Prosodic Effects on Garden-path Sentences

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Abstract

A garden-path sentence has temporary ambiguity that a reader or listener need to resolve. Prosody is well-known to have effects on sentence comprehension so it is expected that it will affect the interpretation of garden-path sentences. However, in an auditory comprehension test with natural speech, the garden-path effect may be unclear because a listener can typically resolve the ambiguity and recover from the garden-path effect when the sentence is completed. Therefore, this paper investigates ways to enhance or suppress garden-path interpretation in Mandarin by manipulating phrasing with pause insertion and pitch reset. The results show that long pause at the garden-path site enhances the garden-path (wrong) interpretation which cannot be undone by pitch reset that encourages the correct phrasing. The most effective way in prosody to enhance the garden-path effect in Mandarin requires both long pause and high pitch reset.
Index Terms: garden-path effect, pause duration, pitch reset, reaction time, sentence comprehension, Mandarin

1. Introduction

Garden-path sentences are grammatical sentences containing a fragment that lures readers into an improper parse. The most famous example is given in (1a) [1]. As readers/listeners receive the sentence sequentially, they tend to take the first section *The horse raced past the barn* as a complete sentence. This initial parse as shown in (1b) is incorrect as it leaves the final word *fell* dangled. A reanalysis is required to incorporate the unattached word *fell*. As presented in (1c), *fell* is the main verb linked to the sentential subject *horse*, and *raced past the barn* is a reduced relative clause modifying the subject.

a. Grammatical garden-path sentence: (1)
The horse raced past the barn fell.
b. The initial parsing:
[$_S$ The horse raced past the barn] fell.
c. Reanalysis:
[$_S$ [$_{DP}$ The [$_{D'}$ horse raced past the barn]] fell.]

In this paper, we define the boundary of the initial wrong parsing as *the garden-path site*, as in (2).

[$_S$ The horse raced past the barn] fell. (2)
⇧
Garden-path site

Another example of garden-path sentences is given in (3a). Here, the temporary ambiguity results from verb bias [2].

a. Grammatical garden-path sentence: (3)
The referees warned *the spectators* would probably get too rowdy.
b. Initial parsing:
[$_S$ The referees warned *the spectators*] would probably get too rowdy.
c. Reanalysis:
[$_S$ The referees warned [$_S$ *the spectators* would probably get too rowdy.]]

The word *warn* is a DO(direct object)-biased verb so that the initial parse tends to treat *the spectators* as the direct object of *warned* (3b). A reanalysis is required to treat *the spectators* as the subject of the embedded clause (3c). This paper defines the boundary where a new phrase is supposed to start as *the disambiguation site*, as in (4).

[$_S$ The referees warned [$_S$ *the spectators* would probably get too rowdy.]] (4)
⇧
Disambiguation site

The garden-path effect has been examined in a great number of word-by-word reading experiments across languages [3][4][5]. But there are pros and cons of different experiment designs. A slowdown in reaction time on the word after the garden-path site suggests that the reader is doing reanalysis to incorporate the extra materials to get the correct interpretation. The comprehension accuracy score of the sentence may be lower, as the reader could fail to recover from the initial parse when the parsed words disappear from the display window and cannot be reread. Nevertheless, while garden-path effect can be measured in Rapid Serial Visual Presentation (RSVP) experiments and moving window reading experiments, the word-by-word display method employed is not a natural mode of reading. Readers may have difficulty recovering from the garden-path effect because of the unnatural pause after each word. Even though the unnaturalness of presentation can be resolved in eye-tracking techniques, the eye-tracking techniques cannot prevent a reader from regressing in and out of a word or from reading words repeatedly.

An auditory comprehension test design can effectively avoid both problems in the sense that sentences can be presented naturally with speech without required pause after each word, and the listener cannot get repeated exposure to the stimuli. However, in an auditory comprehension test with natural speech, the garden-path effect may be unclear because a listener can reach the ceiling effect, resolving the ambiguity and recovering from the garden-path effect by the time the sentence is completed.

If there is a way to increase the task difficulty in an auditory comprehension test, we can then lower the ceiling effect and use the test effectively to examine garden-path effect. In this experiment design, we manipulate prosody to examine the garden-path effect. In particular, we investigate ways to enhance or suppress garden-path interpretation by manipulating phrasing with pause insertion and pitch reset.

1.1. A garden-path structure in Mandarin

The current research takes Mandarin as an example and focuses on one garden-path structure in Mandarin—embedded subject relative clause placed in a matrix object position as presented in (5)—which has a type of temporary ambiguity similar to the English example and is discussed in [6].

NP_1 V_1 V_2 NP_2 REL NP_3 (5)
cunli *xuyao* ***zhiyuan*** *xiaofangyuan de yigong*.
village need support fireman DE volunteer
a. ( )$_{IP}$⇧( )$_{IP}$
Garden-path site
'*The village needs to support firemen's volunteers.'
b. ( )$_{IP}$ (⇧)$_{IP}$
Disambiguation site
'The village needs volunteers who can support the firemen.'

A relative clause in Mandarin is head-final, where the modifying clause comes before the head noun [7]. This is different from English where the head noun comes before the modifying clause. In a head-final relative structure like (5), the reader/listener is unaware of the boundary of a relative clause and tends to take NP2 as the object of the main clause, leading to the garden-path effect and online processing difficulty. The initial parse "The village needs to support fireman" is incorrect. Reanalysis is required when the head noun is reached to form the main clause "The village needs volunteers". The garden-path site is marked in (5a), which indicates the boundary of initial wrong parsing. The disambiguation site is marked in the reanalysis (5b), which indicates the place where a new phrase is supposed to start.

1.2. Prosody in sentence disambiguation

1.2.1. Prosodic boundary

Prosodic boundary can be manifested by pauses between prosodic phrases. Pauses often occur at major syntactic boundaries. However, the more complex the syntactic constituent, the more likely a pause is to appear [8].

In the speech perception of ambiguous sentences, research has shown that the listener can reliably separate meanings by detecting the prosodic breaks (pause) [9]-[10]. However, as the duration of the pause increased, the participants' interpretation of the ambiguous sentences seemed to move away from the intended meaning and towards the alternative meaning.

Based on these studies, this paper hypothesizes that the garden-path effect in auditory comprehension of (5) may be enhanced by inserting a long pause at the garden-path site. With a pause between utterances, the listener may chunk the played speech as a constituent and find it hard to attach the up-coming speech to the fully analyzed constituent. Thus, it is expected that a long pause at the garden-path site may distract the listener from getting the accurate interpretation.

1.2.2. Pitch contours

Intonational contours may provide a cue for the listener to detect the sentence structures. In [11]'s eye movement study, the participants listened to N_1-V-Adv-N_2 sequences in German, where the case marking in N_1 is ambiguous (the nominative case and the accusative case share the surface form). In the SVO prosody, the listeners looked to the patient more than to the agent during the adverb (i.e., before the disambiguating phrase N_2 came out). The postverbal anticipatory movement to the upcoming constituent shows that the intonation could provide a cue for the expected interpretation.

Another two interesting phenomena in prosodic pitch contours are declination and pitch reset. There is a general tendency for pitch to lower as a sentence progresses, which is an effect referred to declination [12]. The declination effect in Mandarin was examined by asking participants to produce sequences of high-level tones (tone 1) ranging from 2 to 11 syllables long [13]. The results show that the F0 decline is salient near the beginning of the utterance. Longer sentences would have higher initial pitch than shorter sentences. On the other hand, the F0 reset in fluent Mandarin speech occurred at the initial of syntactic phrase across speakers [14]. In other words, syntax and semantics influence how phrases are grouped and manifested in prosody. Based on these findings in Mandarin, this study assumes that the garden-path sentences such as (5), with 11 syllables long, should display the tendency of declination in speech as well. To disambiguate such sentence, a pitch reset at the disambiguation site (V_2), signaling the start of a new boundary, may be of assistance.

1.3. Research questions

The current research examines the garden-path sentences in Mandarin as in (5). The research questions this study addresses are: (i) Can pause insertion alone or pitch reset alone enhance or suppress the garden-path effect? (ii) Do pause insertion and pitch reset interact and affect the auditory comprehension of the garden-path sentences? (iii) What are the most effective ways to enhance or suppress the garden-path effect? In other words, this study manipulates two factors, pause insertion at the garden-path site and pitch reset at the disambiguation site, to enhance or suppress in comprehending the garden-path sentences. If the garden-path effect is enhanced, there should be more comprehension errors and longer reaction time. On the other hand, if the garden-path effect is suppressed, there should be fewer comprehension errors and faster reaction time.

The hypotheses underlying this study are as follows. With the pause inserted at the garden-path site which would lead to a temporary ambiguity, it is expected that the auditory comprehension should not benefit from such manipulation, and that the longer the pause, the more likely it is to obtain an incorrect interpretation. On the other hand, the pitch reset at the disambiguation site provides the listener with a cue of starting a new phrase. Unlike the pause insertion at the garden-path site, the pitch reset is more of a benefit for auditory comprehension. Since one prosodic manipulation is designed to mislead the listeners and to enhance the garden-path effect, and another manipulation is designed to aid the listeners and to suppress the garden-path effect, we expect to see the interaction of these two conditions.

2. Experiment

2.1. Methods

Participants. Thirty-five National Taiwan Normal University undergraduate students participated. All were native speakers of Taiwanese Mandarin.

Materials. Five garden-path sentences with the same structure as (5) were created. The sentences were recorded at a normal speaking rate by a male linguist with no prosodic break and pitch reset at phrase junctures.

The original recordings of the garden-path sentences were prosodically manipulated by inserting a pause at the garden-path site, as shown in (5). The pause varied in length, including 0 ms, 200 ms, 400 ms, 600 ms, and 800 ms. The first word at the disambiguation site, V_2, was exaggerated in pitch. The pitch raise included 0 Hz, 20 Hz, 40 Hz, 60 Hz and 80 Hz. This gave rise to a 5 x 5 (pause duration x pitch reset)

design, 25 versions for each sentence. Notice that the tone of the first word at the V_2 in the five target sentences included tone 1, 2, 3, and 4. In the statistical analyses, the tone factor was included as an independent variable in the regression model.

Procedure. First, a fixation appeared on the screen for 500 ms and then a spoken sentence came from the headphones. After the whole sentence was played, one comprehension question appeared on the computer screen. The questions asked whether the matrix subject (NP_1) did something (V_1) to the head noun of relative clause (NP_3), which all required a "yes" answer. Participants were encouraged to achieve high accuracy and to respond as quickly as possible if they knew the answer.

2.2. Analyses

Hierarchical regression model was run to see what factor contributed most to the model. Reaction time and accuracy of the comprehension questions were dependent variables and collected for each trial. The independent variables included tone, pause duration, and pitch reset.

2.2.1. Reaction time

The mean reaction time was plotted against pause duration in Figure 1. Each panel in Figure 1 represents the tonal category of the word with pitch manipulation (i.e., the first word of V_2).

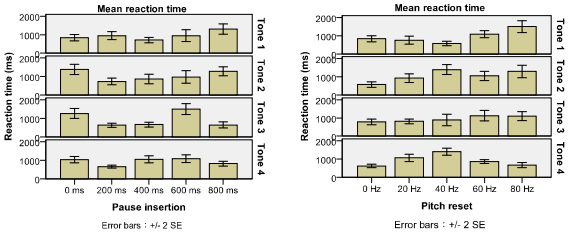

Figure 1. Mean reaction time in each level of pause duration (up)/pitch reset (down) for each tone

As can be seen from the figure, the tone 3 looked different from the other tones that the former elicited relatively short reaction time at the levels of 200 ms, 400 ms, 800 ms, and elicited almost the same amount of reaction time across all levels of pitch reset. This may result from the fact that raising the pitch of tone 3 leads to a change of tonal category. To remove this confounding, tone 3 was excluded in the statistical analysis.

The reaction time data were analyzed by hierarchical multiple regression. The independent variables (tone, pause duration, and pitch reset) were added to the regression model one at a time. The interaction between pause duration and pitch reset was then added to the fourth block. The slopes (beta) reported below referred to the amount of effect the individual levels of independent variables explain for the dependent variable.

In the first block of the regression model, the independent variable tone was entered. The tone had no significance influence on the reaction time, R^2=.004, F(2,522)=.946, p=.389. This gives us confidence to say that the significant differences in reaction time, if any, are due to the manipulation of pause duration or pitch reset.

The pause duration was entered into the second block of the regression model, R^2=.030, F(4,518)=3.470, p<.01. The slopes show that there was a linear effect of pause where longer pauses elicited longer reaction time the slopes show that there was a linear effect of pause where longer pauses elicited longer reaction time (with an exclusion of 0ms, see Figure 2). The pitch reset was entered into the third block of the regression mode, R^2=.085, F(4,514)=7.763, p<.001. The slopes of the pitch reset indicate that there was a linear effect of pitch where higher pitches elicited longer reaction time (Figure 2). The interaction between pause duration and pitch reset was entered into the fourth block of the regression model, R^2=.139, F(16,498)=1.947, p<.05. However, the interaction effects did not have a linear tendency to increase the reaction time. The conditions that contributed significantly to the model only involved 400ms*40Hz (beta=.204, t(498)=3.067, p<.01), 600ms*80Hz (beta=.183, t(498)=2.757, p<.01), and 800ms*20Hz (beta=.153, t(498)=2.304, p<.05). As the three interactions all involved positive slopes, it suggests that their contribution to the model was to increase the reaction time. In other words, the garden-path effect may be enhanced under these conditions.

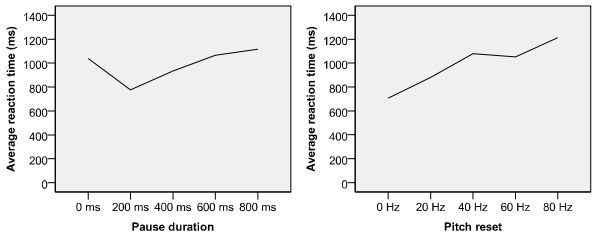

Figure 2. Reaction time in pause duration (left) and pitch reset (right)

2.2.2. Comprehension accuracy

The comprehension accuracy was analyzed by hierarchical logistic regression. The independent variables (tone, pause duration, and pitch reset) were added to the regression model one at a time. The interaction between pause duration and pitch reset was then added to the fourth block. As in the reaction time, the tone (with an exclusion of tone 3) which was entered into the first block had no explanatory power for the comprehension accuracy, R^2=.012, χ^2(2)=2.846, p=.241.

The pause duration was entered into the second block of the regression model, R^2=.064, χ^2(6)=15.593, p<.05. The parameter estimates (slopes) show that there was an effect of pause where longer pauses elicited lower accuracy (Figure 3).

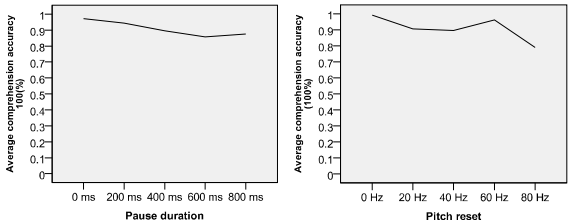

Figure 3. Comprehension accuracy in pause duration (left) and pitch reset (right)

The pitch reset was entered into the third block of the regression model, R^2=.191, χ^2(10)=48.073, p<.001. The slopes of the pitch reset indicate that there was an effect of pitch where higher pitch settings elicited lower accuracy (Figure 3). The interaction between pause duration and pitch reset was entered into the fourth block, R^2=.346, χ^2(26)=90.529, p<.001. However, upon closer inspection of the parameter estimates (slopes), the interaction conditions did not make significant contribution to the regression model.

2.3. Summary

Prosody can either enhance or suppress the garden-path effect. Most of the conditions show an enhanced garden-path effect, with one exception in the reaction time of 200 ms. A long pause (600-800ms) at the garden-path site enhances the garden-path effect, whereas a short pause suppresses the garden-path effect. Pitch reset at the disambiguation site, however, cannot rescue the listener from the garden-path interpretation. Contrary to the expectation, the higher the pitch, the easier it is to make a garden-path effect. The significant interaction lied in the 400ms*40Hz, 600ms*80Hz, and 800ms*20Hz.

3. Discussion

This research investigated the effect of prosody on the interpretation of garden-path effect sentences. As the regression model used the 0ms and 0Hz as the reference groups, the 0ms and 0Hz cannot undergo parameter tests in the regression models. To further explore the effect of each condition (particularly, the reference groups), cross tabular data for comprehension accuracy and reaction time are provided and discussed below.

First, look at the comprehension accuracy in Table 1. Most of the answers were correct. Only a few cells were lower than 90% correct, and they all lied in the lower-right triangle. It means that the native speakers were able to process these sentences, and that these manipulations in themselves do not create sentences that are unnatural and incomprehensible. The results also show that using pause insertion or pitch reset individually (the first row and the first column, respectively) did not contribute to any significant effect in the garden-path sentences. However, employing pause insertion and pitch reset together can produce effects, which is a contribution to the search of ways to enhance the garden-path effect in prosody (shaded cells in Table 1, with the lowest comprehension accuracy occurring in the 600ms*80Hz).

Table 1. Cross tabular data for mean comprehension accuracy (SE) (100%)

Pause / Pitch	0 ms	200 ms	400 ms	600 ms	800 ms
0 Hz	1.00 (.000)	1.00 (.000)	0.95 (.048)	1.00 (.000)	1.00 (.000)
20 Hz	1.00 (.000)	1.00 (.000)	1.00 (.000)	0.76 (.095)	0.76 (.095)
40 Hz	0.95 (.048)	0.90 (.066)	0.67 (.105)	0.95 (.048)	1.00 (.000)
60 Hz	1.00 (.000)	0.90 (.066)	1.00 (.000)	1.00 (.000)	0.90 (.066)
80 Hz	0.90 (.066)	0.90 (.066)	0.86 (.078)	0.57 (.111)	0.71 (.101)

Note. The underlined cell (0ms*0Hz) is the condition where no prosodic manipulation was made. The shaded cells indicate the conditions where the comprehension accuracy was lower than 90% correct.

Now, turn to the reaction time in Table 2. The lower-right triangle was worse both in comprehension accuracy and reaction time. The pause insertion alone (the first row) suppressed the garden-path effect. Every cell in the first row had faster reaction time than the original, unaltered speech (0ms*0Hz). This is opposite to the hypothesis in this study, where a long pause at the garden-path site is supposed to enhance the garden-path effect. One possibility is that pause insertion has multiple functions. Pause insertion without lowering the pitch of the preboundary words may be an indication for listeners to anticipate something going to appear. Signaling phrasing may require the presence of other cues. Then, the pitch reset alone (the first column) suppressed the garden-path effect only at the 20Hz level. However, when pitch reset was further added (40-80Hz), the garden-path effect was enhanced rather than suppressed. This is opposite to the hypothesis in this study, where a high pitch reset at the disambiguation site signaling the start of a new phrase is supposed to suppress the garden-path effect. One possibility is that with raised pitch at V_2 (5), the pitch level right before the pause insertion (NP_2) may be interpreted as final-lowering, which may be closer to the naturally produced prosodic effect of phrasing. Such phrasing would make the listeners to interpret a garden-path sentence incorrectly.

Table 2. Cross tabular data for mean reaction time (SE) (unit: ms)

Pause / Pitch	0 ms	200 ms	400 ms	600 ms	800 ms
0 Hz	945.81 (144.60)	449.57 (54.04)	652.38 (75.92)	547.81 (71.01)	935.72 (92.20)
20 Hz	690.91 (67.05)	641.76 (96.69)	677.72 (95.46)	1093.71 (231.17)	1295.14 (209.46)
40 Hz	1092.90 (129.74)	930.43 (123.00)	1408.95 (223.11)	938.57 (207.41)	1024.67 (116.40)
60 Hz	1330.57 (194.77)	840.33 (75.70)	906.24 (91.30)	1108.57 (129.05)	1070.38 (149.83)
80 Hz	1136.95 (130.44)	1016.86 (164.60)	1029.00 (188.14)	1634.29 (310.84)	1249.19 (183.65)

Note. The underlined cell (0ms*0Hz) is the baseline condition where the speech was unaltered. The shaded cells indicate the conditions where the reaction times were longer than the baseline condition.

4. Conclusions

This study examines how prosody enhances or suppresses the garden-path effect in auditory comprehension. The effects of pause insertion and pitch reset in the garden-path sentences are not linear. To enhance the garden-path effects, using pause insertion or pitch reset alone is not effective. Long pause insertion and high pitch reset are both required for enhancing the garden-path effect. It is expected that the same effective manipulation, long pause insertion and high pitch reset, should assist in raising the ceiling (i.e., more likely to suppress the garden-path effect and obtain accurate interpretation), if prosodic boundary is correctly placed at the non-garden-path site (i.e., the disambiguation site).

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