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The role of prosodic phrasing in silent reading

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Prosodic phrasing plays a crucial role in sentence comprehension, because it helps listeners resolve structural ambiguities. However, explicit prosody is not available in reading. According to the Implicit Prosody Hypothesis, readers are assumed to assign default prosody to sentences, which then guides parsing decisions (Fodor, 2002a, 2002b). This study tested this hypothesis by manipulating the lexical accent of phrases, which affects the prosodic phrasing of sentences in Japanese. The results of a self-paced silent reading experiment showed faster reading times for the structure that matched the prosodic phrasing than the structure that did not. This finding suggests that readers implicitly represent a prosodic structure that plays a functional role in syntactic processing.

1. The role of prosody in ambiguity resolution

Psycholinguistic studies focusing on syntactic processing have shown that people process sentences incrementally (e.g. Clifton et al., 1991; Ferreira & Clifton, 1986; Frazier, 1979, 1987; Frazier & Rayner, 1982). Evidence for this is found in the processing of garden-path sentences, such as *Since Jay always jogs a mile seems like a very short distance to him*, in which *a mile* is temporarily ambiguous as to whether it is an object of the verb *jogs* (the *late-closure* analysis) or the subject of the matrix clause (the *early-closure* analysis) (Frazier & Rayner, 1982). Since the parser tries to incorporate new input into the clause that is currently being processed within the rules of the grammar, this sentence induces a processing difficulty with the word *seems*, as it resolves the ambiguity into a less preferred, early-closure analysis. However, less preferred structures do not always result in garden-path effects, because the parser goes through multiple sources of information to decide which structure to build. One such cue is *explicit prosody* (Frazier et al., 2006; Kjelgaard & Speer, 1999; Schafer et al., 2000; Snedeker & Trueswell, 2003). The garden-path effect disappears when the clause-final word is uttered with a high pitch followed by a pitch fall, which signals a clause boundary (Kjelgaard & Speer, 1999).

The effect of prosody on the processing of garden-path sentences has been interpreted in the framework of constraint-based models, whereby multiple sources of information are rapidly integrated to compute probable syntactic analyses (MacDonald et al., 1994; Tanenhaus et al., 1995; Trueswell et al., 1993). In particular, prosodic cues guide a parsing decision, because prosodic phrasing has a close relationship to syntactic structure (e.g. Ito & Mester, 2013; Selkirk, 2011, 2015).

1.1 The role of implicit prosody in ambiguity resolution

While listeners can rely on prosodic cues when processing sentences, readers do not have access to prosody. However, Fodor (2002a, 2002b) proposed the hypothesis that the parser *internally* generates default prosody, which is then mapped onto a syntactic representation to help decide which analysis to accept (i.e. the Implicit Prosody Hypothesis; see also Bader, 1998; Breen, 2014; Frazier & Gibson, 2015; Hirose, 1999; Swets et al., 2007).

Implicit prosody cannot be measured directly, because it is an internal construct of the parser. However, its existence can be attested by examining whether the prosodic factors that influence the explicit prosody of a sentence also modulate syntactic processing in *silent reading*. If the parser generates a prosodic structure internally, it is expected to guide the resolution of temporal ambiguity.

1.2 Lexical accent and prosodic phrasing in Japanese

Before going into the details of the previous evidence for implicit prosody, we will describe the prosodic system in Japanese, in order to help the reader understand the critical manipulation of the experiment. In Japanese, the presence or absence of pitch accent (a pitch fall) is specified

lexically. For example, *Hosoka¬wa* and *Moriyama* are both family names, but only the former is accented.[1] The difference in accentedness is important, because *at most* one accented word can form a minor phrase. Specifically, accented words such as *Hosoka¬wa* in (1a) must form an independent minor phrase, while unaccented words such as *Moriyama* in (1b) can form a minor phrase together with the following word (Fujisaki & Sudo, 1971; Kubozono, 1993; McCawley, 1968; Poser, 1984). This difference can be seen in the presence of the phenomenon called *initial lowering*, whereby the first mora of the minor phrase is realised as a low (L) tone followed by a high (H) tone. As indicated in boldface in (1), the second word *Morishi¬ta* shows an initial lowering pattern in (1a), because it is the onset of a minor phrase, given that *Hosoka¬wa* forms an independent minor phrase. In contrast, it does not show initial lowering in (1b).

(1) Minor and major phrase formation

a. the +Accent+Accent condition

Hosoka¬wa-to	Morishi¬ta-ga	shi¬nyaku-o	…
LHHLL	**LH**HLL	HLLLL	…
{(Hosokawa-CNJ)	(Morishita-NOM)}	{(new.medicine-ACC)	…

‘Hosokawa and Morishita (did something) to the new medicine.’

b. the −Accent+Accent condition

Moriyama-to	Morishi¬ta-ga	shi¬nyaku-o	…
LHHHH	**HH**HLL	HLLLL	…
{(Moriyama-CNJ	Morishita-NOM)	(new.medicine-ACC)}	…

‘Moriyama and Morishita (did something) to the new medicine.’

c. the −Accent condition

Moriyama-ga	shi¬nyaku-o	…
LHHLL	HLLLL	…
{(Moriyama-NOM	new.medicine-ACC)}	…

‘Moriyama (did something) to the new medicine.’

The parentheses { } and ( ) indicate major and minor phrases, respectively.

Two minor phrases (e.g. *Hosoka¬wa* and *Morishi¬ta*), as shown in (1a), form one major phrase (Beckman & Pierrehumbert, 1986; Poser, 1984; Selkirk & Tateishi, 1991). This can be diagnosed using *downstep*, a phenomenon whereby the pitch peak of accented/unaccented words is realised as lower when they are preceded by an accented word within the same major phrase (compared to when they are preceded by an unaccented word). Specifically, the second word (*Morishi¬ta*) shows downstep, but the third word (*new.medicine-ACC*) does not, because the latter is at the beginning of another major phrase. The major phrase boundary provides important cues for parsing, because it often aligns with syntactic boundaries (e.g. Selkirk & Tateishi, 1991).

[1] The symbol ¬ indicates an accented mora, in which the pitch falls from high to low tone. The accent symbol is for expository purposes only.

1.3 Experimental evidence for implicit prosody

Hirose (2003) conducted a self-paced reading experiment in which Japanese speakers silently read sentences such as (2) phrase-by-phrase. The lexical accent of the matrix subject was manipulated so that it forms a major phrase in (2a) but not in (2b). Since Japanese speakers have a strong preference for the single-clause analysis up to the first verb *trust-pst*, the head of the relative clause *friends-dat* produces a garden-path effect in both types of sentences (Inoue, 2006). When required to reanalyse the single-clause structure to the relative-clause structure, Japanese speakers need to take the matrix subject out of the clause, because the subject who truly trusted the new medicine is friends. Thus, in (2a), the major prosodic boundary aligns with the structural boundary, whereas in (2b), it does not. Hirose (2003) reported that the reading time of the head noun was significantly shorter in (2a) than in (2b). They interpreted this result as evidence that the major phrase boundary facilitated structural revision, because the major phrase boundary was 'recycled' as a relative-clause boundary.

(2) Hirose's (2003) stimuli

a. the +Accent+Accent condition

Hosoka⌝wa-to Morishi⌝ta-ga/ shi⌝nyaku-o/ kokoro⌝kara/
{(Hosokawa-CNJ) (Morishita-NOM)} {(new.medicine-ACC) truly
shinyoshi-ta/ yujintachi-ni/ shohosen-o/ okut-ta/.
trust-PST friends-DAT prescription-ACC send-PST
'Hosokawa and Morishita sent the prescription to the friends who truly trusted the new medicine.'

b. the −Accent condition

Moriyama-ga/ shi⌝nyaku-o/ kokoro⌝kara/ shinyoshi-ta/ yujintachi-ni/
{(Moriyama-NOM new.medicine-ACC) truly trust-PST friends-DAT
shohosen-o/ okut-ta/.
prescription-ACC send-PST
'Moriyama sent the prescription to the friends who truly trusted the new medicine.'

The slash (/) demarcates the regions presented in the reading task.

One of the concerns with Hirose's (2003) experiment was that the results could reflect the difference in the number of syntactic phrases in the stimuli (i.e. 8 phrases in (2a) and 7 phrases in (2b)). In self-paced reading tasks, participants tend to read the later part of sentences faster (e.g. Aoshima et al., 2009; Nakatani & Gibson, 2010). Thus, the faster reading times in (2a) may be due to a general speed-up effect. Furthermore, since two phrases were presented together only in the subject region of (2a), the participants may have been more likely to analyse them as a single chunk, separately from the rest of the sentence. In other words, they may have recognised the clause boundary more easily in (2a), due to an artefact of the presentation method.

2. The present study

This study investigated the role of implicit prosody in the processing of temporarily ambiguous sentences, using a self-paced reading task. To address the previously mentioned concerns, we controlled for potential experimental artefacts by keeping the number of syntactic phrases constant across the critical conditions while manipulating the presence of major phrase boundaries.

2.1 Stimuli

The sentences in (3) show an example set of target sentences. The +Accent+Accent condition in (3a) and the −Accent condition in (3c) were prepared in a way similar to Hirose's (2003) experiment.

(3) Target sentences

a. the +Accent+Accent condition
Hosoka⌝wa-to Morishi⌝ta-ga shi⌝nyaku-o kokoro⌝kara
{(Hosokawa-CNJ) (Morishita-NOM)} {(new.medicine-ACC) truly
shinyoshi-ta yujintachi-ni$_6$ shohosen-o$_7$ okut-ta.
trust-PST friends-DAT prescription-ACC send-PST
'Hosokawa and Morishita sent the prescription to the friends who truly trusted the new medicine.'

b. the −Accent+Accent condition
Moriyama-to Morishi⌝ta-ga shi⌝nyaku-o kokoro⌝kara
{(Moriyama-CNJ Morishita-NOM) (new.medicine-ACC)} truly
shinyoshi-ta yujintachi-ni$_6$ shohosen-o$_7$ okut-ta.
trust-PST friends-DAT prescription-ACC send-PST
'Moriyama and Morishita sent the prescription to the friends who truly trusted the new medicine.'

c. the −Accent condition
Moriyama-ga shi⌝nyaku-o kokoro⌝kara shinyoshi-ta yujintachi-ni$_6$
{(Moriyama-NOM new.medicine-ACC) truly trust-PST friends-DAT
shohosen-o$_7$ okut-ta.
prescription-ACC send-PST
'Moriyama sent the prescription to the friends who truly trusted the new medicine.'

In +Accent+Accent condition, the matrix subject forms a *major* phrase, because both names are accented words. The −Accent+Accent condition was created by replacing the first accented names of the +Accent+Accent condition with unaccented names. The unaccented name *Moriyama-CNJ* forms a minor phrase with its following name *Morishi⌝ta-NOM*, creating a *minor* phrase boundary. The difference in reading times between these conditions can be

attributed to processing differences due to prosodic phrasing, since the number of syntactic phrases is the same. The −Accent condition in (3c) involves the same unaccented names as in (3b). This unaccented name combines with its following phrase *new.medicine-ACC* to form a minor phrase.

For the manipulation of the lexical accent of the matrix subjects, we used common family names. Although Hirose (2003) used several types of nouns, including proper nouns (e.g. *Hosokawa*), occupational nouns (e.g. *fucho* 'chief nurse') and kinship terms (e.g. *kaasan* 'mother'), semantically neutral names are more appropriate, because Japanese speakers have difficulty in recovering from the garden path effect when the subject noun is semantically biased towards the agent of a following verb phrase (Inoue, 2006). The names always had four morae, with the accent nucleus either on the third mora (i.e. +Accent) or absent (i.e. −Accent).

Following a Latin Square design, 18 triplets of the target sentences were distributed into three lists, so that each participant saw only one sentence of each triplet. These target sentences were intermixed with 54 filler sentences (36 of them were simple single-clause sentences, with the remaining 18 having various structures).

2.2 Participants

We recruited 32 native speakers of Tokyo-Japanese for our experiment (mean age = 20.4 years, SD = 1.5). Participants reported no history of language and/or neurological disorders. The experiment was approved by the Ethics Committee of Tokyo Metropolitan University (No. H6-126). Written informed consent was obtained from all participants before the experiment.

2.3 Procedure

Each phrase of the sentences was presented as a separate region, using PCIbex (Zehr & Schwarz, 2018), in contrast to Hirose's (2003) experiment, in which the entire conjoined subject phrase was presented as a single region. We chose this method to avoid any effect of the presentation mode on the syntactic analysis.

Participants were asked to read each phrase silently and to press the space bar to move to the next phrase.[2] At the end of each trial, participants were presented with a comprehension question and asked to respond by pressing the 'Yes' or 'No' button. The response was followed by feedback indicating whether their answer was correct or incorrect.

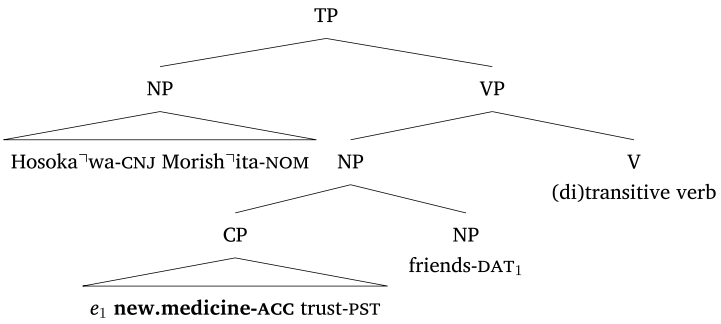
[2] In the instructions, participants were told to read each sentence one *bunsetsu* (a basic unit of Japanese grammar) at a time. Each *bunsetsu* consists of a content word followed by its associated function word(s). This grammatical concept is familiar to all participants, as it is taught in Japanese elementary schools.

2.4 Prediction

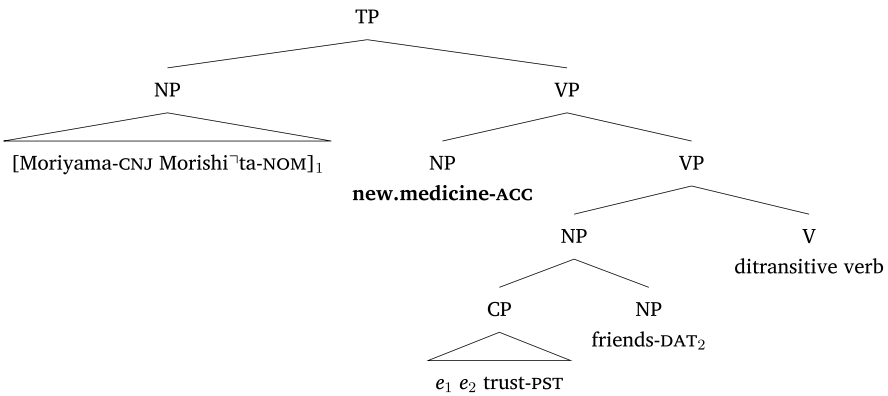
The region of primary interest is Region 6. Because the parser prefers the syntactically simpler, single-clause structure, the head noun of the relative clause would induce a garden-path effect in Region 6, where the relative-clause structure is found to be correct. If the presence of the major phrase boundary facilitates the computation of the relative-clause analysis, as Hirose (2003) proposed, the reading times should be faster in the +Accent+Accent condition than in the −Accent+Accent condition.

However, it is also possible that this difference reflects a difference in the reanalysed structure. In the +Accent+Accent condition, the parser only takes the matrix subject out of the clause, and, thus, it can preserve an existing structure as much as possible, as shown in (4). In contrast, it is possible that the parser reanalyses the structure by detaching the matrix subject and the object into a different clause from other clause mates, as shown in (5), given that the major clause boundary is placed after the object 'medicine-ACC.' Since the late-opening structure is not preferred in Japanese (Mazuka & Itoh, 1995; Oishi et al., 2007), the effect of structure should be examined, in order not to confound it with the 'recycling' effect.

(4) The early-opening structure (the correct structure in the end)[3]



(5) The late-opening structure



[3] '*e*' represents the empty category. The indexes, such as $_1$ and $_2$, indicate that the co-indexed constituents refer to the same person(s).

Region 7 serves this purpose. Here, *prescription-ACC* signals unambiguously that it is the object of the matrix clause. If the parser chose the late-opening structure in the −Accent+Accent condition, it should experience another garden-path effect. This is due to a syntactic constraint in Japanese that restricts multiple accusative-marked arguments within the same clause (Harada, 1973). Consequently, the reading time should be longer in the −Accent+Accent condition than in the +Accent+Accent condition. In contrast, if the parser chose the early-opening structure in the −Accent condition, it should avoid a second garden-path effect in Region 7. This is because *new.medicine-ACC* is analysed as an object inside the relative clause after the first garden-path effect in the early-opening structure, allowing *prescription-ACC* to be easily incorporated as a matrix object. In the −Accent condition, a second garden-path effect should occur, because the parser is expected to choose the late-opening structure, given the absence of a prosodic boundary between *Moriyama-NOM* and *new.medicine-ACC*.

2.5 Data and statistical analysis

We analysed only the trials in which the comprehension question was answered correctly. Reading time data that exceeded 2.5 standard deviations from the mean at each region were discarded.

The reading times were log-transformed and analysed using linear mixed-effects (LME) models, with Accent as a fixed factor and participants and items as random factors. The fixed factor was coded with the Helmert scheme, as shown in **Table 1**. The effect of Type is a factor of primary interest in testing the role of the major phrase in facilitating structural reanalysis. The effect of Boundary (i.e. the presence vs. absence of the prosodic boundary after the matrix subject) involves the comparison between different numbers of phrases; thus, interpreting this effect requires caution. Item Order (the *n*th trial) was included as a covariate to assess task adaptation (e.g. Prasad & Linzen, 2021), but its significance was not of interest.

Table 1: The coding schema of the fixed factors in the LME models.

	Condition A +Accent+Accent	**Condition B −Accent+Accent**	**Condition C −Accent**
Type (A vs. B)	1/2	−1/2	0
Boundary (A/B vs. C)	1/3	1/3	−2/3

The maximal model was built using the *lmer* function of the *lme4* package in R (Bates et al., 2015), and then compared with more parsimonious models with simpler random effects in the backward stepwise method (Matuschek et al., 2017). The *p*-values were calculated based on the Satterthwaite method (Kuznetsova et al., 2017).

2.6 Results

The accuracy of the task did not differ significantly among the three conditions (+Accent+Accent: 91.1% (SE: 2.06), −Accent +Accent: 86.5% (SE: 2.48), −Accent: 92.7% (SE: 1.88)). **Figure 1** shows the results of the self-paced reading experiment.[4] The LME model showed a marginally significant effect of Type in Region 6 ($p = 0.052$), indicating that the +Accent+Accent condition was read faster than the −Accent+Accent condition (**Table 2**). In Region 7, the effect of Boundary was significant, as reading times were shorter in the +Accent+Accent and −Accent+Accent conditions than in the −Accent condition (**Table 3**). There was no significant difference between the +Accent+Accent and −Accent+Accent conditions. Note that the apparent numerical trend suggests shorter reading times for the −Accent+Accent condition (i.e. no evidence for the second garden-path effect in this condition).

As **Figure 1** shows longer reading times for the +Accent+Accent condition in Regions 1–3, an additional analysis was performed to examine this effect. The +Accent+Accent condition took longer to read than the other conditions in Regions 2 and 3 (Region 2: $\hat{\beta} = -0.06$, $t = -1.89$, $p = 0.05$; Region 3: $\hat{\beta} = 0.08$, $t = 2.24$, $p < 0.05$). No significant difference was found in Region 1.

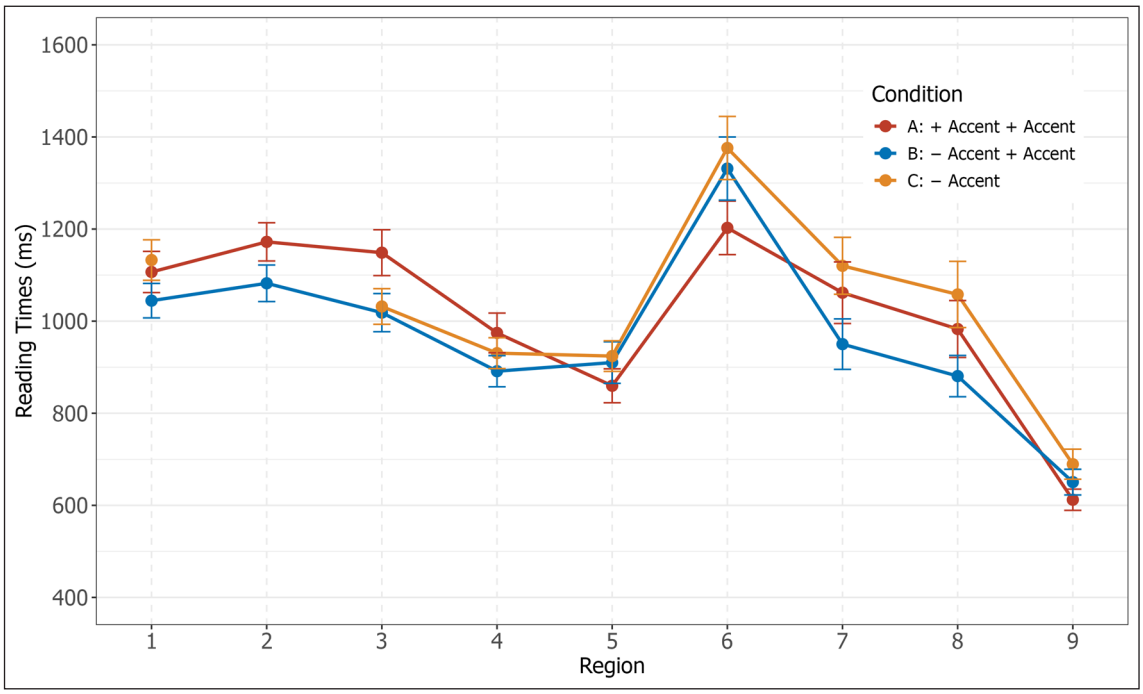


Figure 1: The mean reading times (ms). Error bars represent the standard error of the mean.

[4] Since the −Accent condition lacks the second phrase of the matrix subject, the second region and subsequent regions were shifted by one phrase to match the regions in the other conditions.

Table 2: Summary of the fixed effects in the LME models of the reading times in Region 6.

	Estimate	**SE**	***t***	***p***	
(Intercept)	7.07	0.08	87.40	<0.01	
Type (A vs. B)	-0.09	0.04	-1.94	0.05	+
Boundary (A/B vs. C)	-0.05	0.04	-1.43	0.15	
ItemOrder	<0.01	<0.01	-2.03	0.04	*

SE: standard error. $+p < 0.10$, $*p < .05$.

Table 3: Summary of the fixed effects in the LME models of the reading times in Region 7.

	Estimate	**SE**	***t***	***p***	
(Intercept)	6.74	0.08	81.61	<0.01	
Type (A vs. B)	0.07	0.04	1.63	0.10	
Boundary (A/B vs. C)	-0.09	0.04	-2.35	0.02	*
ItemOrder	<0.01	<0.01	0.61	0.53	

SE: standard error. $*p < .05$.

3. Discussion

This study investigated whether Japanese speakers implicitly generate prosodic structures during silent reading. To test the implicit prosody hypothesis, we conducted a self-paced reading experiment in which the presence vs. absence of major phrases was manipulated. The results showed a slowdown in Region 6, suggesting garden-path effects for the head noun of the relative clause. In this region, the +Accent+Accent condition showed slightly shorter reading times than the other two conditions. As mentioned in 2.4, this effect can be interpreted in two ways. One interpretation, proposed by Hirose (2003), suggests that the major phrase boundary facilitates the insertion of the relative-clause boundary. Alternatively, the speed-up might reflect a structural difference, with the +Accent+Accent condition analysed as having the early-opening structure and the −Accent condition as having the late-opening structure. If the latter interpretation were correct, we would expect to see a second garden-path effect in the −Accent condition in Region 7. However, our results did not support this interpretation. Therefore, our findings supported the hypothesis that recycling the major phrase boundary helps the second-pass reanalysis.

The lack of a significant Type effect in Region 7 suggests that the parser opted for the early-opening analysis in the −Accent+Accent condition by postulating a relative-clause boundary at the *minor* phrase boundary. This result indicates that the parser does not always insert the clause boundary after the major phrase boundary. Instead, the minor phrase appears to be a prosodic unit relevant for guiding syntactic parsing when resolving temporary ambiguity.

Another intriguing observation is that the +Accent+Accent condition showed a slowdown in Regions 2 and 3. This slowdown is likely due to the difficulty of processing two accented words. This interpretation is consistent with the observation that in English, words with two stressed syllables, such as *fúndamèntal*, are read more slowly than words with one stressed syllable, such as *signíficant* (Ashby & Clifton Jr., 2005). As this interpretation is speculative, future studies are needed to test it further.

4. Conclusion

This study showed that major phrase boundaries play a functional role in guiding syntactic analyses of sentences during silent reading. This finding suggests that the parser implicitly computes a prosodic structure and projects it onto written sentences in incremental processing. Our findings contribute to our understanding of the close link between syntactic analysis and prosodic phrasing.

Abbreviations

ACC = accusative, CNJ = conjunction, DAT = dative, NOM = nominative, PST = past.

Data accessibility statement

All data and the R script associated with this study are available at the following link: https://osf.io/k97ny/.

Ethics and consent

The experiment was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Tokyo Metropolitan University (No. H6-126). Written informed consent was obtained from all participants before the experiment.

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Competing interests

The authors have no competing interests to declare.

Author contributions

RM: conceptualization, data collection, formal analysis. MY: supervision, writing – original draft, funding acquisition.

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