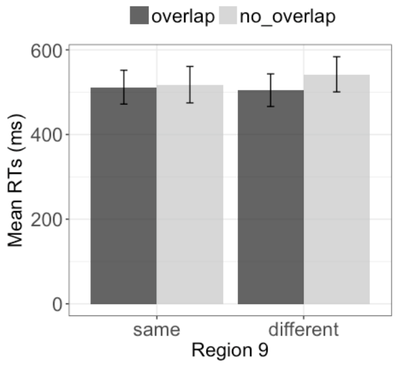

Figure 6. The reading time at region 9 (including wrong answers)

The error bars in the bar graph represent 95% confidence interval.

Table 6. LME results at region 7, region 8, and region 9 (including wrong answers)

	β	*SE*	*df*	*t*	*p*	
	region 7					
(Intercept)	519.570	22.990	25.220	22.602	<.001	***
NE	−20.360	14.650	296.530	−1.390	0.166	
OV	23.120	14.650	296.770	1.577	0.116	
NE:OV	42.870	29.240	295.880	1.466	0.144	
	region 8					
(Intercept)	429.876	14.583	28.795	29.477	<.001	***
NE	−3.628	10.857	296.340	−0.334	0.738	
OV	7.425	10.877	296.841	0.683	0.495	
NE:OV	−7.843	21.754	299.735	−0.361	0.719	
	region 9					
(Intercept)	523.390	24.558	21.419	21.312	<.001	***
NE	8.486	17.524	289.772	0.484	0.629	
OV	21.714	17.524	289.664	1.239	0.216	
NE:OV	35.868	35.051	289.338	1.023	0.307	

3.3 The increase in processing cost at encoding and English proficiency

The results of the LME analysis showed a significant main effect of OV ($p < 0.05$) in both the analysis of correct answers only and including wrong answers: regardless of the score of the OQPT, the reading time at region 3 was significantly longer in OVERLAP than in NO_OVERLAP.

4. Discussion

The significant main effect of OV at region 3 is consistent with the results of Kush et al. (2015) that the phonological similarity interferes with the processing at the encoding. The increase in the reading time at region 3 can be a support for the encoding hypothesis, but it does not confirm the transfer hypothesis because it is possible to consider that the participants may have processed the L2 English sentences according to the phonological similarity in the English context. That is, the similarity between /træk/ and /trʌk/, and /kæt/ and /kɑːrt/, all of which share phonological structures in common except for the difference in the vowels, may have increased the processing cost of L2 silent reading. Still, it is also possible to consider that the phonologically similar words were processed according to L1 Japanese phonological rules: as *track–truck* and *cat–cart* are more similar than *track–path* or *box–cat* when applied to L1 Japanese phonological rule, the processing cost of the OVERLAP became larger than that of the NO_OVERLAP. Additionally, even though the expected significant interaction effect of NE × OV was not found, given the fact that the simple main effect analysis of the data including wrong answers at region 3 revealed a significant main effect of OV only at SAME standard, the pattern is close to the expected NE × OV interaction effect. The results do not contradict the transfer hypothesis that Japanese speakers use L1 Japanese phonology during silent reading of L2 English: the *track–truck* pair is more demanding to process than the *cart–cat* pair, as the former is more phonologically similar than the latter in L1 Japanese phonology.

The marginally significant NE × OV interaction effect at region 9 in the analysis of the data of correct answers, with the reading time of DIFFERENT/OVERLAP being the shortest of the four, suggests that the phonological similarity that does not completely neutralize in L1 phonological rules can facilitate the retrieval process, which was not expected. In the analysis of the data including wrong answers, though the significant interaction effect was not found, the fact that the reading time was significantly shorter in OVERLAP standard than in NO_OVERLAP standard at DIFFERENT standard at region 7 is also thought to reflect the facilitation effect. The results do not correspond to any of the expectations, but the reading time still tends to be longer in SAME/OVERLAP than in DIFFERENT/OVERLAP at region 7. Thus, it can also be argued that the results are a weak support for the transfer hypothesis according to which L1 Japanese phonology transfer to L2 English processing causes a larger increase in processing cost in phonologically non-contrastive words in L1 phonology.

Regarding the hypothesis that less English proficiency means more vulnerability to the phonological similarity judged by L1 phonological rules, the significant main effect of OV in the analysis of OV × STA interaction implies that the effects of phonological similarity interfere with the processing in silent reading, regardless of the level of English grammatical or vocabulary proficiency.

5. Conclusion and further issues

This study investigated the interfering effect of L2 phonological similarity judged by L1 phonological rules in L2 English silent reading by native Japanese speakers. It was hypothesized that Japanese speakers would apply L1 Japanese phonological rules during the processing of L2 English in silent reading, based on the theories about STM-phonology interaction and L1 phonological transfer and that the effect of the phonological overlap would mainly occur at encoding, based on the results of Kush et al. (2015). It was therefore expected that the reading time at region 3 would increase the most in SAME/OVERLAP, in which the two words at region 1 and region 3 become the same sound according to Japanese phonological rules, followed by DIFFERENT/OVERLAP, in which the two words are phonologically similar but not neutralized in the Japanese phonological rules. The significant main effect of OV at region 3 supports the encoding hypothesis but does not strongly support the transfer hypothesis, as there was no significant NE × OV interaction effect, contrary to the expectations. However, despite the absence of the expected significant NE × OV interaction effect, the pattern is similar to the interaction one, and the simple main effect analysis revealed the marginally significant main effect of OV at the SAME condition. This can be attributed to the lack of items or participants, and thus, by increasing the number of items or participants, the pattern might be confirmed by a significant interaction effect. Regarding the retrieval, the results implied the unexpected facilitation effect of phonologically similar but non-neutralized L2 words in L1 phonological rules, which none of the hypotheses can explain. Still, given the fact that the reading time was longer in SAME/OVERLAP than in DIFFERENT/OVERLAP at region 7, the results can also be interpreted as a weak support for the transfer hypothesis at retrieval that supposes a larger increase in the processing cost in phonologically non-distinct L2 words in L1 phonology than in phonologically distinct ones in L1 phonology.

There remain some methodological issues in the current study. For instance, the selection of target words was problematic: in brief, they are not balanced. First, as mentioned before, they include both English vocalic and consonantal contrasts. Second, the orthographic similarity of the target words in each item was not taken into consideration, so the difference in the degree of orthographic similarity within the items may have affected the results. Third, unintentional phonological overlap which may have affected the results occurs in some items: *back* and *wrap* in item 11 share /æ/ and *path* and *truck* share the same vowel /a/ if L1 Japanese phonology is transferred. Moreover, the items include a minimal pair in terms of both vowel and consonant such as *food* vs. *hood* (/fu:/ vs. /hʊ/) in item 3. The contrast may have affected the processing by the participants who were dependent on English phonology.

The result that there was no significant OQPT score × OV interaction effect but that there was a main effect of OV, which implies that the interfering effect by phonological similarity occurs regardless of English proficiency, was different from the expectations. However, it should be noted that OQPT measures only grammatical or vocabulary ability, not listening or speaking ability. If the relationship between listening or speaking proficiency and the increase in the reading time at region 3 in OVERLAP standard were investigated, the results may have shown a significant interaction effect of OV × proficiency score: less English proficiency in listening or speaking will be closely related to an increase in the cost of processing the English words that become the same or similar sounds in Japanese phonological rules in silent reading.

Appendix: the list of target sentences

item	condition	sentence
1	a. same/ overlap	The track/ that/ the truck/ is/ accidentally/ running/ toward/ is/ very/ outstanding.
	b. same/ no_overlap	The path/ that/ the truck/ is/ accidentally/ running/ toward/ is/ very/ outstanding.
	c. different/ overlap	The cart/ that/ the cat/ is/ accidentally/ running/ toward/ is/ very/ outstanding.
	d. different/ no_overlap	The box/ that/ the cat/ is/ accidentally/ running/ toward/ is/ very/ outstanding.
2	a. same/ overlap	The court/ that/ the coat/ is/ regularly/ delivered/ to/ is/ very/ gorgeous.
	b. same/ no_overlap	The house/ that/ the coat/ is/ regularly/ delivered/ to/ is/ very/ gorgeous.
	c. different/ overlap	The mart/ that/ the mat/ is/ regularly/ delivered/ to/ is/ very/ gorgeous.
	d. different/ no_overlap	The shop/ that/ the mat/ is/ regularly/ delivered/ to/ is/ very/ gorgeous.
3	a. same/ overlap	The hood/ that/ the food/ is/ accidentally/ falling/ into/ is/ surprisingly/ dirty.
	b. same/ no_overlap	The pocket/ that/ the food/ is/ accidentally/ falling/ into/ is/ surprisingly/ dirty.
	c. different/ overlap	The mill/ that/ the meal/ is/ carefully/ made/ with/ is/ surprisingly/ dirty.
	d. different/ no_overlap	The pan/ that/ the meal/ is/ carefully/ made/ with/ is/ surprisingly/ dirty.
4	a. same/ overlap	The cloud/ that/ the crowd/ is/ slowly/ walking/ toward/ is/ very/ large.
	b. same/ no_overlap	The moon/ that/ the crowd/ is/ slowly/ walking/ toward/ is/ very/ large.
	c. different/ overlap	The bag/ that/ the bug/ is/ slowly/ walking/ toward/ is/ very/ large.
	d. different/ no_overlap	The pot/ that/ the bug/ is/ slowly/ walking/ toward/ is/ very/ large.
5	a. same/ overlap	The leader/ that/ the reader/ is/ eagerly/ talking/ about/ is/ very/ attractive.
	b. same/ no_overlap	The tutor/ that/ the reader/ is/ eagerly/ talking/ about/ is/ very/ attractive.
	c. different/ overlap	The gull/ that/ the girl/ is/ eagerly/ talking/ about/ is/ very/ elegant.
	d. different/ no_overlap	The hawk/ that/ the girl/ is/ eagerly/ talking/ about/ is/ very/ elegant.
6	a. same/ overlap	The lighter/ that/ the writer/ is/ seriously/ gazing/ at/ is/ really/ beautiful.

	b. same/ no_overlap	The ashtray/ that/ the writer/ is/ seriously/ gazing/ at/ is/ really/ beautiful.
	c. different/ overlap	The cheek/ that/ the chick/ is/ temporarily/ gazing/ at/ is/ very/ dirty.
	d. different/ no_overlap	The hand/ that/ the chick/ is/ temporarily/ gazing/ at/ is/ very/ dirty.
7	a. same/ overlap	The ankle/ that/ the uncle/ is/ consistently/ pointing/ at/ is/ heavily/ damaged.
	b. same/ no_overlap	The elbow/ that/ the uncle/ is/ consistently/ pointing/ at/ is/ heavily/ damaged.
	c. different/ overlap	The campus/ that/ the compass/ is/ consistently/ pointing/ at/ is/ heavily/ damaged.
	d. different/ no_overlap	The building/ that/ the compass/ is/ consistently/ pointing/ at/ is/ heavily/ damaged.
8	a. same/ overlap	The crown/ that/ the clown/ is/ gradually/ attracted by/ is/ extremely/ mysterious.
	b. same/ no_overlap	The jewel/ that/ the clown/ is/ gradually/ attracted by/ is/ extremely/ mysterious.
	c. different/ overlap	The seller/ that/ the sailor/ is/ gradually/ attracted by/ is/ extremely/ mysterious.
	d. different/ no_overlap	The clerk/ that/ the sailor/ is/ gradually/ attracted by/ is/ extremely/ mysterious.
9	a. same/ overlap	The seat/ that/ the sheet/ is/ temporarily/ lying/ on/ is/ very/ dirty.
	b. same/ no_overlap	The chair/ that/ the sheet/ is/ temporarily/ lying/ on/ is/ very/ dirty.
	c. different/ overlap	The road/ that/ the rod/ is/ temporarily/ lying/ on/ is/ very/ dirty.
	d. different/ no_overlap	The yard/ that/ the rod/ is/ temporarily/ lying/ on/ is/ very/ dirty.
10	a. same/ overlap	The prayer/ that/ the player/ is/ quite/ fond/ of/ is/ really/ useless.
	b. same/ no_overlap	The nurse/ that/ the player/ is/ quite/ fond/ of/ is/ really/ useless.
	c. different/ overlap	The butter/ that/ the batter/ is/ quite/ fond/ of/ is/ really/ delicious.
	d. different/ no_overlap	The salt/ that/ the batter/ is/ quite/ fond/ of/ is/ really/ delicious.
11	a. same/ overlap	The lap/ that/ the wrap/ is/ temporarily/ lying/ on/ is/ seemingly/ damaged.
	b. same/ no_overlap	The back/ that/ the wrap/ is/ temporarily/ lying/ on/ is/ seemingly/ damaged.
	c. different/ overlap	The pass/ that/ the purse/ is/ temporarily/ lying/ on/ is/ seemingly/ old.
	d. different/ no_overlap	The file/ that/ the purse/ is/ temporarily/ lying/ on/ is/ seemingly/ old.
12	a. same/ overlap	The mouth/ that/ the mouse/ is/ aggressively/ rushing/ into/ is/ extremely/ large.
	b. same/ no_overlap	The ear/ that/ the mouse/ is/ aggressively/ rushing/ into/ is/ extremely/ large.
	c. different/ overlap	The ship/ that/ the sheep/ is/ aggressively/ rushing/ into/ is/ extremely/ large.
	d. different/ no_overlap	The boat/ that/ the sheep/ is/ aggressively/ rushing/ into/ is/ extremely/ large.

Notes

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[1] The mean recall score for the phonologically similar group was 1.7 percent while that for the phonologically dissimilar group was 58.3 percent.

[2] They use the term ‘phonological loop’ to refer to the role and Baddeley corrects the working memory model in Baddeley (2000), adding an interactive role between STM and LTM (long-term memory) to the phonological loop.

[3] *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$

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