Lack of Implicit Prosody Effects in Deaf Readers of Japanese

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Prosodic contours have been claimed to be implicitly imposed on sentences read in silence, thereby affecting the interpretation of ambiguous constructions (the implicit prosody hypothesis, Fodor 2002). Some of the strongest evidence supporting this hypothesis manipulated the prosodic length of segments (Hirose 2003). However, such manipulations also increase the number of characters in the critical words, thus the results may not reflect the influence of prosodic factors but rather how perceptual mechanisms and working memory handle written words with larger numbers of characters. If so, such results should be replicable with readers who have low ability in handling prosodic information. We report experimental results suggesting that deaf readers are not sensitive to Hirose’s length manipulations. Therefore, the manipulations are likely to be related to prosodic contours rather than some other type of length measurement.

Areas of interest: psycholinguistics, sentence comprehension

1. Introduction
Prosodic contours associated with spoken utterances have been claimed to be implicitly imposed on sentences read in silence, thereby affecting the interpretation of ambiguous constructions (the implicit prosody hypothesis or IPH, Fodor 2002). The effects of such implicit prosodic contours have been explored recently both in formal syntax as well as in the language processing literature (e.g., Kitagawa & Fodor 2003). A number of empirical results have been reported on implicit prosody effects, but many of them have not addressed alternative explanations. The most common type of manipulation increases the length of constituents in order to show that longer phrases are more likely to modify the farther of two potential attachment sites (see Fodor 2002, for a summary).

One of the strongest sets of results providing support for the IPH has used ambiguous relative clause constructions in Japanese (Hirose 2003; see also Hirose & Kakei 1998). However, as in other similar studies, the manipulation used leads to unavoidable side-effects such as longer words and phrases, as measured in number of characters, and not just longer in terms of prosodic length as was intended. This is a problem because it allows for the possibility that it is not implicit prosody that is driving the effect. Instead, perceptual processes for longer written words or the way that working memory handles longer phrases could be the crucial factor.

Ideally, one would like to compare how silent reading is conducted with and without implicit prosody, but this is not easily achieved (but see Miyamoto, Nakamura & Takahashi 2004, Experiment 2; Slowiaczek & Clifton 1980, on the possibility of eliminating inner speech during reading through simultaneous articulation of nonsense syllables).

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We report the results of a fragment-completion study indicating that deaf readers of Japanese are not sensitive to the manipulations used by Hirose (2003); therefore, the results are compatible with the assumption that the effects are related to prosodic contours rather than working memory or perception, under the assumption that deaf readers are less likely to be affected by implicit prosodic contours during silent reading.

2. Ambiguous relative clauses in Japanese

Japanese is a head-final language with subject-object-verb order. There are no overt markers to indicate the beginning of clauses, therefore words in the embedded clause are commonly taken to be part of the matrix clause (but see Venditti 2006, for prosodic cues in speech). For example, readers usually interpret the fragment in (1) as a single clause (‘Morisita truly trusted the medicine’, where Morisita is a proper name).

(1) Morishita-ga shinyaku-o kokorokara shinyooshita
    -NOM medicine-ACC truly trusted

However, when a noun such as yuujintachi ‘friends’ is read after ‘trusted’, it is clear that this verb is part of a relative clause modifying the noun (relative clauses in Japanese precede the noun they modify) and readers have to decide where the beginning of the relative clause is likely to be. The two most common alternatives are schematically shown in the following examples (square brackets are used to indicate the boundaries of relative clauses; the extraction sites are indicated with a gap coindexed with the head noun; pro indicates dropped arguments).

(2) a. Early opening
    Morishita-ga [RC gap; shinyaku-o kokorokara shinyooshita] yuujintachi
        -NOM medicine-ACC truly trusted friends

b. Late opening
    Morishita-ga shinyaku-o [RC pro gap; kokorokara shinyooshita] yuujintachi
        -NOM medicine-ACC truly trusted friends

In the early opening interpretation, the relative clause starts at the direct object ‘medicine-ACC’ (the relative clause is subject extracted as indicated by the gap in subject position); whereas in the late opening interpretation, the relative clause starts after the direct object (the subject is missing in the object-extracted relative clause in this case and the matrix subject is likely to be the antecedent as the coindexation indicates; see Mazuka & Itoh 1995, who were the first to discuss such constructions; also Hirose 2003, on the early versus late opening labels; and Inoue 1990; Miyamoto 2002, for related experimental results).

Consider the kinds of predicates that could complete such fragments assuming that the head noun ‘friends’ is dative marked. If the late opening interpretation is chosen, the direct object ‘medicine-ACC’ is to the left of the embedded clause boundary; therefore, it belongs to the matrix clause together with the matrix subject (‘Morishita-NOM’). In this case, the matrix verb at the end of the sentence must be a predicate that can take the direct object as an argument. The dative-marked ‘friends’ is also attached to the matrix verb, therefore ditransitive predicates such as susumeru ‘recommend’ would be a natural continuation as in ‘Morishita, recommended the medicine to the friends that (he) really trusts’.

If an early opening interpretation is chosen, the direct object is part of the relative clause, hence only the matrix subject ‘Morishita-NOM’ and the head noun ‘friends-DAT’ have to attach to the matrix
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2.1. Prosodic contours for relative clauses in overt speech

During oral communication, prosodic contours (such as pauses and word-end lengthening) produced by speakers can help listeners choose between early and late opening interpretations (Sakamoto, Muraoka & Matsuura 2005; also Venditti 2006).

Furthermore, Experiment 3 in Hirose (2003) provides evidence that the length of the matrix subject in fragments such as (1) affects the prosodic contours produced by speakers. When an accented noun such as ‘Morishita’ is used, the subject spans one minor phrase and it becomes part of a major phrase together with an accented noun such as the direct object ‘medicine’ in (3a). In contrast, with two accented nouns (e.g., the conjoined proper names Hosokawa-to Morishita ‘Hosokawa and Morishita’), the subject alone constitutes a major phrase as shown in (3b).

(3) a. Single-name matrix subject (‘Morishita’)
Morishita-ga shinyaku-o kokorokara shinyooshita yuujintati-ni
\[ \text{[ MinP MinP ] MajP} \]

b. Conjoined-names matrix subject (‘Hosokawa and Morishita’)
Hosokawa-to Morishita-ga shinyaku-o kokorokara shinyooshita yuujintati-ni
\[ \text{[ MinP MinP ] MajP} \]

The inclusion of the extra accented noun does not change the nature of the syntactic ambiguity. That is, the left edge of the relative clause remains ambiguous and both alternatives in (2) are still possible when ‘Morishita’ is replaced by ‘Hosokawa and Morishita’. This is similar to the well-known garden-path the horse raced past the barn fell, which remains ambiguous even if the initial NP contains two conjoined nouns (e.g., the horse and the mare).

The prosodic markings often accompanying major phrase boundaries can bias listeners’ interpretations as they are preferentially aligned with the beginning of the embedded clause. Thus, the major phrase boundary immediately after the conjoined names in (3b) favors the adoption of the early-opening interpretation in (2a); whereas the major phrase boundary after the direct object in (3a) is preferentially aligned with the beginning of the relative clause boundary in the late opening interpretation in (2b).

2.2. Implicit prosody and relative clauses

In Experiment 1 in Hirose (2003), native Japanese speakers read fragments as in (3a, b) in silence, and were asked to complete them into full sentences. The fragments containing conjoined names were more likely to be completed with early opening interpretations than the single-name fragments (Hirose 2003, who also reports similar results when the conjoined names were replaced with a family name followed by a first name, therefore without increasing the number of discourse entities).

Although the syntactic ambiguity in (2a, b) remains the same, the results suggest that a change in the length of the matrix subject affects the way readers interpret relative clauses even when the fragments are not overtly articulated, thus providing support for the IPH.

A few observations are probably in order. First, this type of completion questionnaire task is commonly used in the sentence processing literature to investigate the types of interpretations that are...
likely to be pursued after a given fragment (see Hirose 2003, Experiments 4 and 5, for reading time data confirming the questionnaire findings).

Second, it could be argued that plausibility factors (how likely is it that ‘Morisita really trusts his friends’ compared to ‘Morishita’s friends really trust the medicine’?) or preferences in gap position within the relative clause (gaps in subject position are preferred over gaps in object position in Japanese; e.g., Miyamoto & Nakamura 2003) could affect the preference for early opening versus late opening. However, such differences are orthogonal to the subject-length manipulation and are equally likely to affect the interpretations of fragments with a single name as well as fragments with conjoined names; therefore they do not constitute a problem in this case.

Third, if the phonological length and accentual pattern of ‘Hosokawa and Morishita’ are having an effect, then the readings of their kanji characters must have been available. Therefore, an implication of Hirose’s interpretation of her results is that the phonological representations of kanjis must be accessed during silent reading. Although such a conclusion could have been controversial a few years ago, currently available evidence indicates that this is indeed the case for Mandarin Chinese (e.g., Spinks et al. 2000; Xū, Pollatsek & Potter 1999). For Japanese, reading times measured in eye-tracking and self-paced reading studies have been found to correlate not only with number of characters but also with number of moras (Mazuka, Itoh, Kondo & Brown 1999).

The crucial question then is whether the length manipulation in (2a, b) is indeed phonological in nature. It is conceivable that the relevant length measurement is in terms of number of characters, rather than the prosodic length as was intended by Hirose. In this case, a number of alternative explanations to the IPH would be possible. For example, at least since the 1970s (e.g., Frazier & Fodor 1978) there have been proposals that the perceptual span during reading may affect how phrases are associated together. Another possibility is the way working memory may handle longer strings of letters as they are concatenated into more complex chunks, which in turn may define phrasal boundaries.

If non-phonological aspects of the input strings are responsible for the effects reported by Hirose (2003), it should be possible to replicate them with readers who are less likely to generate implicit prosodic contours.

3. Deaf readers

Experimental results indicate that deaf readers of English access phonological representations for individual words during silent reading as they have difficulty with tongue-twister sentences (i.e., sentences with similar sounds repeated such as the fricatives in ‘the spacious zoo sits beside a sandy seashore’) especially when simultaneously recalling numbers whose names start with the repeated sounds in the sentences (e.g., the fricatives ‘six’, ‘seven’, ‘sixty-six’, Hanson, Goodell & Perfetti 1991).

But it is less likely that deaf readers also access suprasegmental information such as intonation contours that can span more than a single word. Even when using hearing-aid devices, the deaf may hear partially distorted input and they often learn pronunciation of individual words through painstaking training by looking at a model, repeating the sound and getting feedback. As a consequence they have difficulty differentiating sounds that do not lead to visible differences (e.g., in mouth shape, position of the lips, tongue). For example, voiced (e.g., du) and voiceless (tu) are sometimes mistaken. Because prosodic contours are not associated with obvious visible signs, it is conceivable that they are not appropriately perceived by the deaf. Moreover, if the deaf are less skilled in articulating utterances, then automatic processes such as production of implicit prosody during silent reading may be impaired or in the very least their purported effects may not be as evident as in hearing readers.

It is unclear at the moment how rich a phonological representation the deaf build during silent reading, and we will not attempt to address this issue here. We will adopt as a starting assumption that deaf...
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Readers are less likely to produce implicit prosodic contours compared to hearing readers. Therefore, previous effects that have been claimed to support the IPH should not be observed in deaf readers.

In particular, if the length effects on clause boundary insertion discussed in the previous sections are prosodic in nature as claimed by Hirose (2003), then they should absent in deaf readers. In other words, if deaf readers’ responses differ from those of hearing readers in Hirose’s task, this would support the claim that the length effects she observed are related to prosody and not to some other factor. Such a result would also be compatible with our assumption that deaf readers do not make use of prosodic information during silent reading.

In contrast, if the behavior of deaf readers and hearing readers is similar, then a couple of alternatives can be considered. One is that deaf readers do produce implicit prosodic contours and are influenced by them in the same way that hearing readers are. Another possibility is that the length effects reported by Hirose are not related to prosody, but rather to the perception and/or memory retention of longer words and phrases.

4. Experiment

A completion questionnaire experiment was conducted with deaf Japanese readers in order to determine the effects of length on their interpretations of relative clause boundaries.

4.1. Method

4.1.1. Participants

Forty-one deaf students at the Tsukuba University of Technology were paid to take part in the experiment. One of the requirements for entrance in this university is that the candidate is unable to hear sounds below 60 dB or unable to carry out conversations even with the use of hearing aids (there is a different set of requirements for blind candidates). In the case of the participants, hearing levels for the right ear were between 65 and 140 dB ($M = 104$), and between 77 and 140 dB for the left ear ($M = 105.7$). Twenty-nine participants were deaf since birth, five since the age of 1 year, another four since the age of 2 years, two others since the ages of 3 and 4 years, and one participant did not provide this information. At the time of the experiment, their ages ranged from 18 to 27 years ($M = 20.1$). Because of the diverse educational backgrounds, the age of initial exposure to Japanese Sign Language (JSL) varied considerably (one participant since birth, two at 3 years, seven between 6 and 10 years, six between 12 and 14, seven at 15 years, seventeen between 16 and 23 years, and one never learned JSL). Twenty-two participants reported to use one of the dialects of the Kanto (Tokyo and surroundings) or the Kansai (Kyoto or Osaka) areas.

As control group, 56 hearing students at Kobe Shoin Women’s University, volunteered to take part in the experiment. Their age range was between 18 and 23 years ($M = 19.7$) and 45 of them reported to be users of one of the dialects of the Kansai area (Kobe, Kyoto or Osaka).

4.1.2. Materials

Eight pairs of fragments (from Hirose 2003) like the ones shown in (3a, b) were used. The fragments included up to the head of the relative clause (‘friends’), which was always followed by the dative marker $ni$. Each pair of sentences was exactly the same except that in the single-name condition, the fragment included a matrix subject with a single name (or a profession) as in (3a), while in the conjoined-names condition, the matrix subject contained two conjoined names (or two professions) as in (3b).

Assuming that deaf readers are less likely to produce prosodic contours when reading in silence, they should not be affected by the length manipulations in (3a, b) if those are prosodic in nature. However, if the manipulations affect a non-phonological process during sentence comprehension, then deaf readers should show biases similar to those reported by Hirose (2003), namely matrix subjects that contain two
conjoined names should lead to more completions with the early opening interpretation than matrix subjects that contain only one single name.

4.1.3. Procedure
The eight pairs of test sentences were distributed into two lists according to a Latin Square design, and filler items were added to each list. Each of the two resulting lists was ordered pseudo-randomly so that at least one filler intervened between two test items. Each participant saw one list and was instructed to complete each fragment into a sentence using a pen. Fragments were presented in Japanese fonts followed by a straight line as in (4) (which corresponds to (3a)).

(4) 森下が新薬を心から信用した友人達に______________________________

For the control group, 44 fillers were included in each list. However, because the procedure took longer than expected (around 30 minutes), the number of fillers was decreased to 28 for the deaf participants in order to avoid long sessions. With 36 items (8 test items and 28 fillers), the deaf participants completed the questionnaire in around 30 minutes. Although the number of fillers was smaller, their variety was kept the same for the two groups, with some fragments requiring one predicate while others requiring two predicates to yield complete sentences.

Each questionnaire was preceded by a consent form, a profile (requesting information such as age and major at the university attended) and instructions.

For the deaf participants, the profile also requested self-assessments of their Japanese (e.g., grammar, pronunciation) and JSL. The completion questionnaire was followed by a kanji (Chinese origin characters used in written Japanese) test. Because the critical manipulations in (3a, b) require the proper names and professions in the matrix subject to be read correctly, the kanji test included those words intermixed with 16 unrelated kanji words, and participants were requested to write their readings in kana (syllabic characters). Although some of the answers were not the most standard for the names used (proper names can have virtually any reading), they fell within the uses in current Japanese, and most important for our purposes, the readings were compatible with the prosodic manipulations described earlier.

4.1.4. Analysis
Completions obtained for the eight test items were classified according to their grammaticality. Ungrammatical completions were not analyzed further.

Following Hirose (2003), grammatical completions were analyzed as being of the early opening or the late opening type depending on the matrix clause produced by participants. For example, completions with a matrix verb that cannot take an accusative NP as argument were analyzed as early opening because in this case the direct object ‘medicine-ACC’ in (3a, b) cannot be part of the matrix clause. In contrast, completions with a matrix verb that requires an accusative NP as an argument were analyzed as being of the late opening type if that argument position was not saturated by another accusative NP appearing in the completion.

Analyses of variances (ANOVA) on participant means ($F_1$) and on item means ($F_2$) were conducted with the percentages of grammatical completions and with the percentages of early opening completions. Participant group (control or deaf participants) was entered in the analyses as a between-participants factor, and matrix-subject type (single-name or conjoined names) as a within-participants factor.

Arcsine corrected analyses were also conducted and revealed trends similar to the ones obtained for the analyses on the raw percentages reported.
4.2. Results

In terms of percentage of grammatical completions, there was no interaction between group (control × deaf) and type of matrix subject (single name × conjoined names; both \( F_s < 0.5 \)). The main effect of matrix-subject type was not reliable either (\( F_s < 0.2 \)). There was, however, a main effect of group as the control group produced more grammatical completions (single name: 96%; conjoined names: 97.3%) than the deaf participants (single name: 88.4%; conjoined names: 89%; \( F_1(1,95)= 13.2, P < 0.001; F_2(1,7) = 7.61, P < 0.05 \)). This is compatible with earlier reports that the deaf tend to have an imperfect command of Japanese (Matsui, Watanabe, Sato & Hosoya 2006, and references therein).

For the grammatical completions, the percentage of early openings did not differ between the two groups (deaf: 74.7%; control: 72.5%; \( F_s < 1 \)). This overall preference for early opening (where 50% would be chance) is compatible with earlier literature (Mazuka & Itoh 1995; also Miyamoto 2002, for experimental results) and it indicates that the deaf and hearing participants are not interpreting the construction in completely different ways. Detailed results are reported in the following sections and in Table 1.

Table 1: Percentage of early-opening completions for the control group (column A) and for the deaf participants (B to G). Deaf participants were classified as high skill or low skill according their self-assessments of their pronunciation skills (C and D) and grammar knowledge (E and F) of Japanese.

<table>
<thead>
<tr>
<th>Group</th>
<th>Control</th>
<th>Deaf participants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
<td>Pronunciation</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Number of participants</td>
<td>56</td>
<td>41</td>
</tr>
<tr>
<td>(I) Conjoined-names</td>
<td>77.7</td>
<td>71.7</td>
</tr>
<tr>
<td>(II) Single-name</td>
<td>67.4</td>
<td>77.6</td>
</tr>
<tr>
<td>Difference: (I) – (II)</td>
<td>10.3</td>
<td>-5.9</td>
</tr>
</tbody>
</table>

4.2.1. Types of completions for the control group

In the control group (column A in Table 1), the conjoined-names condition led to more early-opening completions than the single-name condition according to the participant analysis (\( F_1(1,55) = 7.57, P < 0.01; F_2(1,7) = 4.12, P = 0.082 \)). Restricting the analysis to the 45 participants in the control group who claimed to use dialects of the Kansai area, the conjoined-names condition led to more early opening completions (76.8%) than the single-name condition (66.7%) in the participant analysis (\( F_1(1,44) = 5.34, P < 0.05; F_2(1,7) = 4.25, P = 0.078 \)). These results replicate previous findings (Hirose 2003) according to which the conjoined-names condition tend to lead to more early opening interpretations. The weak results in the analysis by items is probably due to the small number of items used (in Hirose 2003, 12 items or more were used in each experiment).
The results with the speakers of Kansai dialects suggest that the effect is not restricted to speakers of Kanto dialects (as the ones in Hirose 2003). This is unsurprising given that the Kanto accent is adopted as standard Japanese, is widely used in spoken media and is likely to be enforced when students read aloud in school (see Sakamoto, Muraoka & Matsuura 2005, who report that speakers of the Hakata dialect are sensitive to Kanto prosodic cues when they hear sentences similar to (3a)).

4.2.2. Types of completions for the deaf participants
For the deaf participants (column B in Table 1), the conjoined-names condition led to numerically fewer early opening interpretations (71.7%) than the single-name condition (77.6%) but the difference was not statistically reliable ($F_1(1,40) = 1.1, P = 0.301; F_2(1,7) = 1.09, P = 0.332$). In the analysis including group (control × deaf; i.e., A × B in Table 1) and matrix-subject type (conjoined names × single name), an interaction is observed in the participant analysis ($F_1(1,95) = 6.2, P < 0.05; F_2(1,7) = 3.84, P = 0.091$). A similar interaction was detected when the deaf participants were restricted to the 22 users of Kansai or Kanto dialects ($F_1(1,76) = 11.02, P < 0.005; F_2(1,7) = 9.41, P < 0.05$). The latter analysis was conducted because the influence that the various dialects may have is uncertain, and right now it is only clear that the prosodic manipulation works for speakers of Kanto (Hirose 2003) and Kansai (the control group) dialects.

We also conducted analyses with a more strict cutoff with the 29 deaf participants who claimed to have hearing levels equal or above 100 dB (right ear $M = 110.72$ dB, left ear $M = 108.83$ dB). In this case as well (column G in Table 1), the conjoined-names condition led to fewer early opening completions (70.4%) than the single-name condition (81.3%) but the difference was only marginal in the participant analysis ($F_1(1,28) = 3.47, P = 0.073$) and not reliable in the item analysis ($F_2(1,7) = 1.87, P = 0.214$). However, this group of participants and the control group (G × A) interacted with the type of matrix-subject in the fragments according to both types of analyses ($F_1(1,83) = 10.05, P < 0.005; F_2(1,7) = 6.74, P < 0.05$).

Another analysis was also conducted according to age of JSL acquisition. Although it is not clear which specific aspects of JSL could be transferred and affect implicit prosody effects in Japanese, there are reports suggesting that the early acquisition of a first language (e.g., American Sign Language) is crucial to the acquisition of a second language (e.g., English; Mayberry & Lock, 2003). There were 10 deaf participants who were exposed to JSL before they were 12 years of age, however their early-opening responses (single name: 86.7%; conjoined names: 72.5%) did not differ from late learners of JSL (single name: 74.7%; conjoined names: 71.5%; $Ps > 0.12$).

The results indicate that deaf readers (and the ones with hearing levels equal or above 100 dB in particular) behave differently from hearing readers with respect to the matrix-subject manipulation. This difference can be readily understood if one assumes that the deaf participants are less likely to be sensitive to prosodic manipulations. If some non-phonological feature had been responsible for the effect, the same result should have been observed with the deaf participants.

There is, however, the possibility that deaf readers’ imperfect knowledge of the grammar of Japanese (Matsui, Watanabe, Sato & Hosoya 2006, and references therein) may have had some influence on the results. The syntactic constructions investigated are complex, involve relative clauses and, more crucially, require reanalysis in order to correct an initial misparse of the sentence as a simple clause. However, this is unlikely given that the number of ungrammatical completions produced by deaf participants, although reliably larger than for the control group, was small (an average of less than one incorrect completion per participant). Analyses based on the deaf participants’ self-assessments of their knowledge of Japanese grammar are reported in the following section and tend to confirm this claim.
4.2.3. Self-assessment scores
In the profile form, deaf participants were asked to assess their knowledge of Japanese grammar as well as their skill in pronouncing Japanese aloud on a scale from 0 (poor) to 7 (perfect). This type of self-rating is commonly used in the assessment of participants’ linguistic knowledge and is considered to be one of the best measures available in the bilingual literature (e.g., Fishman & Cooper 1969).

Participants who rated themselves from 5 to 7 were classified as high skill for each individual category (grammar or pronunciation), and participants who rated themselves from 0 to 4 were classified as low skill. In terms of grammar, there were 23 high-skilled participants and 18 low-skilled. For pronunciation, there were 18 high-skilled and 23 low-skilled. There were 13 participants who rated themselves as low skilled for both grammar and pronunciation, another 13 were high skilled in both categories, 10 were high skilled in grammar but low skilled in pronunciation, whereas the reverse pattern included the remaining five participants.

The percentages of early-opening completions for each subgroup in each category are shown on columns C to F in Table 1. For the grammar-based breakdown, the difference between the conjoined-names and single-name completions (last row on the table) are similar for the low-skill (-6.0, column E) and high-skill (-5.8, column F) participants, and this is reflected in the lack of interaction between the two skill groups (E × F) and matrix-subject type (conjoined names × single name; Fs < 0.3).

When each skill group is compared to the control group (column A), a tendency for interaction between group and matrix-subject type is observed in each case (A × E: F₁(1,72) = 3.35, P = 0.072; F₂(1,7) = 4.3, P = 0.077; A × F: F₁(1,77) = 5.41, P < 0.05; F₂(1,7) = 1.8, P = 0.22). In other words, the result is uniform across deaf participants with different levels of proficiency in Japanese grammar.

In contrast, when we consider pronunciation, the high-skilled participants show more early opening interpretations with conjoined-names than with single-name subjects (column D: 5.1% difference) similar to the control participants, whereas the low-skilled participants show the reverse tendency (column C: -15.5%), although the interaction is only marginal in the participant analysis (F₁(1,39) = 3.15, P = 0.084) and not reliable in the item analysis (F₂(1,7) = 1.31, P = 0.29). When compared to the control group, the differences become more evident. There is no interaction between the control and the high-skilled participants (A × D) and matrix-subject type (Fs < 1), whereas the equivalent interaction is reliable with the low-skilled participants (A × C: F₁(1,77) = 11.76, P < 0.005; F₂(1,7) = 9.63, P < 0.05).

In sum, while the classification according to grammar knowledge does not have any detectable effect, different levels of pronunciation skills reveal differences in the types of completions produced. Hence, these results reinforce the possibility that the manipulations conducted are having an effect at the phonological level.

The difference between the conjoined-names condition and the single-name condition for the deaf participants was consistently negative (last line of Table 1 for columns B to G, except for column D) indicating a larger number of early-opening interpretations for the single-name condition, although none of the pairwise comparisons was statistically reliable. At the moment we do not have an explanation for such a possible bias and future work should investigate it further.

5. General discussion
The present results suggest that deaf readers, especially the ones that are most likely to have problems handling phonological information (i.e., the participants that can only hear sounds above 100 dB, on column G of Table 1; or the ones with low self-assessed pronunciation skills, on column C), are less likely to be affected by the length of the matrix subject when compared to the control group. The results are therefore compatible with claims concerning the phonological nature of the effect, and they raise the
likelihood that it is implicit prosodic contours that are affecting the way ambiguous sentences are interpreted by hearing participants as proposed by the implicit prosody hypothesis (Fodor 2002).

However, a version of the alternative explanation based on working memory factors may still be sustainable. It is possible that the way the phonological loop (Baddeley 1992) handles longer-sounding phrases or how it converts written input into phonological representations may influence phrasal-boundary analysis (which in turn could affect prosodic contours rather than the other way around as assumed in the IPH). It is not clear at this point how to differentiate between a purely prosody-based explanation from the possible effects of the phonological loop. But the present results contribute in determining more firmly that the phenomenon considered is phonological in nature, thus at least restricting the kinds of explanations that can be entertained.

It is not our intention to claim that deaf readers generate no implicit prosody when they read. At least for those who are highly skilled in pronouncing Japanese, there does seem to be a tendency for prosody to affect sentence comprehension (column D of Table 1) in a way similar to the control group. Even for the other deaf participants who show the opposite tendency, it is possible that prosodic structures are being created but that these readers are unable to use this type of information in order to disambiguate the input.

Another possibility is that the self-assessment scores do not reflect skill alone, but are also influenced by the participants’ confidence in their skills. Thus, it is conceivable that even participants with low scores generate implicit prosodic contours, but they use this information less consistently because of their lack of confidence. In short, these are the initial results of a long-term project investigating deaf readers’ linguistic representations and a number of alternative explanations can be considered at this point.

Moreover, note that we have emphasized deaf readers’ ability in producing overt utterances under the assumption that this would be an indicator of how automatically they are able to generate similar representations implicitly during silent reading. But as pointed out by an anonymous reviewer, a more detailed analysis of perception ability may be more relevant given that hearing loss can target specific frequency ranges. Therefore, detailed profiles could help us make more precise predictions by determining which participants have hearing loss in the ranges most relevant to perceive the types of prosodic contours being considered.

A final caveat is in order in relation to grammatical knowledge. We have claimed based on self-assessments of grammatical knowledge that the deaf readers’ less than perfect command of Japanese language is not an issue here. This should not be taken to mean that grammatical knowledge is not important in the processing of the relative clause constructions investigated. On the contrary, grammatical knowledge is crucial in understanding the experimental sentences as they involve complex structures that lead to longer reading times even for hearing participants with full command of the language (Inoue 1990; Miyamoto 2002; and references therein). It just seems that for the particular deaf participants in our study, their overall grammatical knowledge is high enough not to interfere with our results (this is probably because students at this university are likely to be relatively successful academically as this is the only institution of higher education for the deaf in Japan).

References
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