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# Effect of Word Familiarity on Non-native Phoneme Perception: Identification of English /r/, /l/, and /w/ by Native Speakers of Japanese.

*Reiko A. Yamada, Yoh'ichi Tohkura, and Noriko Kobayashi*

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ATR視聴覚機構研究所

〒619-02 京都府相楽郡精華町乾谷　☎07749-5-1411

**ATR Auditory and Visual Perception Research Laboratories**

Inuidani,Sanpeidani, Seika-cho, Soraku-gun, Kyoto 619-02 Japan

Telephone: +81-7749-5-1411
Facsimile: +81-7749-5-1408
Telex: 5452-516 ATR J

# Effect of word familiarity on non-native phoneme perception: Identification of English /r/, /l/, and /w/ by native speakers of Japanese.

Reiko A. Yamada, Yoh'ichi Tohkura, and Noriko Kobayashi

ATR Auditory and Visual Perception Research Laboratories, Kyoto 619-02, Japan

## ABSTRACT

The effect of semantic familiarity that stimuli have on the identification of word initial English /r/, /l/, and /w/ phonemes by native speakers of Japanese learning English was studied. The identification test of initial consonant of stimuli presented auditorily was performed. The subjective familiarity of the stimuli for Japanese natives was also measured. The responses in the identification test significantly correlated with the score of familiarity for Japanese natives on average. Furthermore, when only the initial CV part of the same stimuli were presented, the responses did not correlate with word familiarity. Responses in Japanese subjects highly skilled in identifying /r/, /l/, and /w/ phonemes did not correlate with word familiarity. These results suggest that word familiarity affects the identification judgement of non-native phonemes in words when the ability to identify those phonemes is poor.

## INTRODUCTION

In speech perception studies, stimuli are often presented as words regardless of whether they are naturally-spoken or synthesized. When stimuli are presented as words, linguistic context affects the results. The phoneme restoration effect (Warren, 1970; Warren & Sherman, 1974; Samuel, 1981) is the typical example which shows that linguistic context aids word identification when the words are in sentences. The fact that the intelligibility of spoken words was higher in sentences than in isolation (Miller et al., 1951) also shows the effect of linguistic context carried by sentences. Other constraints also work as linguistic context when recognizing words, e.g. semantic association between presented words, semantic category of the words, etc. (Bruce, 1955; Rubenstein & Pollack, 1963; Schuberth & Eimas, 1977). Furthermore, the isolated word itself has linguistic context. This context is called lexical context, and is related to the semantic familiarity of words or the frequency of words used in the language. The phoneme detection reaction time is shorter in words than in nonwords (Rubin et al., 1976). Ganong (1980) reported that subjects make phonetic categorizations that make words. Even though these effects were not well studied in non-native speech perception, there is a possibility that the linguistic context also affects non-native speech perception and may work in a different way, especially when those phonemes are not acquired completely by listeners. If the linguistic context affects perception, it should be taken into account when analyzing the results of the experiment.

One kind of incompletely acquired phoneme perception is the case of the perception of American English (AE) /r/-/l/ contrast by native speakers of Japanese. Japanese natives learning AE were revealed to have considerable difficulty perceiving /r/-/l/ contrast even though they start learning English in high-school at about age 12. In studies on /r/ and /l/ perception by native Japanese, both naturally-spoken and synthetic stimuli have been used. The studies using synthetic stimuli have revealed that

Japanese natives perceive the synthetic /r/-/l/ series continuously, even though AE native speakers do so categorically (Miyawaki et al. 1973; McKain et al. 1981; Mochizuki. 1981; Shimizu & Dantsuji. 1987; Strange & Dittmann. 1984). Goto (1971) reported that Japanese natives have difficulty in discriminating naturally-spoken /r/ and /l/ sounds. The studies using naturally-spoken stimuli after Goto's study essentially concern the vocalic context effect on the identification of Japanese natives (Mochizuki. 1981; Dissosway-Huff, 1982; Shimizu and Dantsuji. 1983). In these studies, data are analyzed according to the vocalic context effect. It is interesting to reanalyze the data according to the lexical context.

This paper is concerned with the effect of word familiarity on the perception of AE /r/ and /l/ by Japanese natives. The first experiment was preliminary. We have observed the effect by reanalyzing the data obtained from the identification test of naturally spoken words whose initial consonants were /r/, /l/, or /w/, and compared it to the AE listeners' result. These tests were performed as a screening to measure the ability to identify such naturally spoken stimuli for subjects in some studies testing /r/, /l/ and /w/ perception using synthetic speech stimuli (e.g. Yamada & Tohkura, under submission). Accordingly, we have seen only the total correct score for each subject in those studies. Second and third experiments were also based on such screening test data. However, one more session was added to the screening test. In the second experiment, we estimated the word familiarity of Japanese natives and observed the relationship between identification judgement of words and estimated word familiarity. The extent to which lexical context has an effect on the perception of words was studied using word frequency (e.g. Broadbent, 1967; Luce, 1985) and subjective familiarity (e.g. Nasbaum, et al., 1984). Even though these two indexes were correlated (Brown, 1984;, Kreuz, 1987), subjective familiarity is a far better predictor for word recognition than word frequency (Kreuz, 1987). Moreover, word frequency for natives cannot be applied for non-native listeners, because word frequency is expected to be different between native and non-native populations. Finally, in this paper, we have adopted subjective familiarity. Word subjective familiarity has been estimated using magnitude estimation (Carrol, 1971; Shapiro, 1969) and rating scales (Gersbacher, 1984; Nasbaum, et al., 1984; Kreuz, 1987). Using rating scales modified for Japanese natives, we have estimated their familiarity with English word stimuli. The third experiment was designed to confirm the results obtained in the second experiment by comparing the results when the stimuli are presented as words and CV syllables.

## I. EXPERIMENT 1

### *A. Purpose*

The purposes of this experiment were (1) to compare the identification result of word initial /r/,/l/, and /w/ by AE listeners and Japanese listeners, and (2) to determine whether word familiarity affects the identification results.

### *B. Stimuli*

Naturally spoken words were used as stimuli. Sixteen combinations of three words in Table 1 were used as speech material. In each combination, words differed only in the initial consonant, /r/, /l/, or /w/. The forty-eight words (sixteen combinations each containing three words) were spoken by two native speakers of AE ( one female and one male) to produce a total of ninety-six stimuli. They were recorded on tape using a DAT recorder, SONY DTC-1000ES, and converted from analog to digital at a 20kHz sampling frequency with 16-bit accuracy.

Stimuli stored on a computer hard disk were reproduced with 16-bit accuracy at a sampling frequency of 20 kHz and low-pass filtering with a cutoff frequency of 10-kHz. The stimuli were reproduced at a 20 kHz sampling frequency with a cutoff frequency of 10 kHz, and several sessions with different randomizations of stimuli were recorded on digital audio tape. In each session, each of the 96 stimuli occurred once in random order to make 96 trials in total, with the 96 trials arranged in nine blocks of ten trials and one block of six trials. Stimuli were recorded with inter-trial intervals (ITI) of 2 seconds, and inter-block intervals (IBI) of 8 seconds. The block start signal was a beep sound recorded 2 seconds prior to the beginning of each block. These stimuli were presented to listeners binaurally over headphones, STAX SR Lambda Professional, in a soundproof room at a fixed level.

### *C. Subjects*

Ten native speakers of AE born and raised in the U.S. served as A subjects. Fifty native speakers of Japanese who had never resided abroad served as J subjects. All subjects reported medical histories free of hearing or speaking disorder, and naive regarding this kind of experiment. These conditions also prevailed in the following experiments.

### *D. Procedure*

Each listener participated in one session of identification tests. Listeners were asked to identify word initial consonants, and make forced choices among the given response categories, /r/, /l/, and /w/, however difficult. They were also told that although both real words and nonsense words would be presented, their judgement should be independent of the meaning of the words.

### *E. Results*

The identification judgements by A subjects was almost errorless, 99.8 % on average. The averaged correct response rates across J subjects was 66.9 %. The J subject results were analyzed with regard to the initial consonant, and are shown in the confusion matrix in Table 2. Correct response rates for /r/ initial words, /l/ initial words, and /w/ initial words were 58.2%, 66.1%, and 76.5%, respectively.

When confusion among combinations was observed, imbalanced confusions were found in some of the combinations. Typical examples are shown in Table 3(a, b). For the combination "red, led, wed", the response rate strongly inclined to /r/ as shown in Table 3(a). In contrast, for the combination "rook, look, wook", the response rate strongly inclined to /l/ as shown in Table 3(b). These phenomena are thought to be caused by an imbalanced familiarity of word combination in which only the initial consonants differ. For Japanese, in the combination "red, led, wed", the word "red" is far more familiar than the word "led" and "wed", and in the combination "rook, look, wook", the word "look" is familiar, "rook" is unfamiliar, and "wook" is a meaningless made up word. Thus, it is assumed that word familiarity affects the identification of word initial /r/, /l/, and /w/ by Japanese listeners.

## II. Experiment 2

### *A. Purpose*

The results of Exp. 1 showed that AE listeners always identified the initial consonant of stimuli used in this experiment correctly, but Japanese listeners confused them, and word familiarity may have affected the results. The purpose of this experiment was to measure Japanese subjects' subjective familiarity with words used in this paper, and to determine the correlation between identification by Japanese subjects and their subjective familiarity.

### *B. Procedure*

Fifty-eight native speakers of Japanese served as subjects. They are not the same J subjects in Exp.1. The experiment consisted of two sessions. The first session was designed to observe the influence of word familiarity on the identification result. Stimuli and procedures were identical to those in the Exp.1.

The second session was designed to measure the subjective familiarity of words used in this experiment. However, Japanese natives confuse not only /r/, /l/, and /w/, but also a various AE phonemes. For example, they usually identify the word "wush" as "wash". Our aim is to measure the familiarity of words which Japanese subjects listened to. Thus the words were presented auditorily to the subjects in order to measure the familiarity of the auditorily perceived words. Only the initial consonants of the stimuli, however, were printed on the answer sheet so that the subjects did not confuse initial consonants. Subjects were instructed that the printed initial consonants did not represent the beginning of the spelling of each word, but the beginning of the sound. Without these visual aids, the familiarity of unfamiliar words beginning with /r/, /l/, or /w/ sounds could not be measured because those unfamiliar words, e.g. "rook", are hardly perceived by Japanese subjects as observed in Exp. 1. The 48 stimuli which had been uttered by male AE speaker were used as stimuli. These stimuli were recorded on tape, each of the 48 stimuli occurring once in random order with 10 seconds of ITI. A beep sound was recorded as a start signal 2 seconds prior to each trial. In each trial, subjects were asked to dictate the word and write down the Japanese translation if they could. If not, they were asked to make a forced choice between the following three response categories: "word", "maybe word", and "non-word". Subjects were instructed that "word" would indicate that they are sure that the stimulus they heard was a word, but they cannot recall its translation, "maybe word" that they think the stimulus was a word, but do not know its translation, and "non-word" that they think that the stimulus is a made-up word. They were also instructed that the test they were going to receive was not an English vocabulary test, but a measurement of word familiarity for English learners, so they should write down the translation only when they were sure, and when they did not know the translation, they should choose honestly.

## *C. Results*

The correct response rates in the identification test (first session) were 48.7%, 59.3%, and 88.9% for /r/-initial words, /l/-initial words, and /w/-initial words, respectively.

The data from the second session, which was aimed at measuring word familiarity were analyzed as follows. The response for each category was converted to digits from 3 to 0: When the translation was written, the score was 3 whether it was correct or not, the response for “word”, “maybe word”, and “non-word”, were scored 2, 1, and 0, respectively. This score is called the Familiarity Score (FS), and FS(st) represents the FS for st, which is replaced by stimulus, “r”, “l”, “w”, or “all”. FS(r), FS(l), FS(w), and FS(all) represents the FS for /r/-initial, /l/-initial, /w/-initial, and all stimuli, respectively. Pooled data for all subjects are FS(r)=1.38, FS(l)=1.73, FS(w)=1.69, FS(all)=1.62.

The response rate for each word cannot be obtained directly, because only the initial consonants were identified in our experiment design. In order to see the correlation between response and familiarity, we estimated the response rates for words as follows. We have assumed that confusion occurs mainly among combinations which consist of three words differing only in the initial consonant. Thus, the error responses were assumed to be errors of words whose parts succeeding the initial consonant were common in the presented stimuli. For example, the response /r/ to the stimulus "light" was considered a response to "right".

The correlation between FS and response rates of words was significant, on average, across all the subjects; Spearman's rank correlation coefficients are 0.547 ($p<0.002$; by the two-tailed T test) as shown in Table 4. Furthermore, the subjects were classified into three groups, Group40-60, Group60-80, and Group80-100, according to the total correct response rate in the first session. The correct response rate for the subjects in Group40-60 varied from 40% to 60%, that for the subjects in Group60-80 varied from 60-80%, and that for the subjects in Group80-100 varied from 80-100%. All the subjects in this experiment belonged to these three groups, and the number of subjects and the averaged correct response rate for each of the three groups were 15 and 56.8%, 40 and 67.1%, and 4 and 84.6%, respectively. The correlation between FS and response rate is also shown in Table 4. In Group 40-60, and group60-80, the FS significantly correlated with the response; 0.428 ($p<0.01$), and 0.545 ($p<0.002$), respectively. Only for Group80-100, whose identification ability was highest, did the rank of FS and the response rate have no significant relationship. This result indicates that the word familiarity affects the perception of /r/, /l/, and /w/ identification for Japanese subjects with poor identification ability of those phonemes. However, it does not affect the judgement of subjects with higher identification ability of those phonemes.

## III. Experiment 3

### *A. Purpose*

There remains a possibility that the response inclination observed in Exp. 2 might be caused not only by the word familiarity effect but also by the vocalic context effect. This experiment aims to confirm our finding that Japanese listeners' /r/ and /l/ identification is affected by subjective word familiarity, by comparing the identification pattern when target phonemes are presented in words/nonwords and CV syllables.

### *B. Stimuli and Procedure*

This experiment consisted of two sessions: one session called the Word Context session, identical to Exp.1, and the other session called the CV Context session. Only the initial CV part of stimuli were presented. The stimuli in the CV Context were prepared by cutting the final part of stimuli in the Word Context session with a cutoff durations of 10ms. This operation was done only for the stimuli which had to be cut to make CV syllables. Forty-four native speakers of Japanese served as subjects.

### *C Results*

A result similar to that of Exp.1 and 2 was obtained from the Word Context session. The response rates for CV Context stimuli, whose response tendencies are thought to be caused by the vocalic contextual effect, were subtracted from the response rate for the Word Context stimuli, called "W-CV values". The results of combinations of “red, led, wed”, and “rook, look, wook”, which were typical in EXP.1, are shown in Table 5. In the Word Context stimuli, the effect of word familiarity equal to that in the former two experiments. In contrast, in the CV Context stimuli, imbalances between /r/ and /l/ were smaller than in Word Context stimuli, and the response inclination pattern was different from that observed in Word Context session. As a result, word familiarity also has a considerable effect on the W-CV values in these two combinations (Table 5, lowest matrix). In order to determine the effect of word familiarity on the Word context responses, CV Context responses, and W-CV values, the FS ranking measured in Exp2 was applied to the present data. The similar tendencies observed in Word Context stimuli in Exp.2 (Fig.1) were observed in Word Context response and W-CV values. Spearman’s rank correlation coefficients were calculated in order to examine the relationship between FS and Word Context, CV Context, and W-CV responses. The results are shown in Table 4. On average, across all the subjects, the relationship between FS and Word Context responses was significant; Spearman's rank correlation coefficients are 0.472 ($p<0.002$). Furthermore, the W-CV value also correlated with FS significantly (0.384; $p<0.01$). When the subjects were classified into three groups, as was done in Exp.2, FS correlated with Word Context responses and W-CV values significantly in Group40-60 and Group 60-80. In Group 80-100, FS did not correlate with responses. These results were similar to those in Exp.2, offering stronger evidence that word familiarity affects Japanese listeners who were asked to identify the /r/, /l/, and /w/ phonemes in words.

## IV. Discussion

Through three experiments, we have found that (1) word familiarity affects the identification of /r/, /l/, and /w/ for Japanese listeners, and (2) the identification judgement of subjects less able to identify these phonemes was more easily affected by the lexical effect than that of subjects with higher ability. Because the present experiments were based on the reanalysis of screening tests as mentioned in the introduction and there was a time limitation, the experiment designs seemed to be rather redundant. However, these findings lead us to understand that word recognition is influenced by the listeners' subjective familiarity with the stimulus words, and the effect depends on language listening skills.

With Japanese natives learning English are asked to differentiate between /r/, /l/, or /w/ in isolated English words, the following two processes are assumed to exist and interfere with each other: The phoneme categorization process, in which target /r/, /l/ or /w/ sounds might be categorized into /r/, /l/, or /w/ categories. However, these categories are poorly differentiated, because the identification ability of those phonemes is very poor in Japanese listeners. Among these three categories, only /w/ exists in Japanese. There also exists /r/ in Japanese, however it differs considerably from English /r/ acoustically. The /r/ and /l/ categories are assumed to correspond to, or overlap with, the Japanese /r/ category. One reason for this assumption is that, in Japanese, various English words are used as loanwords and written with Japanese "letters", and in such descriptions, both AE /r/ and /l/ sounds are described with "letters" used to describe Japanese /r/ even though Japanese /r/ is not similar to either AE /r/ or /l/. The other process is the access to the mental lexicon. By this process, judgements are influenced by the subjective familiarity of words and listeners tend to perceive the stimuli as familiar words. The first process is associated with the listeners' skill in identifying English phonemes, and the second process is associated with the listeners' vocabulary skill.

The nature of word recognition by non-native learners differs significantly from that by natives in the skill to identify phonemes, and in the characteristics of the mental lexicon. In addition, the individual differences are larger in non-native learners than in natives speakers. Thus, the present results cannot be generalized into the other cases of native word recognition. However, it is possible that, together with the studies of children (Elliott, et al. 1983) and those of elderly (Bell, 1989), studies of non-native word recognition may offer unique insights into the nature of the word recognition process. The advantage of our approach is that we can manipulate the identification ability of phonemes and lexical characteristics.

In order to determine the native language word recognition process, various models have been studied, i.e. Morton's (1976) logogen model, Forster's (1976) search model, Becker's (1976) verification model, the cohort model of Marslen-Wilson and Welsh (1978), Klatt's (1979) LAFS model, Norris' (1986) checking model , and the Trace model of McClelland & Elman (1986). However, general agreement has not yet been obtained. It is interesting to study the ability of models when applied to non-native perception data. When doing so, some questions may arise. For example, is modification of models needed, or should an entirely new model be developed? Furthermore, how do we treat an insufficient ability to identify phonemes? We would like to avoid discussing in detail the process of word recognition, because the present study is limited to phenomenology and further experiments designed to attack the accumulated problems are necessary.

Another contribution of the present finding is revealing the importance of considering the lexical effect when studying non-native word recognition. However, the data in the previous reports on recognition of English words including /r/ and /l/ sounds by Japanese listeners (Mochizuki. 1981; Dissosway-Huff, 1982; Shimizu and Dantsuji. 1983) cannot be reanalyzed and compared with the present data according to the word familiarity, because the tasks are different . In the previous works, a detection task in which subjects were asked to choose one of the words printed on the answer sheet, e.g. "rock" or "lock", was used, whereas a shadowing task in which only the target phonemes, "r", "l", and "w", are printed on the answer sheet was used in this study. In general, task differences might alter the contextual effect. Actually, Marslen-Wilson & Welsh (1978) revealed that word contextual effect works in the shadowing task, but not in the detection task. Even in non-native word recognition, the task difference should be taken into account.

This paper showed that the contextual effect acts also in non-native speech perception. This finding implies the necessity of well controlled studies of contextual constraint on speech perception, e.g. cross-linguistic study, training study in which mental lexicon and listening ability are manipulated, etc. Such studies also seem interesting from a practical viewpoint, i.e. second language education. Sentence or word context may act as a facilitative factor in understanding sentences or words, but may interfere with developing listening skills. Studies on the contextual effect in non-native speech perception might give some theoretical background for an effective training method.

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**Table 1**

List of Word Context stimuli used in Exp1-3. Three words in one line form one combination, and in each combination, the pronounciation of words differed only in the initial consonant, /r/, /l/, or /w/.

| | | | |
|---|---|---|---|
| 1. | read | lead | weed |
| 2. | rip | lip | wip |
| 3. | red | led | wed |
| 4. | rack | lack | wack |
| 5. | ra | la | wa |
| 6. | rock | lock | wock |
| 7. | raw | law | waw |
| 8. | rook | look | wook |
| 9. | root | loot | woot |
| 10. | rush | lush | wush |
| 11. | rate | late | wait |
| 12. | right | light | wite |
| 13. | royal | loyal | woyal |
| 14. | row | low | woe |
| 15. | rout | lout | wout |
| 16. | rear | lear | weer |

**Table 2**

Exp 1: Confusion matrix of response by J. subjects when the data were analyzed according to the initial consonant.

| stm. \ resp. | /r/ | /l/ | /w/ |
|---|---|---|---|
| /r/ initial words | 58.2 | 32.8 | 8.8 |
| /l/ initial words | 31.4 | 66.1 | 2.4 |
| /w/ initial words | 16.5 | 6.8 | 76.5 |

**Table 3(a)**

Exp 1: Confusion matrix of response by J. subjects for the stimulus combination "red, led, wed".

| stm. \ resp. | /r/ | /l/ | /w/ |
|---|---|---|---|
| red | 83.6 | 9.6 | 6.6 |
| led | 47.5 | 52.4 | 0.0 |
| wed | 41.6 | 4.1 | 54.1 |
| Total | 57.6 | 22.0 | 20.2 |

**Table 3(b)**

Exp1: Confusion matrix of response by J. subjects for the stimulus combination "rook, look, wook".

| stm. \ resp. | /r/ | /l/ | /w/ |
|---|---|---|---|
| rook | 44.5 | 48.6 | 6.8 |
| look | 11.1 | 86.1 | 2.6 |
| wook | 7.1 | 8.3 | 84.5 |
| Total | 20.9 | 47.7 | 31.3 |

**Table 4**

Exp 2,3: The Relationship between the FS and the response rate are represented as Spearman's rank correlation coefficients. The results from the two-tailed T test were also shown.

| | Total | Group40-60 | Group60-80 | Group80-100 |
|---|---|---|---|---|
| Exp 2 | | | | |
| Word Context | .547*** | .428** | .545*** | .222 |
| Exp3 | | | | |
| Word Context | .472*** | .503*** | .380** | .144 |
| CV Context | .141 | .149 | .079 | .113 |
| Word - CV | .384** | .392** | .379** | .015 |

* : $p < 0.05$
** : $p < 0.01$
*** : $p < 0.002$

**Table 5**

Exp 3: Confusion matrix of response by J. subjects for the stimulus combination "red, led, wed" (left), and "rook, look, wook" (right). The top tables show the confusion matrix for Word Context responses, middle tables show those of CV Context responses, and the bottom tables show the CV Context response values subtracted from Word Context responses.

| stm. \ resp. | /r/ | /l/ | /w/ |
|---|---|---|---|
| red | 83.3 | 12.5 | 4.1 |
| led | 57.2 | 42.7 | 0.0 |
| wed | 43.7 | 3.1 | 53.1 |
| Total | 61.4 | 19.4 | 19.0 |

| stm. \ resp. | /r/ | /l/ | /w/ |
|---|---|---|---|
| rook | 29.1 | 60.4 | 10.4 |
| look | 4.2 | 95.8 | 0.0 |
| wook | 3.1 | 12.5 | 84.3 |
| Total | 12.1 | 56.2 | 31.5 |

| stm. \ resp. | /r/ | /l/ | /w/ |
|---|---|---|---|
| re | 60.4 | 30.2 | 9.3 |
| le | 29.1 | 51.0 | 19.7 |
| we | 32.2 | 12.5 | 55.2 |
| Total | 40.6 | 31.2 | 28.1 |

| stm. \ resp. | /r/ | /l/ | /w/ |
|---|---|---|---|
| ru | 42.7 | 32.2 | 25.0 |
| lu | 16.6 | 57.2 | 26.4 |
| wu | 7.2 | 8.3 | 84.3 |
| Total | 22.2 | 32.6 | 45.1 |

| stm. \ resp. | /r/ | /l/ | /w/ |
|---|---|---|---|
| red - re | 22.9 | -17.7 | -5.2 |
| led - le | 28.1 | -8.3 | -19.7 |
| wed - we | 11.4 | -9.3 | -2.0 |
| Total | 20.8 | -11.8 | -9.0 |

| stm. \ resp. | /r/ | /l/ | /w/ |
|---|---|---|---|
| rook - ru | -13.5 | 28.1 | -14.5 |
| look - lu | -12.5 | 38.5 | -26.0 |
| wook - wu | -4.1 | 4.1 | 0.0 |
| Total | -10.0 | 23.6 | -13.5 |