The Minimal Structure Principle and the Processing of Preposition Stranding

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1. Introduction

The purpose of this study is to investigate the role that the principles of Generative Grammar play in language processing. More specifically, we examine whether the Minimal Structure Principle (MSP) is active during the processing of Preposition-Stranding (P-Stranding) and Pied-Piped Constructions. Because the MSP prefers derivations with fewer projections, we hypothesize that the parser prefers P-Stranding Constructions if the MSP is active during language processing. To test this hypothesis, a self-paced reading task was conducted with thirty monolingual English speakers.

2. Preposition Stranding in English

In English, prepositional phrases (PPs) may be targeted by movement, resulting in all or part of the PP undergoing movement. When the entire PP moves, a Pied-Piped Construction occurs. When only the prepositional complement (P-complement) moves, leaving the preposition, a P-Stranding Construction occurs. Consider the following:

(1) a. Pre-movement:
The graduate student will present the paper at which conference
b. P-Stranding Construction:
Which conference will the graduate student present the paper at?
c. Pied-Piped Construction:
At which conference will the graduate student present the paper?

While both constructions are possible in English, P-Stranding Constructions have been claimed to be rare cross-linguistically. Merchant (1999) uses Dryer's (1997) sample of 625 languages as evidence for this: "The facts are simple and well-known: in English and the Scandinavian languages, wh-movement may strand a preposition in all the standard wh-movement environments: interrogatives, topicalization, relativization (including clefts and psuedoclefts), and comparatives. (In the continental West Germanic languages, such preposition stranding . . . is restricted to a small class of displaceable elements known as 'R-pronouns')" (p. 126). The example in (2) shows that P-Stranding is not possible in Italian, a claim that is claimed to hold in general across Romance languages. The example is (3) shows that P-Stranding is not possible in colloquial German, except for when there is movement of an R-pronoun. These examples are provided in Law (2006):

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(2) Italian
*Che$_i$ hai parlato di t$_i$?
what have-you talked about
'What did they talk about?'

(3) German
Wo$_i$/*Was$_i$ redest du von t$_i$?
what talk you from
'What are you talking about?'

Gries (2002) argues from a Corpus Linguistics perspective that P-Stranding Constructions are less common cross-linguistically because they have greater processing costs than Pied-Piped Constructions: "filler-gap constructions are known for the processing load they impose on interlocutors compared to their pied-piped counterparts, which is why they are cross-linguistically quite rare" (p. 2). Gries hypothesizes that, as a result, P-Stranding Constructions (SC) are used when processing costs are low; in all other instances, a Pied-Piped Construction (PPC) is used. He supports this hypothesis with the corpus data provided in (4):

(4) Gries's data: Distribution of constructions relative to VERB

	Transitive	Intransitive	Prep.	Phrasal-prep.	Copula	Totals
PPC	73	24	4	0	21	122
SC	38	65	14	6	56	179
Total	111	89	18	6	77	301

According to Gries, transitive sentences are more costly processing-wise than intransitive sentences, and thus Pied-Piped Constructions occur more frequently with transitive verbs.

Interestingly, P-Stranding Constructions occur more frequently than Pied-Piped Constructions overall. This is illustrated by Gries's (2002) corpus data, presented in (5):

(5) Gries's data: Analyzed data from the BNC (raw frequencies + column percentages)

	Written	Spoken	Row totals
PPC	122 (49.39%)	0 (0%)	122 (40.53%)
SC	125 (50.61%)	54 (100%)	179 (59.47%)
Column totals	247 (100%)	54 (100%)	301 (100%)

According to the data above, P-Stranding and Pied-Piped Constructions occur in written data with the same frequency; however, P-Stranding Constructions occur in 100% of spoken data, indicating that English speakers prefer P-Stranding Constructions in discourse. For researchers who argue that frequency influences processing costs, these results may be assumed to show that P-Stranding Constructions will have lower processing costs due to frequency of occurrence.

However, according to Weinberg (1999), frequency and grammatical principles work together during language processing. More specifically, Weinberg argues that economy principles and multiple Spell-Out are active during parsing. "The language faculty is extremely well designed in the sense that the same principles that govern language learning also contribute to a theory of processing" (Weinberg, 1999, p. 284).

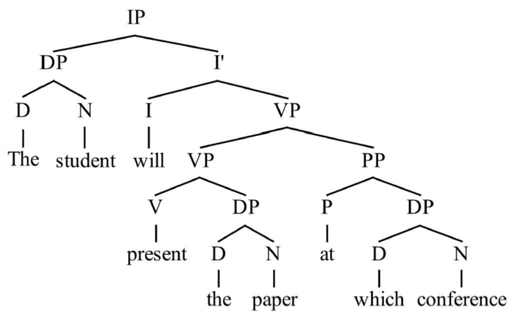
Adopting Weinberg's approach, we investigate whether the Minimal Structure Principle (MSP), a principle of economy, is active during language processing. The MSP, defined in (6), prefers derivations with fewer projectors present in its syntactic representation.

(6) Minimal Structure Principle (MSP):
"Provided that lexical requirements of relevant elements are satisfied, if two representations have the same lexical structure and serve the same function, then the representation that has fewer projections is to be chosen as the syntactic representation serving that function " (Bošković, 1997, p. 25).

If the MSP is active during language processing, P-Stranding Constructions will have lower processing costs than Pied-Piped Constructions because there are fewer projections present in their syntactic representations.

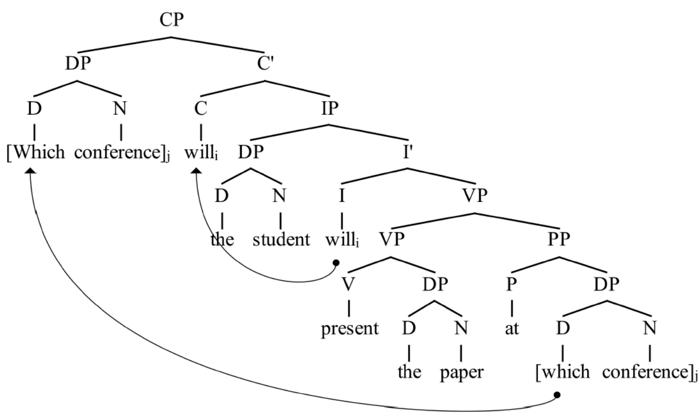
Consider the sentences from (1) again. The tree diagram for (1a), presented in (7), shows the structure for both (1b) and (1c) before movement occurs.

(7) Pre-movement structure:

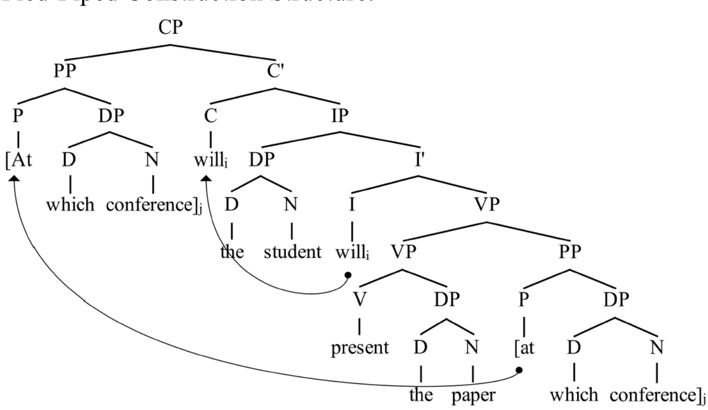


Under the COPY and DELETE approach to Movement, the moved phrase is copied and raised to [Spec, CP], leaving a copy of the phrase in its original position. The structures for this point in the derivation are shown below. In (8), the structure for (1b) is shown; in (9), the structure for (1c) is shown.

(8) P-Stranding Construction Structure:



(9) Pied-Piped Construction Structure:



At this point in the derivation, the sentence with the P-Stranding Construction has 23 projections, while the sentence with the Pied-Piped Construction has 25. Thus, the MSP should prefer P-Stranding Constructions to Pied-Piped Constructions. If this is the case, P-Stranding Constructions should be less costly processing-wise than Pied-Piped Constructions.

In order to test this prediction, we conducted a self-paced reading experiment, an on-line processing task that uses reading times to measure participants' unconscious reaction to linguistic stimuli. This study is presented in the following sections.

3. Methodology

3.1. Participants

Thirty monolingual English speakers were tested in this study. The participants were between the ages of 18 and 65 (mean age 36, age range 45), were both male and female (17 males, 13 females), and had received at least a high school diploma or equivalent. Further, there were two versions of the experiment (explained in section 3.2.1). As a result, the 30 participants were split into two groups of 15; each group participated in one version of the experiment. The participants from Experiment 1 had a mean age of 32.4 and an age range of 37; the group consisted of 9 males and 6 females. The participants from Experiment 2 had a mean age of 39.6 and an age range of 45; the group consisted of 8 males and 6 females.

3.2. Stimuli

3.2.1. Linguistic Stimuli

A self-paced reading task experiment crucially assumes that longer reading times are an indicator of greater processing costs (Marinis, 2010).

The self-paced reading task consisted of 100 total sentences. Of those sentences, 48 were target sentences and 52 were filler sentences. The target sentences were split between the two construction types: 24 sentences contained a P-Stranding Construction (P-Stranding Sentences), and 24 sentences contained a Pied-Piped Construction (Pied-Piped Sentences). All of the target sentences were in question form. The remaining 52 filler sentences did not contain either target construction and were not in question form.

All of the sentences included a sentence-final optional modifier in order to mitigate Wrap-Up Effects (Hirotani et al., 2006). In addition, no nouns or verbs were repeated in order to eliminate recency effects, and no pronouns were used in order to avoid the processing complexity of the reference of pronouns. Furthermore, no prepositional phrases were used in the experiment, other than those used as the target constructions, to prevent participants from noticing an overuse of prepositional phrases, calling attention to the experiment's purpose.

In order to counterbalance the sentences, two version of the experiment were created. The sentences in Experiment 1 that contained P-Stranding Constructions were the sentences in Experiment 2 that contained Pied-Piped Constructions, and vice-versa. For example, the sentences in (10a) are sentences from Experiment 1, while the sentences in (10b) are sentences from Experiment 2:

(10a) P-Stranding: What bar did the band perform at originally?
Pied-Piping: At what restaurant does the businessman eat every week?

(10b) P-Stranding: What restaurant does the businessman eat at every week?
Pied-Piping: At what bar did the band perform originally?

The purpose of counterbalancing the sentences was to ensure that factors other than the construction type used (semantic, lexical, length, etc.) did not influence processing costs. Further, the sentences were counterbalanced to ensure that both construction types were permissible in the sentences.

The 24 P-Stranding Sentences and 24 Pied-Piped Sentences were divided evenly amongst three non-bare wh-word complement types: *what* followed by a noun (*what*+noun), *which* followed by a noun (*which*+noun), and *whose* followed by a noun (*whose*+noun). Thus, there were eight sentences of each wh-word complement type. This was done was to investigate whether the type of wh-word undergoing movement would influence participants' processing costs. Examples of the three complement types are presented in (11) below:

(11) P-Stranding:
(i) What remark did Jack apologize for yesterday?
(ii) Which computers did the sixth graders learn to type on last year?
(iii) Whose friend did Mary go to the theatre with last night?
Pied-Piping:
(i) For what remark did Jack apologize yesterday?
(ii) On which computers did the sixth graders learn to type last year?
(iii) With whose friend did Mary go to the theatre last night?

As part of the experiment, in addition to the self-paced reading task, participants completed a comprehension question task. Half of the total sentences (50 sentences) were followed by a simple yes/no comprehension question about the content of that sentence. The purpose of this task was to ensure that participants were reading and processing the sentences presented to them.

The comprehension questions were evenly distributed between the target and filler sentences. Thus, there were 12 comprehension questions following P-Stranding Sentences, 12 comprehension questions following Pied-Piped Sentences, and 26 comprehension questions following filler sentences. Further, the comprehension questions were evenly distributed across wh-complement types: of the 12 P-Stranding and 12 Pied-Piped Sentences' comprehension questions, there were included 4 comprehension questions following the *what*+noun, *which*+noun, and *whose*+noun complement types. Last, the comprehension questions that required *yes* or *no* responses were spread evenly across the sentence types and complement types.

Further, to aid the participants in distinguishing between target sentences (in question form) and comprehension questions, the comprehension questions appeared in all capital letters. Examples are provided below:

(12) a. Filler
The couple held hands all night.
DID THE COUPLE HOLD HANDS ALL NIGHT? (Yes)
b. P-Stranding:
What walls did Aaron hang the posters on this afternoon?
DID AARON HANG A MIRROR ON THE WALL? (No)
c. Pied-Piping:
Over whose land did the neighbors fight all the time?
DID THE NEIGHBORS FIGHT OVER LAND? (Yes)

3.2.2. Non-linguistic Stimuli

The experiment was conducted on a laptop computer. The SuperLab 4.5 software presented participants with the linguistic stimuli on screen, recording their reading times and responses. The sentences were presented to participants as a whole (not divided into words or phrases); thus, a sentence's reading time was the time from the presentation of the sentence on screen to the time the participant responded. In addition to presenting stimuli and recording responses, the SuperLab 4.5 software randomized the order of the sentences for each participant. To move between sentences and answer the comprehension questions, participants used the laptop keyboard.

3.3. Procedure

Participants were seated at a table, in front of a laptop computer, in a quiet environment. Before beginning the experiment, participants were given a pre-trial test. At the start of the pre-trial, participants were presented with instructions both verbally and on screen. The pre-trial experiment consisted of ten sentences to read and five comprehension questions. The setup of the pre-trial was the same as the full experiment. In addition, participants were allowed to ask questions during this time.

Once participants were comfortable with the setup of the experiment, they began the full trial. At this time, the instructions appeared again on screen. To start, the participant pressed the space bar, causing a sentence to appear on screen. Once the participant read the sentence, they pressed the space bar to be presented with another sentence. After half of the sentences, a comprehension question would appear. To answer the question, participants pressed the Y key for *yes* or the N key for *no*. After their response, a new sentence to read would appear. The participants continued to read sentences and answer questions until the sentence *This is the end of the experiment* appeared on screen.

At the end of the experiment, the SuperLab 4.5 software saved the participants' reading times and responses for future analysis. The results are presented in the following section.

4. Results

4.1. Comprehension Question Task

For the comprehension question task, the highest score received was 100%, and the lowest score received was 86%; thus, the score range was 14%. The mean score was 96.33%, and the mode score was 100%.

Comparing the comprehension question task scores for Experiment 1 and 2 separately, the scores are similar to the overall scores. The mean score for Experiment 1 was 96.26%, while the mean score for Experiment 2 was 96.4%. The mode score for both Experiment 1 and 2 was 100%. The score range for Experiment 1 was 14%, while the score range for Experiment 2 was 12%.

4.2. Self Paced Reading Task

The results for the self-paced reading task (henceforth, *SPRT*) were analyzed in several ways. First, reading times for full sentences were compared. Then, reading times per character were compared; this was done to account for length differences (Ferreira & Clifton, 1986). Also, the reading times for each wh-complement type were compared separately, both per sentence and per character. For all comparisons mentioned above, a paired samples t-test was used to measure statistical significance.

Reading times that were greater than three standard deviations from the mean reading time for that sentence were removed from the data; further, reading times for sentences with incorrect comprehension question responses were removed.

4.2.1. Reading Times per Sentence Type: Whole Sentence

The mean reading times of the P-Stranding Sentences versus the Pied-Piped Sentences for All Experiments were compared. A paired samples t-test did not reveal a significant difference in these reading times. Further, the mean reading times for the P-Stranding Sentences and Pied-Piped Sentences in both Experiment 1 and Experiment 2 were compared. Again, this difference was not statistically significant. The mean reading times are presented in (13).

(13) Mean Reading Times per Sentence (in ms.)

	P-Stranding Sentences	Pied-Piped Sentences
All Experiments	4024. 06	4079.39
Experiment 1	3962.31	4221.18
Experiment 2	4085.80	3937.60

4.2.2. Reading Times per Sentence Type and Complement Type: Whole Sentence

The results were analyzed separately for each of the three complement types: *what*+noun, *which*+noun, and *whose*+noun.

For wh-complement *what*+noun, the mean reading times for P-Stranding Sentences and Pied-Piped Sentences were compared for All Experiments, as well as Experiments 1 and 2 separately.

The results are presented in (14). For each of these comparisons, a paired samples t-test did not reveal a significant difference in reading times.

(14) Mean Reading Times per Sentence (in ms.) – *what*+noun

	P-Stranding Sentences	Pied-Piped Sentences
All Experiments	3908.19	3966.21
Experiment 1	3946.28	3955.18
Experiment 2	3870.10	3977.25

Next, results for wh-complement *which*+noun were analyzed. As with *what*+noun, the mean reading times for P-Stranding Sentences and Pied-Piped Sentences were compared for All Experiments, as well as Experiments 1 and 2 separately. The results are presented in (15). For each of these comparisons, a paired samples t-test did not reveal a significant difference in reading times.

(15) Mean Reading Times per Sentence (in ms.) – *which*+noun

	P-Stranding Sentences	Pied-Piped Sentences
All Experiments	4117.45	4094.30
Experiment 1	4029.49	4392.76
Experiment 2	4159.11	3840.13

Last, results for wh-complement *whose*+noun were analyzed. The mean reading times for P-Stranding Sentences and Pied-Piped Sentences were compared for All Experiments, Experiment 1, and Experiment 2. The results are shown in (16). Again, for each of these comparisons, a paired samples t-test did not reveal a significant difference in reading times.

(16) Mean Reading Times per Sentence (in ms.) – *whose*+noun

	P-Stranding Sentences	Pied-Piped Sentences
All Experiments	3998.81	4007.92
Experiment 1	3725.55	4017.50
Experiment 2	4253.85	3998.98

4.2.3. Reading Times per Sentence Type: Rate per Character

Next, to control for length differences, reading times for each sentence were divided by the number of characters present in that sentence. Then, as was done for the full sentence reading times, the mean reading times of the P-Stranding Sentences and Pied-Piped Sentences for All Experiments, Experiments 1, and Experiments 2 were compared. Again, the results were consistent with the comparisons above: paired samples t-tests did not reveal significant differences in these reading times. The mean reading times per character are presented in (17).

(17) Mean Reading Times per Character (in ms.)

	P-Stranding Sentences	Pied-Piped Sentences
All Experiments	76.96	76.83
Experiment 1	77.82	76.53
Experiment 2	76.10	77.12

4.2.4. Reading Times per Sentence Type and Complement Type: Rate per Character

The reading times were divided by characters for each of the three complement types: *what*+noun, *which*+noun, and *whose*+noun.

For wh-complement *what*+noun, the mean reading times for P-Stranding Sentences and Pied-Piped Sentences were compared for All Experiments, Experiment 1, and Experiment 2. The results are presented in (18). For each of these comparisons, a paired samples t-test did not reveal a significant difference in reading times.

(18) Mean Reading Times per Sentence (in ms.) – *what*+noun

	P-Stranding Sentences	Pied-Piped Sentences
All Experiments	76.96	76.83
Experiment 1	77.82	76.53
Experiment 2	76.10	77.12

Next, results for wh-complement *which*+noun were compared for All Experiments, as well as Experiments 1 and 2 separately. The results are presented in (19). For All Experiments and Experiment 1, a paired samples t-test did not reveal a significant difference in reading times. However, for Experiment 2, a paired samples t-test revealed a significant difference between the mean reading times of P-Stranding and Pied-Piped Sentences per character (M = -8.48, SD = 14.98), t(14) = -2.19, p = .046.

(19) Mean Reading Times per Sentence (in ms.) – *which*+noun

	P-Stranding Sentences	Pied-Piped Sentences
All Experiments	75.35	74.92
Experiment 1	70.29	81.54
Experiment 2	76.77	68.29

Lastly, results for wh-complement *whose*+noun were analyzed. The mean reading times for P-Stranding Sentences and Pied-Piped Sentences were compared for All Experiments, Experiment 1, and Experiment 2. The results are shown in (20). For each of these comparisons, a paired samples t-test did not reveal a significant difference in reading times.

(20) Mean Reading Times per Sentence (in ms.) – *whose*+noun

	P-Stranding Sentences	Pied-Piped Sentences
All Experiments	77.72	79.02
Experiment 1	75.15	81.05
Experiment 2	80.28	77.12

4.2.5. Summary of Results

As previously mentioned, longer reading times imply greater processing difficulty. In nearly all comparisons made above, P-Stranding and Pied-Piped Sentences had similar reading times. In one instance (reading times per character with wh-complement *which*+noun), the Pied-Piped Sentences had significantly shorter reading times than the P-Stranding Sentences. This would suggest that there may be an influence of the specificity of the nominal complement on the processing costs associated with movement.

However, because this difference occurred only for Experiment 2, not Experiment 1 or All Experiments, it cannot be concluded that it is the result of the construction type present. Therefore, it can be concluded that P-Stranding and Pied-Piped Sentences in general have similar processing costs.

5. Discussion

Because P-Stranding and Pied-Piped Sentences were found to have similar processing costs, this does not support the claim that the MSP is active during language processing. We are faced with more intriguing questions: Why do P-Stranding and Pied-Piped Constructions have similar processing costs? Does specificity play a role in determining processing complexity? What role does the mode of input (reading versus hearing) play in the processing of these constructions?

These questions suggest several lines of inquiry for future research. Examining P-Stranding and Pied-Piped Constructions in transitive and non-transitive sentences is of interest because of the predictions of Gries's (2002) hypothesis stated above. Further, utilizing an eye-tracker to pinpoint precise gaze fixations will help us understand what is contributing to increased processing costs, and if this is related to the construction type used. Additionally, conducting the study utilizing a listening-based task may provide different results, since P-Stranding Constructions are more frequently found in spoken discourse.

In conclusion, through further experimentation, we hope to elucidate the multiple factors that play a crucial role in the processing of P-Stranding and Pied-Piped Constructions. If we assume that the structural difference between P-Stranding and Pied-Piped Constructions is not one of how much material is moved, but rather, at which link in the chain of movement the deletion of material takes place (see Nunes 2004 for discussion), then further investigation utilizing eye-tracking methodology may help us to discover differential gaze measurements on the head and tail of the chain of movement.

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