

Does Word Order Affect Processing?

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Introduction

Although many parts of English syntax have fixed order, the position of many constituents after the verb are flexible. For example, here are two sentences where we exchange the position of the indirect and direct objects:

Bill threw the dirty baseball sitting in the mud puddle to Carl.

Bill threw Carl the dirty baseball sitting in the mud.

We can also move around other particles and phrases. For example, the previous sentence could have been written as “We can also move other particles and phrases around.”

According to Behaghel’s law, speakers tend to put the heavier constituents of sentences last. Speakers determine the “heaviness” of a constituent by both length and grammatical complexity¹.

Although Behaghel’s law generally holds, I couldn’t find justification for it. Many justifications exist for other methods of ordering constituents, including²:

- Speakers want to present old information before new information
- Speakers want to avoid ambiguity
- Certain orderings help to plan utterances

None of these justifications, however, address Behaghel’s law directly. Sentences should either be constructed for the benefit of the speaker or the benefit of the listener. I am interested in whether Behaghel’s law affects listeners and how much if it does.

¹ Wasow, Thomas. “Remarks on grammatical weight”. *Language Variation and Change* 9: 81-105. 1997

² Wasow, Thomas and Jennifer Arnold. "Post-verbal Constituent Ordering in English". In G. Rohdenburg and B. Mondorf (eds) *Determinants of Grammatical Variation in English*, 119-154. Mouton. 2003.

Specifically, I am curious if differences in word order affect a listener's ability to process or comprehend sentences. Speakers may prefer the lighter to heavier ordering to present information in an easier format. This format could be a potential justification for Behaghel's law. To test this hypothesis, I wrote a simple story where several sentences could be written either with the lighter constituent first (following Behaghel's law) or with the heavier constituents first. There are two versions of the story, where each has half of the varied sentences lighter first and the other half heavier first. My hypothesis is that readers will take longer to read a sentence with the heavier constituent first than it will for readers to read the same sentence with the lighter constituent first. If so, the longer reading time indicates more effort required to process a sentence because of the constituent ordering.

Methods

26 subjects participated in the study. They are all fluent English speakers and are mostly college students. The study was packaged as a program and was either run from my computer or emailed to subjects and run from their computer³. Even though I couldn't monitor all of their testing environments, subjects were instructed to perform the study without distractions. In either case, their environment should not be an important factor in the study.

The program begins by explaining the steps to complete the study. Sentences are displayed one at a time on the screen with a "next" button at the bottom. After reading the instructions, the subjects then read a 30 sentence story about two brothers building a tree house. Of those 30 sentences, 20 are constant between both versions of the story and used to normalize for reading speed. The other 10 vary between the two versions: one has the lighter constituent

³ The program and source code are available at <http://kevinleung.com/files/psychexperiment.zip>

first for a sentence and the other has the heavier constituent first. For example, version A of the story has

Chip climbs up the large, oak tree that they're going to use quickly.

while version B has

Chip climbs quickly up the large, oak tree that they're going to use.

Version A presents 5 of the 10 sentences as heavier-first and the other 5 as lighter-first. Version B presents the 5 sentences that A selects as heavier-first to be lighter-first instead, and similarly for the other 5. This way, version A is the control condition for half of the sentences and the experimental condition for half of the sentences, and B plays the opposite role for both halves. The complete stories for both versions are in appendix 1.

The program randomly assigns a subject to either version A or B. As the subject goes through the story, the program times the subject from when the sentence is first presented until he or she clicks “next”. This time, in milliseconds, is stored.

After the story is done, the subject answers a simple 5 question true-false quiz on the story. The quiz is not intended to be difficult but does ensure that the subject read the story. The questions in the quiz are in appendix 2.

Finally, the test condition, reading times, and answers to the quiz are compiled into a file automatically, which the subject can send back to me for processing.

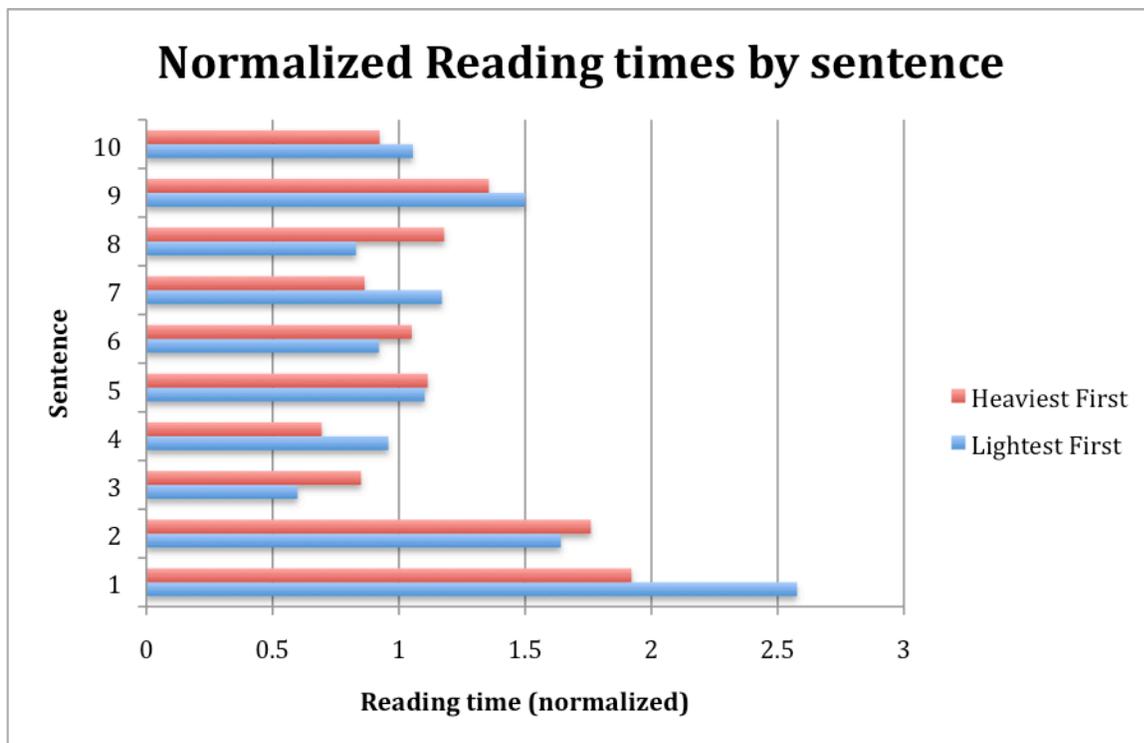
Results⁴

I first discard all results where the subject answered less than 4 of the 5 questions correctly. Next, for each subject, I average the reading time on the 20 invariant sentences to get an average reading time for that subject. I use that average to normalize the reading times across

⁴ The raw data can be found at <http://kevinleung.com/files/data.xls>. It was a little unwieldy to add as an appendix.

the experiment sentences by dividing the experiment reading time by the average reading time. This normalized reading time indicates whether the subject took more or less time to read a sentence than it took them to read the average sentence.

The normalized reading time allows for comparisons between subjects as it accounts for whether a subject is a fast or slow reader. For each sentence variant, I average the normalized reading times for both the lighter-first version and the heavier-first version. The results of this comparison are below:

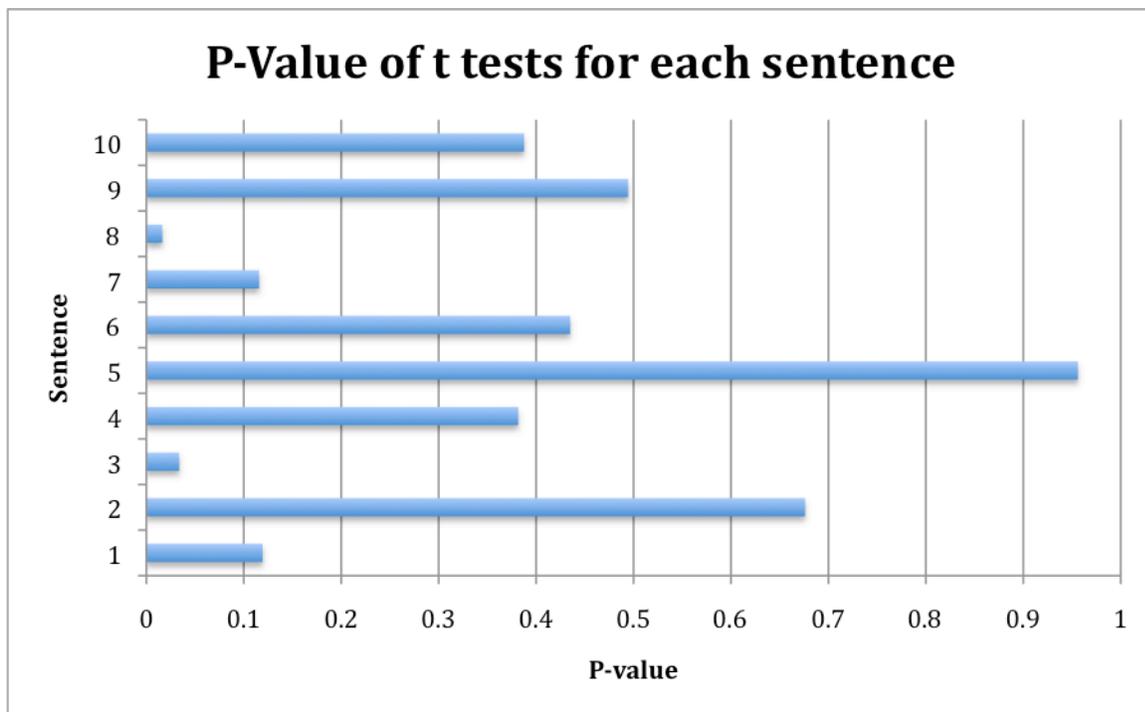


The reading times don't correlate with heavier-first or lighter-first constituents. In half of the experiment sentences, the subjects were faster in the lighter-first condition, but in the other sentences, the subjects were faster in the heavier-first condition. This result doesn't correspond to my hypothesis that subjects read faster when sentences with lighter constituents are first.

To see if there was a significant and consistent difference in reading time between these two conditions, I did a t-test. Whether a sentence does or does not follow Behaghel's law doesn't

affect a reader's processing time as the heavier-first and lighter-first conditions took the same time ($p = .7728$).

Going further, I wanted to see if each sentence individually had a significant difference in reading times between the two conditions. Even if all types of sentences amalgamated didn't have any correlation, particular sentences might. To do that, I compared only the normalized reading time on a specific sentence with 10 t-tests. The graph of p-values are below, where a p-value less than .05 indicates a difference between the conditions.



Of the 10 sentences, sentences 3 and 8 consistently took subjects longer to read the heavier-first condition than the lighter-first condition ($p < .05$). The rest of the sentences did not have a significant difference between the two conditions.

Discussion

According to these results, deviations from Behaghel's law don't significantly affect how long it takes a reader to process a sentence. Although the results would have been more accurate

with a larger sample size, I don't believe the results would be different enough to come to a difference conclusion. I have, however, made several smaller observations.

Caveats to the design of the study. In doing this study, I saw two concerns that lead in possible directions for other research.

First, this entire study is language-dependent because Behaghel's law makes assumptions about the syntax of the language in question. One subject commented to me afterwards that he thought this was a cross-linguistic study because the word ordering reminded him of German (ironically, Otto Behaghel was himself German). Depending on their background, polyglots might have different processing times for different constituent orderings.

Second, subjects might have clicked "next" before fully processing a sentence. For example, the sentence

She takes the medicine bag not touched for several months out.

places "out" at the end of the sentence, which appears suddenly. If a subject anticipates the end of the sentence, he or she might click "next" before processing the word "out." In this case, we would observe the additional processing time in the following sentence. In fact, the example above had the smallest difference between the two conditions. How people interact with technology and process sentences, however, is beyond the scope of this study.

Sentence-specific differences. Across the individual sentences, we saw that there was not a significant difference with most of the sentences. Sentences 3 and 8, however, did have significantly different reading times. We can take a closer look at why this happened.

The two versions of sentence 3 are:

James passes it to Chip.

James passes Chip it.

Although these sentences are both grammatically correct, several subjects commented afterwards that they believed that “James passes Chip it” was grammatically incorrect. They were, however, all easily persuaded that it is technically correct, albeit grammatically awkward. Most speakers prefer to say “James passes it to Chip.” This preference could be a product of Behaghel’s law, but it becomes a phenomena on its own. I therefore consider it separate from Behaghel’s law. The subjects recognized “James passes Chip it” as more than just strange, but actually incorrect, and that belief explains the difference in reading times.

The two versions of sentence 8 are:

Chip shows his parents all of the hard work he has done while up in the tree.

Chip shows all of the hard work he has done while up in the tree to his parents.

Of the 10 sentences, only sentences 3, 8, and 9 switched direct and indirect objects in the experimental condition; the rest moved other smaller particles and phrases. Grammatically, the construction of sentence 8 and sentence 9 are very similar, yet the difference in reading time is clear for sentence 8, but not for sentence 9 ($p = .0164$ for sentence 8, $p = .4944$).

For comparison, the two versions of sentence 9 are:

Their father brings the boys the tray of pineapple, apples, and oranges he had just cut up.

Their father brings the tray of pineapple, apples, and oranges he had just cut up for the boys.

I originally hypothesized that subjects would take less time to read the sentence with “the boys” first, but they actually took more time. In hindsight, the words “brings the boys the tray...” introduce both objects with “the,” and that sounds strange and makes it difficult to parse. We can’t be certain whether this awkwardness explains the difference, but it appears to be the most

likely cause. If so, that awkwardness would have a much greater impact on reading time than the ordering of constituents based on Behaghel's law does alone. Different constituent orderings caused the fluency and clarity of the sentence to change, and that might account for readers taking more time with certain ordering.

Although these fluency changes are confounding variables in this study, they seem unavoidable in any test of Behaghel's law. This relationship between constituent ordering and fluency explains the focus of previous research. Researchers, such as Wasow, focused more on justifications for orderings other than Behaghel's law because they overshadow Behaghel's law.

Conclusion. Readers do not consistently take any more or less time to read a sentence because of the lightest-to-heaviest ordering suggested by Behaghel's law. This result implies that the ordering alone does not appear to have a significant effect in processing sentences. However, different orderings (not determined by Behaghel's law) may cause fluency differences that do affect processing.

Appendix 1: 2 versions of the story

Below are the two versions of the same story. Experiment sentences are marked with either (heavier) or (lighter) for which constituent came first.

Version A

James and Chip are building a treehouse in their backyard.
Although they are both teenagers, they have lots of time during the summer to do it.
They have been planning on doing this for many years, but the tree wasn't big enough until now.
James drew yesterday morning a plan on the chalkboard in the hallway of their house. (lighter)
First, they need to clear out some of the extra branches.
Chip climbs up the large, oak tree that they're going to use quickly. (heavier)
This past weekend, James and Chip had borrowed their neighbor's chainsaw.
The chainsaw is in good shape and easy to use.
As Chip climbs, James gets the chainsaw from the garage.
James passes it to Chip. (lighter)
Chip begins to cut through a branch as James watches.
The branch suddenly breaks off and tumbles to the ground towards James.
James jumps out of the way, but part of the branch scratches his arm.
Chip immediately turns off the roaring chainsaw. (lighter)
Their mother comes out and takes a look at James's arm.
Although it's a light scratch, she insists on treating it immediately.
She takes the medicine bag not touched for several months out. (heavier)
Meanwhile, their father helps Chip to get out of the tree.
He gingerly takes the chainsaw from Chip's outstretched arms. (lighter)
Chip climbs back down and goes in to check on James.
When he gets in, James had a big bandage over the scratch already. (heavier)
Because the scratch isn't serious, they go back out to finish the treehouse.
This time, James gets out of the way before Chip starts cutting the branches away.
By the time Chip is done, James has finished building a rope ladder.
Chip shows his parents all of the hard work he has done while up in the tree. (lighter)
James and Chip stop working and take a break from their work.
Their father brings the tray of pineapple, apples, and oranges he had just cut up for the boys. (heavier)
After the break, they tie the rope ladder to the tree and begin lifting boards.
They clean up all of the loose branches, leaves, and twigs that evening. (heavier)
James and Chip will continue their work in the morning.

Version B

James and Chip are building a treehouse in their backyard.
Although they are both teenagers, they have lots of time during the summer to do it.
They have been planning on doing this for many years, but the tree wasn't big enough until now.
James drew a plan on the chalkboard in the hallway of their house yesterday morning. (heavier)
First, they need to clear out some of the extra branches.
Chip climbs quickly up the large, oak tree that they're going to use. (lighter)
This past weekend, James and Chip had borrowed their neighbor's chainsaw.
The chainsaw is in good shape and easy to use.
As Chip climbs, James gets the chainsaw from the garage.
James passes Chip it. (heavier)
Chip begins to cut through a branch as James watches.
The branch suddenly breaks off and tumbles to the ground towards James.
James jumps out of the way, but part of the branch scratches his arm.
Chip turns off the roaring chainsaw immediately. (heavier)
Their mother comes out and takes a look at James's arm.
Although it's a light scratch, she insists on treating it immediately.
She takes out the medicine bag not touched for several months. (lighter)
Meanwhile, their father helps Chip to get out of the tree.
He takes the chainsaw from Chip's outstretched arms gingerly. (heavier)
Chip climbs back down and goes in to check on James.
When he gets in, James already had a big bandage over the scratch. (lighter)
Because the scratch isn't serious, they go back out to finish the treehouse.
This time, James gets out of the way before Chip starts cutting the branches away.
By the time Chip is done, James has finished building a rope ladder.
Chip shows all of the hard work he has done while up in the tree to his parents. (heavier)
James and Chip stop working and take a break from their work.
Their father brings the boys the tray of pineapple, apples, and oranges he had just cut up.
(lighter)
After the break, they tie the rope ladder to the tree and begin lifting boards.
That evening, they clean up all of the loose branches, leaves, and twigs. (lighter)
James and Chip will continue their work in the morning.

Appendix 2: The quiz

The quiz questions asked at the end of the study are below, along with the correct answer.

James and Chip are building a treehouse.

true

James drew plans for the treehouse weeks ago.

false

Their mother insists on treating the injury immediately.

true

James and Chip continue to work after the injury.

true

Their father brings out a bag of chips as a snack.

false