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Original Article

QJEP

Quarterly Journal of Experimental Psychology
2020, Vol. 73(5) 781–798
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DOI: 10.1177/1747021820903461
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Processing gapping: Parallelism and grammatical constraints

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Abstract

This study aims to test two hypotheses about the online processing of Gapping: whether the parser inserts an ellipsis site in an incremental fashion in certain coordinated structures (the Incremental Ellipsis Hypothesis), or whether ellipsis is a late and dispreferred option (the Ellipsis as a Last Resort Hypothesis). We employ two offline acceptability rating experiments and a sentence fragment completion experiment to investigate to what extent the distribution of Gapping is controlled by grammatical and extra-grammatical constraints. Furthermore, an eye-tracking while reading experiment demonstrated that the parser inserts an ellipsis site incrementally but only when grammatical and extra-grammatical constraints allow for the insertion of the ellipsis site. This study shows that incremental building of the Gapping structure follows from the parser's general preference to keep the structure of the two conjuncts maximally parallel in a coordination structure as well as from grammatical restrictions on the distribution of Gapping such as the Coordination Constraint.

Keywords

Gapping; ellipsis; parallelism; grammatical constraint; coordination

Received: 7 October 2018; revised: 16 October 2019; accepted: 24 November 2019

Introduction

Ellipsis is a pervasive process in human language. To avoid redundancies in sentences, some portion of the sentence can be elided (Merchant, 2001). For example, in the Gapping construction in (1), the redundant verb *hid* is omitted (Chaves, 2005; Jackendoff, 1971; Johnson, 1994, 2006; Lobeck, 2007; Neijt, 1979; Nerbonne, Iida, & Ladusaw, 1989; Postal, 2004; Yoshida, Wang, & Potter, 2012).[1,2]

(1) The guitarist hid behind the curtain suddenly, and the singer ~~hid~~ behind the stage.

Ellipsis constructions like (1) raise a unique challenge to incremental parsing. Namely, the parser may not be able to recognise the ellipsis site incrementally, because a string that is compatible with an ellipsis structure is compatible with a non-ellipsis structure as well, and most of the time the decisive evidence for ellipsis appears at a position later than the ellipsis site. Thus, in an example of Gapping as in (2), the string *the singer behind the stage* is compatible with a Gapping structure in which the verb is elided, and a non-ellipsis structure where the prepositional phrase (PP) *[$_{PP}$ behind the stage]* modifies the noun phrase (NP) *[$_{NP}$ the singer]*.

(2) The guitarist hid behind the curtain suddenly, and the singer behind the stage . . .

a . . . and [$_{IP}$ the singer [$_{VP}$ hid [PP behind the stage]]].
b . . . and [$_{NP}$ the singer [$_{PP}$ behind the stage]] . . .

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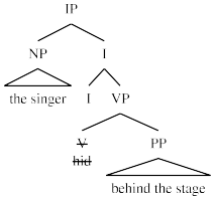
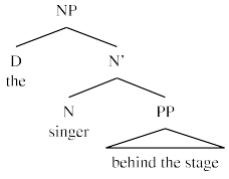
This means that an aspect of the processing of ellipsis constructions like Gapping involves ambiguity resolution. The challenge for incrementality lies in this particular aspect of the processing of ellipsis constructions.

The example in (2) illustrates this challenge. In this and many other cases, whether or not the sentence involves ellipsis becomes clear at a point later than where the actual ellipsis site is located. For example, in (2), if there is a verb after the PP, then the PP must be analysed as the modifier of the NP ($[_{IP}\ [_{NP}$ *the singer* $[_{PP}$ *behind the stage]]* $[_{VP}$ *hid]]*) as in (3b), and it becomes clear that ellipsis is not involved. However, if the sentence ends with the PP, then there must be an omitted verb; that is, the Gapping structure in (3a) should be built ($[_{IP}\ [_{NP}$ *the singer]* $[_{VP}$ *hid* $[_{PP}$ *behind the stage]]]*). An example like (2), therefore, suggests that the parser can recognise ellipsis when it is confirmed that the verb does not appear after the potential ellipsis site.

(3) a.



b.



An additional factor is that the parser obeys a local attachment bias with a preference for the structure which contains fewer nodes (Frazier, 1979; Frazier & Rayner, 1982; Gibson, 1998; Gibson & Pearlmutter, 2000; Phillips, 1995; Phillips & Gibson, 1997). Thus in (2), the parser should prefer attaching the PP *behind the stage* to the NP rather than the VP (verb phrase) with the elided verb, because the NP-attachment structure avoids postulating the intervening VP structure and the insertion of an additional node within the VP. Thus, the NP-attachment structure is a temporarily more local and simpler structure containing fewer nodes.[3] Taken together, these facts suggest that in the processing of sentences like (2), the ellipsis structure is not the structure that the parser would prefer. Thus, it is plausible that the ellipsis site is not posited in an incremental manner by the parser; that is, ellipsis insertion is a last resort and ellipsis is postulated only at a point when it becomes clear that there are no other options. We call this the Ellipsis as a Last Resort Hypothesis.

Even though it is plausible to think that the insertion of an ellipsis site is the parser's last resort, there are, at the same time, reasons to believe that it could be the parser's first resort. Ellipsis structures, such as Gapping, are often observed in coordination contexts like in (2). It has long been known that the reader strongly prefers for the conjuncts to have parallel structures when process- ing coordinated sentences (Carlson, 2001; Frazier et al., 1984; Frazier, Munn, & Clifton, 2000; Knoeferle, 2014; Knoeferle & Crocker, 2009; Poirier et al., 2010; Sturt, Keller, & Dubey, 2010). Below we illustrate the effect of parallelism in coordination (Frazier et al., 2000).

(4) a. Hilda noticed a strange man and a tall woman when she entered the house.
b. Hilda notice a man and a tall woman when she entered the house.

In these examples, both (4a) and (4b) are perfectly acceptable, and no grammatical rules are violated. However, Frazier et al. (2000) found that the noun phrase *a tall woman* is read faster in (4a) than in (4b); that is, the parser prefers the internal structure of the two conjuncts to be parallel. Because these sentences are grammatical either way, this parallelism preference is an extra-grammatical constraint on the parser when it builds the structure of the coordinated sentence online.

In an example like (2), comparing the Gapping structure and the NP-attachment structure, it is obvious that the Gapping structure is more parallel to the structure of the first conjunct than the NP-attachment structure. In the first conjunct, the subject NP does not have any PP modifier, and the first conjunct has the structure $[_{IP}$ NP $[_{VP}$ V PP]]. Thus, if the parser prefers for the two conjuncts to be maximally parallel, then the Gapping structure, an ellipsis structure, is one way to satisfy this parallelism preference.

Furthermore, note that copying the elements in the antecedent to the ellipsis site might be sufficient to create structural parallelism according to some mechanisms of ellipsis. Frazier and Clifton (2001, 2005) posit that copying information of the antecedent to the ellipsis site in the second conjunct involves a cost-free mechanism (Martin & McElree, 2008, suggest a different but also cost-free mechanism). These kinds of cost-free mechanisms impose less effort than building a new syntactic tree in the ellipsis site. Thus, it is plausible to think that the parser might insert a gap at an early stage. We call this the Incremental Ellipsis Hypothesis.

This project finds that the parser indeed inserts an ellipsis site in an incremental fashion (supporting the Incremental Ellipsis Hypothesis) in certain coordinated structures. Examining the offline and online processing of sentences that can potentially involve Gapping, like (2), we show that the parser prefers the Gapping structure over the NP-attachment structure. When there is a verb following the last PP in (2), the verb gives rise to a surprise effect because the parser is forced to reanalyze the structure from Gapping to the NP-attachment structure. Investigating the processing of the Gapping structure in detail, we show that this preference for the Gapping structure follows from the parser's general preference to keep the structure of the two conjuncts maximally parallel in a coordination structure (an extra-grammatical

constraint), as well as from grammatical restrictions on the distribution of Gapping.

Background

Gapping

The Gapping construction is usually analysed as a structure in which the verb head of the VP in the second conjunct is missing, and two constituents (the subject and an adjunct PP or the subject and the object) are left intact (Chaves, 2005; Jackendoff, 1971; Johnson, 1994, 2006; Lobeck, 2007; Neijt, 1979; Nerbonne et al., 1989; Nerbonne & Mullen, 2000; Postal, 2004; Yoshida et al., 2012). In terms of the component parts in a Gapping construction, we follow the following conventions. As illustrated in (5), the second clause involves the ellipsis and we call it the *gapped clause*. The elements in the first clause serve as the antecedent of the gapped clause, and we call the first clause the *antecedent clause*. In addition, we call the elements that remain in the gapped clause (*the singer* and *behind the stage*) *remnants* (Reinhart, 1987; Yoshida et al., 2012).

(5) The guitarist hid behind the curtain and the singer ~~hid~~ behind the stage
Remnant *Gap* *Remnant*
Antecedent clause *Gapped clause*

In the literature, it has been observed that there are several properties that distinguish Gapping from other ellipsis constructions (Johnson, 1994, 2000, 2004, 2006, 2009). The property that is most relevant to our study is that Gapping is available only with a certain class of connectives. Specifically, the gapped clause and the antecedent clause are not allowed to be connected by subordinators such as *whereas, that, because*, and *although* but only selectively with coordinators such as *and, or*, and *but*, as shown in the contrast between (6a) and (6b). This restriction is referred to as the Coordination Constraint (Jackendoff, 1971; Johnson, 1996, 2004; Kennedy, 2001; Neijt, 1979; Ross, 1967).

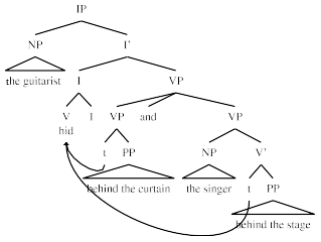
(6) a. The guitarist hid behind the curtain, and the singer hid behind the stage.
b. *The guitarist hid behind the curtain, whereas the singer hid behind the stage.

One of the dominant analyses of Gapping attributes the Coordination Constraint to a general property of coordination (Johnson, 1994, 2006). As has long been known, coordinated structures impose a special restriction on extractions, the so-called Across-the-Board movement constraint (Ross, 1967; Williams, 1978): when an element is extracted from the coordinated structure, the extraction must be from all the conjuncts. Thus, for example, in (7), when a wh-phrase is extracted from the coordinated VPs, the wh-phrase must be extracted from both the first and second conjuncts (7a). When the phrase is extracted merely from a single conjunct (7b), the example is not acceptable.

(7) a. Who did John praise and scold ?
b. *Who did John praise and scold Mary?

Under Johnson's (2004) analysis of Gapping, it is assumed that the verb is extracted from a coordination structure, and thus the verb must be extracted from both conjuncts, as illustrated in the simplified structure in (8) for example (6a).

(8)



If the gap in a Gapping construction is produced by the movement of the verb as in (8), the Coordination Constraint follows straightforwardly. If the verb can move out of the second clause only in a coordination context, but not in a subordination context, then the gap is possible only in the coordination context. In this approach to Gapping, the Coordination Constraint is understood as a grammatical constraint on the distribution of Gapping.[4]

On the other hand, there may also be a plausible processing-based account of the distribution of Gapping. It is known that in a coordination context, the parser prefers to have various types of parallelism among the conjuncts (Carlson, 2001; Frazier et al., 1984, 2000; Knoeferle, 2014; Knoeferle & Crocker, 2009; Poirier et al., 2010). Thus, a coordination structure is processed more easily when the conjuncts exhibit parallelism, but when the conjuncts are not parallel, the coordination structure induces some processing cost. The observation that Gapping appears in coordination is compatible with this parallelism preference. As we can see in the structure in (8), within the Gapping structure, the structure of the conjuncts is maximally parallel. Thus, it could be that Gapping is observed only in coordination as a consequence of the parser's preference to favour structural parallelism in coordination structures.

This explanation of the distribution of Gapping, however, poses some potential problems. Sturt et al. (2010) provide reading-time evidence that subordination structures also show the parallelism effect. For example, in a sentence that involves subordination, the parser prefers to have parallelism between NPs in the matrix clause and the subordinated clause, as illustrated in (9). Both the subject NP in the matrix clause (*a demanding boss*) and

the subject NP in the subordinate clause (*a lazy worker*) have the same structure, that is, [$_{NP}$ Article [Adjective [Noun]], and they are structurally parallel. When one of the NPs does not contain the adjective (e.g., *a worker*), these two NPs are not structurally parallel. The parser prefers the structure in which these two NPs exhibit structural parallelism over the one where they are not structurally parallel.

(9) A demanding boss said that a lazy worker did not do the job properly.

If the parser prefers the Gapping structure as a way to maximise parallelism among the two clauses, then we would expect that Gapping should be able to appear in certain subordination contexts as long as parallelism between the clauses occurs. However, as we have seen, Gapping does not seem to appear in the subordination context.

These considerations lead us to the following question. To what extent is the distribution of Gapping controlled by parallelism versus the Coordination Constraint? Is the fact that Gapping is observed in coordination contexts due to the parallelism preference or due to the grammatical Coordination Constraint (Jackendoff, 1971, among others), or both factors? We explore how a clearly extra-grammatical feature such as the parser's preference for parallelism affects processing versus a grammatical constraint. Specifically, are readers tempted to violate grammatical constraints to make the two conjuncts maximally parallel, or is Gapping only considered as an option when the syntactic constraints permit?

Experiment 1

Although the Coordination Constraint has been observed in the syntax literature for some time (Jackendoff, 1971; Johnson, 1994, 2000, 2006; Kennedy, 2001; Neijt, 1979; Ross, 1967), there has not been a systematic test of the constraints on Gapping or the relation between parallelism and Gapping. To empirically test the relation between parallelism and the Coordination Constraint, we conducted two offline acceptability rating experiments. These experiments were designed to examine what structure is preferred by the parser offline when confronted with an ambiguous string like *the singer behind the stage*. We specifically explore whether the parser prefers or allows Gapping when parallelism is maximally satisfied, and whether Gapping is considered only when the grammatical constraint allows. If readers violate the grammatical constraint to maximise parallelism, we expect Gapping to be licenced wherever parallelism is observed. On the contrary, if readers choose Gapping only when grammatical constraints are met, we expect Gapping only in the coordination context, even when parallelism between the connected clauses is observed.

Experiment 1a: an acceptability judgement task with the first conjunct only. The first acceptability judgement task was conducted on only the first conjunct of the sentences as independent sentences, to examine the acceptability of the adverb at the end of the first clauses in preparation for Experiment 1b. We needed the adverb to avoid an additional temporary ambiguity, in which the most minimal attachment of the conjuncts is as a coordination of NPs. Specifically, we needed to avoid structures like the following: *[The guitarist hid behind [$_{NP}$ the curtain, and the singer behind the stage]]*. The comma after *the curtain* biases against this structure, but an adverb rules it out completely. Thus, we only anticipate either the Gapping analysis with the hidden verb inside VP, or a simple NP with a PP modifier.

The purpose of this particular experiment was to examine how natural the first conjunct is in isolation, with an adverb being either in a medial position before the first verb, or in a final position at the end of the clause. It is possible that clause-final adverbs are difficult to parse or less natural than medial ones. Thus, we conducted a rating study of the initial clause of these sentences, including the adverb, to see whether there are any important differences in their acceptability. Note that the term "Structural Parallelism" in this experiment refers to whether the clauses are parallel to second clauses used in Experiment 1b and following experiments. The Structural Parallelism of the two clauses (Parallel vs. Non-parallel: Contrast Coding 0.5 vs. −0.5) and Adverb Placement (Medial vs. Final: Contrast Coding 0.5 vs. −0.5) were manipulated as independent factors in a 2×2 factorial design. A sample set of stimuli is listed in Table 1 (the full set of stimuli is in the Supplemental Appendix). The prediction is that there should be no differences between the Adverb Placement conditions (Medial vs. Final), or if there are any, that both versions are still reasonably acceptable.

Participants, materials, and design. Participants were 34 native speakers of English from the Northwestern University community with no history of language disorders. All participants provided informed consent and earned credit in one of the introductory linguistics classes. No participants were excluded.

Critical items consisting of 32 sets of sentences were arranged in a 2×2 within-subjects factorial design, in which Adverb Placement (Medial vs. Final) and the Structural Parallelism (Parallel vs. Non-parallel) were manipulated as independent factors. As mentioned, the Parallel and Non-parallel first clauses here are not parallel to anything without a following second conjunct, but these are the versions of the first conjuncts that appear in the Parallel or Non-parallel conditions elsewhere in this article. Therefore, we did not expect to find any significant differences between ratings due to this factor. Items

were distributed in four lists using a Latin square design, and in each list the items were pseudo-randomised to avoid identical experimental items appearing adjacent to each other. The experimental items were mixed with 36 filler sentences. The fillers included grammatical and ungrammatical sentences with different wh-phrases, a manipulation which was irrelevant to the current experiment.

Table 1. Sample stimuli for Experiment 1a.

Condition	Sample stimuli
A: Parallel/Adv-Final	The guitarist hid behind the curtain suddenly.
B: Parallel/Adv-Medial	The guitarist suddenly hid behind the curtain.
C: Non-parallel/ Adv-Final	The guitarist noticed his recording agent suddenly.
D: Non-parallel/Adv-Medial	The guitarist suddenly noticed his recording agent.

Procedure. Stimuli were presented on a desktop PC using Linger software (Rohde, 2003). In this experiment, participants rated the naturalness of each sentence on a scale of 1 (*very unnatural*) to 7 (*very natural*). At the beginning of the experiment, it was explained to the participants that there are no right or wrong answers. The experiment took approximately 30 min to complete.

Analysis. Obtained data were analysed using linear mixed effect regression models (Baayen, 2008; Baayen et al., 2008; Bates et al., 2014; Jaeger, 2008), using R software (version 3.2.3) with the lme4 package. Each model included sum-coded fixed effects of Parallelism (whether the clauses are parallel or not in other experiments) and Adverb Placement (Medial vs. Final), and their interactions, as well as random intercepts for participants and items and the maximum number of random slopes given that the data were justified (Barr et al., 2013). We first used the maximal random effects structure and in situations where the maximal model did not successfully converge, the random effect with the least variance was taken out in a stepwise fashion.

Results. A summary of the statistical analysis is shown in Table 2[5] and mean acceptability scores are shown in Figure 1.

The linear mixed effect model revealed a main effect of Adverb Placement, such that sentences with medial adverbs were judged to be slightly more natural than sentences with final adverbs. No other main effect or an interaction was revealed. The average ratings for the grammatical filler sentences were 5.68 (*SE* = 0.11),

Table 2. Statistical analysis for Experiment 1a.

	Estimate	*SE*	*t* value	*p* value
(Intercept)	5.93	0.15	39.44	
Parallelism	−0.12	0.09	−1.38	.18
Adverb Placement	−0.57	−3.62	−3.62	<.001***
Parallelism × Adverb Placement	0.14	0.80	0.80	.43

***$p < .001$.

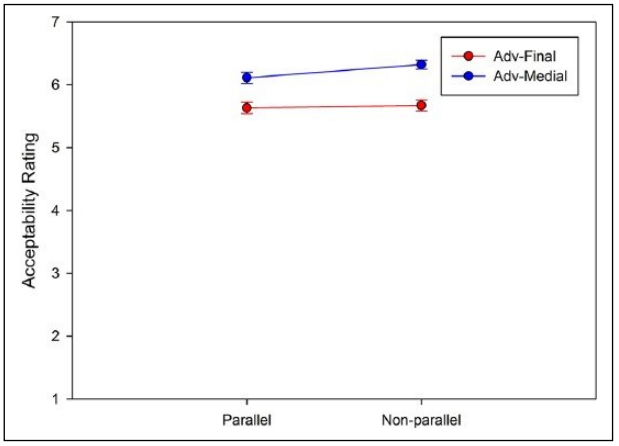


Figure 1. Mean acceptability scores for Experiment 1a.

whereas the ungrammatical filler sentences were 2.55 (*SE* = 0.11). Based on the average ratings for the filler sentences, we can argue that the average ratings of the first conjuncts of the experimental items were relatively high regardless of the position of the adverb. This shows that there are no intrinsic problems with the inclusion of the adverbs, which are crucial in avoiding the temporary NP-coordination parse.

Experiment 1b: gapping acceptability judgement experiment. In this experiment, we examined the acceptability of sentences with verb omission, the gap, in the second clause. The Connective Types (Coordinate: *and* vs. Subordinate: *whereas*: Contrast Coding 0.5 vs. −0.5) and Structural Parallelism between the two clauses (Parallel vs. Non-parallel: Contrast Coding 0.5 vs. −0.5) were manipulated as independent factors in a 2×2 factorial design. A sample set of stimuli is listed in Table 3.

If Gapping is the result of the parser's preference for structural parallelism and is not restricted by the Coordination Constraint, then we would expect gapped clauses to be more acceptable when the connected clauses respect parallelism, regardless of the connective types. Thus, we would expect a main effect of Parallelism. However, if Gapping respects the Coordination Constraint, we expect that the gapped clause is acceptable only when

the clauses are connected by the coordinating connective, *and*. Thus, in this case, we expect a strong main effect of Connective. Finally, if Gapping is the result of the interaction between the parallelism preference and the Coordination Constraint, we expect an interaction between Connective and Parallelism. Note that if readers constructed a Gapping structure in the Non-parallel conditions, then the second clause should be read as *the singer noticed his recording agent behind the stage*.

Participants, materials, and design. Participants were 38 native speakers of English from the Northwestern University community with no history of language disorders. All participants provided informed consent and earned credit in one of the introductory linguistics classes. No participants were excluded.

Critical items consisting of 32 sentence sets were distributed in four lists using a Latin square design, and in each list the items were pseudo-randomised to avoid identical experimental items appearing adjacent to each other. The experimental items were mixed with 36 filler sentences. The fillers included grammatical and ungrammatical sentences with different wh-phrases, a manipulation which was irrelevant to the current experiment.

Table 3. Sample stimuli for Experiment 1b.

Condition	Sample stimuli
A: Parallel/ Coordinate	The guitarist hid behind the curtain suddenly, and the singer behind the stage.
B: Parallel/ Subordinate	The guitarist hid behind the curtain suddenly, whereas the singer behind the stage.
C: Non-parallel/ Coordinate	The guitarist noticed his recording agent suddenly, and the singer behind the stage.
D: Non-parallel/ Subordinate	The guitarist noticed his recording agent suddenly, whereas the singer behind the stage.

Procedure. The same procedure as that of the previous acceptability judgement experiment was used.

Analysis. Data analysis was carried out using R software (version 3.2.3) with the lme4 package for estimating the linear mixed effect regression (Baayen, 2008; Baayen et al., 2008; Bates et al., 2014; Jaeger, 2008). Each model included sum-coded fixed effects of Parallelism (whether the structure is parallel or not) and Connective (whether the clauses are connected with the coordinating conjunction *and* or the subordinating conjunction *whereas*). We first used the maximal random effects structure and in situations where the maximal model did not successfully converge, the random effect with the least variance was taken out in a stepwise fashion.

Results. A summary of the statistical analysis is shown in Table 4[6] and mean acceptability scores shown in Figure 2.

A linear mixed effect model revealed a significant main effect of Parallelism such that Parallel conditions were rated higher than the Non-parallel conditions. A significant main effect of Connective Type was also observed such that coordinated structures were rated higher than subordinated structures. A significant interaction between these two factors was also observed such that the Parallel/Coordinate condition was judged significantly better than the Parallel/Subordinate condition, but there were no differences in the Non-parallel conditions. Further subset analysis showed that the Coordinate conditions were judged significantly better than the Subordinate conditions within the Parallel condition ($\beta = 0.67$, $SE = 0.15$, $t = 4.36$, $p < .001$), but no such difference was found within the Non-parallel conditions ($\beta = 0.12$, $SE = 0.08$, $t = 1.43$, $p > 0.1$).

As for the fillers, the average ratings for the grammatical sentences were 5.69 ($SE = 0.12$) and 2.87 ($SE = 0.11$) for ungrammatical sentences. Compared with the ratings for these filler sentences, the acceptability ratings are relatively low for all experimental sentences (the mean of the Parallel/Coordinate condition, the best one, was 3.57 [0.10]). Given that Gapping requires a contrastive interpretation, when encountering a Gapping construction, readers need to construct an appropriate context where Gapping remnants are contrasted against the correlates. These results show that readers required some effort in understanding sentences with a gap when encountering the Gapping constructions without context.

Table 4. Statistical analysis for Experiment 1b.

	Estimate	*SE*	*t* value	*p* value
(Intercept)	2.74	0.15	18.63	
Parallelism	1.00	0.14	7.00	<.001***
Connective Type	0.39	0.10	3.92	<.001***
Parallelism × Connective Type	0.54	0.17	3.23	<.01**

**$p < .01$, ***$p < .001$.

Discussion. Our results showed that readers accept the Gapping structure primarily in coordination contexts, as revealed by higher acceptability ratings for the coordinated conditions in Experiment 1b. This fits the Coordination Constraint, suggesting that Gapping is truly grammatical only in coordination structures. However, ratings for both Parallel conditions were also higher than Non-parallel conditions even with subordinating conjunctions, showing that there is a role for a parallelism preference as well.

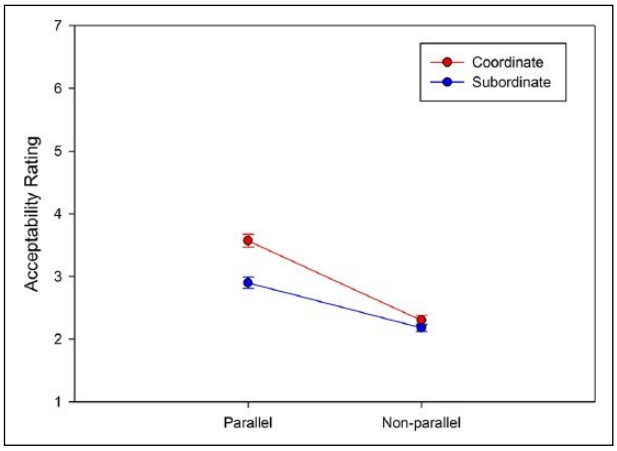


Figure 2. Mean acceptability scores for Experiment 1b.

The sentences in Experiment 1a with only the first conjunct showed similar ratings regardless of the adverbial position, although sentences with adverbs located in medial position were judged to be slightly better than those in final position. This shows that the sentences are intrinsically well-formed.

Overall, the results of Experiment 1b reveal that Parallel conditions were judged to be better than the Non-parallel conditions, and that Coordinate conditions were judged to be better than the Subordinate conditions in the Parallel conditions, but not in Non-parallel conditions. Nevertheless, it seems that Gapping may also be possible in subordinated contexts when Parallelism is present. This provides evidence that Gapping is possible and employed to some extent as a consequence of Parallelism (extra-grammatical constraints) as well as mostly bound by grammatical constraints.

Experiment 2: sentence fragment completion experiment

The second acceptability rating experiment, Experiment 1b, revealed that readers prefer the Gapping structure most in the grammatically licit condition (i.e., with coordination), following the Coordination Constraint, but also rated Gapping higher in conditions with increased parallelism. In this experiment, we further explore through a sentence fragment completion experiment to what extent Gapping is allowed or preferred over non-elliptical continuation when confronted with a temporarily ambiguous string like *the singer behind the stage*. The stimuli used in Experiment 1b were presented as possible sentence fragments in this experiment. Participants were instructed to insert any word after the second clause/sentence fragment to complete the sentence. Crucially, they were also instructed not to insert any words if they felt they had no need to do so.

In this experiment, we pay special attention to the rate of verb insertion. If the participants analyse the NP-PP sequence as involving a gap, then the second conjunct is understood as a complete clause. In this case, the participant would not insert any words after the NP-PP sequence, especially verbs. On the contrary, if the NP-PP sequence is analysed as the NP-attachment structure, then a verb is necessary in the second conjunct, and thus the participants should want to insert a verb after the NP-PP sequence. This way, we can assess where the Gapping structure is preferred or allowed by examining the rate of verb insertion.

Participants, materials, and design. Participants were 38 native speakers of English from the Northwestern University community with no history of language disorders. All participants provided informed consent and earned credit in one of the introductory linguistics classes. No participants were excluded.

Critical items consisting of 32 sets of sentences were arranged in a 2×2 within-subjects factorial design, in which Parallelism (Parallel vs. Non-parallel) and Connective Types (Coordinate vs. Subordinate) were manipulated as independent factors. The same stimuli and format were used as in Experiment 1b (refer to Table 3). Items were distributed in four lists using a Latin square design, and in each list the items were pseudo-randomised to avoid identical experimental items appearing adjacent to each other. The experimental items were mixed with 16 filler sentences of similar length. Other fillers ranged from complete simple sentences (e.g., *Darsy was tall*) to incomplete sentences (e.g., *Wendy ponders which statue of the birds will be*) which obligatorily required the insertion of words.

Procedure. Stimuli were presented on a desktop PC using Linger software (Rohde, 2003). Participants were asked to complete the sentences by typing in words on the line following each sentence. They were assured that there was no need to write anything when they believed the sentence to be complete. The task took approximately 20 min to complete.

Analysis. The sentences were coded based on whether the continuation contained a verb or not. Obtained data were analysed using a logistic regression model (Baayen, 2008; Baayen et al., 2008; Bates et al., 2014; Jaeger, 2008), using R software (version 3.2.3) with the lme4 package. Each model contained sum-coded fixed effects of Parallelism (whether the structure is parallel or not), Connective (whether the conjuncts are connected with the coordinate *and* or the subordinate *whereas*), and their interactions, as well as random intercepts for participants and items and the maximum number of random slopes given that the data were justified (Barr et al., 2013). We first used the maximal random effects structure and in situations where the maximal model did not successfully converge, the random effect with the least variance was taken out in a stepwise fashion.

Results. Mean rates of fragment completions containing verbs are shown in Figure 3, and a summary of model results for Experiment 2 is in Table 5.

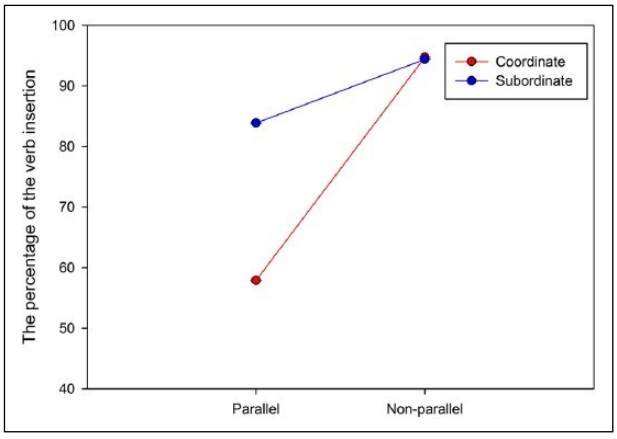


Figure 3. The average percentage of verb insertion in Experiment 2.

Table 5. Statistical analysis for Experiment 2.

	Estimate	*SE*	*z* value	*p* value
(Intercept)	3.37	0.41	8.17	<0.001***
Parallelism	−0.42	0.56	−0.75	0.45
Connective type	−0.52	0.35	−1.50	0.13
Parallelism × Connective Type	−2.00	0.48	−4.18	<0.001***

***$p < .001$.

The Logistic Regression model analysis revealed a significant interaction between Parallelism and Connective Type such that the Parallel/Coordinate condition received a low rate of verb insertion (close to chance) but verb insertion was quite high in all other conditions. Further subset analysis revealed a significant difference between the Parallel/Coordinate and Parallel/Subordinate conditions ($\beta = -3.49$, $SE = 0.85$, $t = -4.11$, $p < .001$). There was no significant difference between the Non-parallel/Coordinate and Non-parallel/Subordinate conditions ($\beta = -0.10$, $SE = 0.87$, $t = -1.17$, $p = .24$). These results show that half of the continuations in the Parallel/Coordinate construction did not include the insertion of a verb. Participants failed to insert a verb in this condition often even though they were told they could. The extent to which the readers overcame a desire to fill in elements can be regarded as at least a strong readiness to consider Gapping in this condition.

We also examined what types of verbs were added in the sentence completion study, in addition to how often they were added. When a verb was added in the Parallel Coordinate condition, filling in the same verb creates the most parallel sentence overall, but does lead to the subjects of the two clauses not being parallel: the first conjunct subject does not contain a PP and the second conjunct subject does. Filling in a different verb, however, just results in two conjoined clauses expressing two different events.[7] In the Parallel/Coordinate condition, the same verb is used as in the first clause in 14.8% of trials, or almost 25% of the times when any verb was inserted. This suggests that readers prefer to not insert any verb (sometimes by inserting an adverb instead) or use verbs different from the one used in the first conjunct, though they were not unwilling to reuse the same verb either. As for the verbless completions, the completed strings were all compatible with the Gapping structure and had no obvious other interpretation. For example, a participant completed a sentence by inserting an adverb as in the following sentences: "The merchant ate in the office happily, and the photographer in the cafe *sadly*" or "The toddler climbed over the rock happily, and the picnickers over the hill *gleefully*." These strings must be interpreted as having an elided verb *ate* or *climbed*, respectively.

The other important point is that Gapping is rarely observed in the Subordinate and Non-parallel conditions, confirming that Gapping is not allowed outside of coordinated contexts or in conditions without parallelism. This pattern would not be expected if Gapping were the consequence only of a parallelism preference. Rather, what we are observing is that Gapping is indeed allowed when the two connected clauses exhibit structural parallelism, but only in a coordination context, not in a subordination context. These results suggest that the Coordination Constraint is crucial in licencing Gapping, and Parallelism alone is not sufficient to licence Gapping. Parallelism does increase the rate of Gapping substantially within coordinated contexts, though. Interestingly, Experiment 2 shows a stronger effect of the Coordination Constraint than Experiment 1b did.

Discussion. We examined to what extent readers allow Gapping constructions over non-elliptical continuations when faced with a structurally ambiguous string like *the singer behind the stage*, which is structurally compatible with an NP-attachment structure as well as a Gapping structure. Only if a second verb is found in the second clause are readers able to be certain that it is not a Gapping construction but rather an NP-attachment structure. Thus, the sentence fragment completion task was conducted to reveal whether the parser prefers Gapping in the construction that maximises parallelism, and if the gapped structure is only available when connected clauses are connected by a coordinating conjunction like *and* but not by subordinate conjunctions. Our results showed that readers employ the Gapping structure, as revealed by lower rates of insertion of the verb, only when allowed by the Coordination Constraint and with parallelism.

Experiment 3

In the previous experiments, we showed that readers will postulate a Gapping structure as well as an NP-attachment structure offline when the clauses are parallel and when grammatical constraints like the Coordination Constraint are met. In this experiment, we aim to test to what extent

the parser prefers ellipsis in online processing. As we discussed, the Gapping structure and NP modification by the PP are both possible structures. Furthermore, the reader is able to recognise Gapping ellipsis only after the actual ellipsis site due to the lack of an obvious cue that signals ellipsis. In this sense, inserting a gap as a first resort may result in an incorrect analysis, after which the parser needs to reanalyze the structure. This suggests that the parser would naturally opt for a non-ellipsis structure to avoid the reanalysis process, and positing an ellipsis site could be an option only in cases where sufficient disambiguation information provides evidence that ellipsis is present: the Ellipsis as a Last Resort Hypothesis. However, it is also plausible that the parser would posit the gap whenever Gapping is grammatically licenced and favoured by parallelism (the Incremental Ellipsis Hypothesis), due perhaps to the cost-free nature of ellipsis structure or a desire to maximise parallelism. Thus, our interest lies in whether insertion of an ellipsis is done incrementally by the parser by making use of the properties of Gapping.

We aim to examine whether the parser would incrementally posit the gap during online processing, and whether this is only allowed in coordination contexts. Specifically, we carried out an eye-tracking experiment intended to show whether the parser immediately prefers a Gapping structure over other structures when two clauses are joined in online processing. We manipulated Parallelism (Parallel vs. Non-parallel) and Connective Type (Coordinate vs. Subordinate) and crucially allowed the NP-PP sequence in the second clause to be structurally ambiguous only temporarily, as in (10): this differs from the Experiment 1b items in Table 3 in that a verb and PP always followed the ambiguous material in the second conjunct.

(10) a. *Parallel/Coordinate*
The guitarist hid behind the curtain suddenly, **and** the singer behind the stage hid from the sneaky photographers.

b. Parallel/Subordinate
The guitarist hid behind the curtain suddenly, **whereas** the singer behind the stage hid from the sneaky photographers.

c. Non-parallel/Coordinate
The guitarist noticed his recording agent suddenly, **and** the singer behind the stage hid from the sneaky photographers.

d. Non-parallel/Subordinate
The guitarist noticed his recording agent suddenly, **whereas** the singer behind the stage hid from the sneaky photographers.

In our study, the NP-attachment structure could, in principle, be preferred as a default choice because it involves the structure that is least costly and the PP is attached to the most recent position. The PP is just attached to the noun as a modifier (i.e., $[_{NP}$ *[N the singer]* $[_{PP}$ *behind the stage]]*) and the NP is both the phrase that is currently being parsed and the most local attachment position. For the Gapping analysis, however, another VP layer is needed for a PP to play a role as an adjunct (i.e., $[^{IP}$ $[_{NP}$ *the singer]* $[_{VP}[_{V}$ *hid]*$[_{PP}$ *behind the stage]]]*) where the input is associated with more nodes. If local attachment principles exert a strong influence on the reader, the reader should prefer the NP-attachment structure over the Gapping structure, and we would expect no slowdown in terms of the reading time at the upcoming verb as it creates a globally grammatical analysis.

At the same time, we have shown that Gapping is licenced only in the coordination structures (the Coordination Constraint). If the parser respects such grammatical constraints on Gapping, then the parser should not be surprised to see the verb in the second clause in (10b) or at (10d), because Gapping is not expected in the subordination context. Thus, if the parser builds the structure of the second conjunct that is parallel to the first conjunct, but only between two coordinated clauses, we expect a slowdown at the verb for (10a) but not in other conditions. If Gapping is not preferred when there is structural parallelism or the parser does not abide by the grammatical constraints, we would expect no differences between the different conditions.

Norming of the items. We discussed the fact that readers can analyse an NP-PP sequence either as the structure where PP is attached to NP, which reflects readers' preference to build a structure that incurs the least cost, or as a Gapping construction. Given that readers may realise that the structure involves the non-ellipsis continuation only at the disambiguation point (i.e., the second verb at the second clause), readers may undergo costly reanalysis processes upon being confronted with the second verb in the second clause. This kind of reanalysis can contribute to difficulty in comprehending the overall sentence (Schneider & Phillips, 2001; Sturt et al., 2001). Thus, we explore whether these sentences are acceptable in general. The prediction is that the parser may analyse the PP as an adjunct of an elided verb and be surprised at the second verb. However, it is plausible that the parser might have enough time to recover from the reanalysis in an offline rating task. This would lead to similar acceptability ratings across all four conditions.

Participants were 38 native speakers of English from the Northwestern University community with no history of language disorders. All participants provided informed consent and earned credit in one of the introductory linguistics classes. No participants were excluded.

Critical items consisting of 32 sets of sentences were arranged in a 2×2 within-subjects factorial design, in which Parallelism (Parallel vs. Non-parallel) and Connective Types (Coordinate vs. Subordinate) were manipulated as independent factors. A sample set of stimuli is in (10). The experimental items were mixed with 36 filler sentences of similar length. Fillers included items that contained subject–verb (dis)agreement constructions, a manipulation that was irrelevant to the current experiment.

Analysis. Each model contained sum-coded fixed effects of Parallelism (whether the structure is parallel or not), Connective (whether the conjunct is connected with the coordination *and* or the subordinate *whereas*), and their interactions, as well as random intercepts for participants and items and the maximum number of random slopes given that the data were justified (Barr et al., 2013). We first used the maximal random effects structure and in situations where the maximal model did not successfully converge, the random effect with the least variance was taken out in a stepwise fashion.

Results. A summary of model results is shown in Table 6[8] and the mean acceptability scores are shown in Figure 4. The linear mixed effect model showed that there was no main effect nor interaction, meaning that the sentences were judged equally acceptable. The judgements were also high across conditions. Given that the whole sentence was given to the participants, they might have had sufficient time to recover from the Gapping structure even if a Gapping structure is preferentially postulated. Furthermore, the average ratings for the filler items were 5.59 for constructions without subject–verb disagreement and 3.80 for sentences violating subject–verb agreement. This suggests that the experimental sentences were judged acceptable overall.

Table 6. Statistical analysis for the norming study.

	Estimate	*SE*	*t* value	*p* value
(Intercept)	4.52	0.17	26.00	
Parallelism	0.13	0.08	1.59	>.05
Connective	0.10	0.08	1.35	>.05
Parallelism × Connective	−0.22	0.16	−1.40	>.05

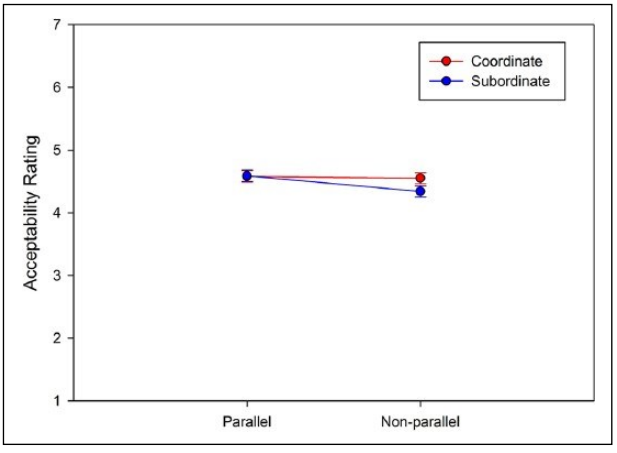


Figure 4. Mean acceptability scores for the norming study.

Discussion. The results of the acceptability judgement norming task revealed that sentences including the complete VP in the second clause were judged similarly acceptable across all four conditions. This suggests that the sentences do not have intrinsic problems. Note that in these sentences, the NP-PP sequence is temporarily compatible with both Gapping and non-elliptical continuation. However, the relatively high ratings for all four conditions can be attributed to the fact that readers have a sufficient amount of time to recover from the reanalysis, even if they may have initially interpreted the NP-PP sequence as Gapping structure. Thus, it remains unclear whether the parser picks the Gapping structure as a first resort or only when ellipsis is necessary. This open question leads us to an online processing experiment.

An eye-tracking experiment. We showed above that acceptability ratings for single-clause sentences with final adverbs (Experiment 1a) and for two-clause sentences with potential Gapping analyses (Norming Study) were similar across conditions. This suggests that the sentences are intrinsically well-formed. However, we would like to examine to what extent the parser prefers to construct an ellipsis site over other structures when presented with this structural ambiguity in real-time. Specifically, we investigate whether the parser actively postulates ellipsis when it is grammatically licenced (following the Incremental Ellipsis Hypothesis) or waits for disambiguation evidence to be present (as per the Ellipsis as a Last Resort Hypothesis).

In this experiment, Connective types (Coordinate: *and* vs. Subordinate: *whereas*) and Parallelism (Parallel vs. Non-parallel) were manipulated as independent factors in a 2×2 factorial design. The prediction is as follows: if the parser does not insert the gap immediately and instead waits for overt disambiguation information, the second verb should not create a reading time slowdown when a Gapping analysis is grammatically licenced. However, if the parser inserts a gap as soon as possible in cases where parallelism between two coordinate clauses arises, the parser should be surprised to see the second verb as the parser has already inserted the gap as a first resort. In this case, we expect an interaction between Parallelism and Connective Type at the second verb.

Participants, materials, and design. Participants were 52 native speakers of English from the Northwestern University community with no history of language disorders. All participants provided informed consent and earned credit in one of the introductory linguistics classes. No participants were excluded.

Critical items consisting of 32 sets of sentences were arranged in a 2×2 within-subjects factorial design, in which Parallelism (Parallel vs. Non-parallel: Contrast Coding 0.5 vs. −0.5) and Connective (Coordinate vs. Subordinate: Contrast Coding −0.5 vs. 0.5) were manipulated as

independent factors. The stimuli are same as the ones in (10). Items were distributed in four lists using a Latin square design, and in each list the items were pseudo-randomised to avoid the identical experimental items appearing adjacent to each other. The experimental items were mixed with 70 filler sentences of similar length. These filler sentences contained sentences with locative constructions, anaphoric elements, and some sentences with reflexives or islands, all irrelevant to the current Gapping experiment. Approximately, half of the filler sentences were grammatical sentences, and others were ungrammatical sentences (e.g., in terms of implausibility of the preposition with certain verbs) with different lengths and difficulties.

Procedure. Participants read a single sentence at a time while their eye movements were tracked with an EyeLink 1000 eye-tracker. The eye-tracker was calibrated prior to the experiment with a nine-point calibration, and recalibration was performed whenever necessary throughout the experiment. At the start of each experimental trial, a little black rectangle appeared on the left edge of the screen, which signals the initial character of the text. Upon successful calibration, the rectangle was automatically replaced by the experimental stimulus. There were line breaks such that the second conjunct which starts with *and* or *whereas* always appeared on the second line. Participants were instructed to read each sentence at a natural pace. Comprehension questions were presented for all the sentences. Sample comprehension questions were *Was the junior hiding in his seat?* or *Was a candidate's manager mentioned?* Participants responded to the questions by pressing the left or right button on a control pad. The experiment lasted approximately 40 min, and always started with six practice stimuli before the actual experiment started.

Analysis. The data gathered on eye-fixation were manually corrected for vertical drift. Fixations less than 80 ms, as well as fixations over 1200 ms, were excluded from the analysis. We will report data for four eye-movement measures. First fixation duration (FFD) is the duration of the first fixation in a region. Regression path duration (RPD) is the sum of fixation durations from when the region is first entered until exiting to the right. This measure is sometimes referred to as *go-past time* (Staub & Rayner, 2007). Total fixation time (TFT) is the sum of all fixations on the region, which includes re-reading times. In trials where fixations were absent, that trial was regarded as a missing value (Sturt, 2003).

The statistical analysis was conducted with log-transformed data for the purpose of normality (Box & Cox, 1964; Nicenboim & Vasishth, 2016). Each model contained sum-coded fixed effects of Parallelism (whether the structure is parallel or not), Connective (whether the conjuncts are connected with the coordination *and* or the subordinate *whereas*), and their interactions, as well as random intercepts for participants and items and the maximum number of random slopes given that the data were justified (Barr et al., 2013). The skipping rate for the verb (*hid*) was 55%, for Spillover Region 1 (*from the*) was 44%, and for Spillover Region 2 (*sneaky photographer*) was 0%. The larger skipping rate for the verb is likely due to the small size of the region. The verb region is quite short, and most of the time involves an average of only 3–6 letters.

Results. The statistical analysis of results for the Eye-Tracking Experiment on the Verb region, Spillover Region 1, and Spillover Region 2 is on Tables 7–9.

Verb Region (*hid*)

In the RPD measure, a marginal interaction between Parallelism and Connective was observed such that the verb in the Coordinate condition was read slightly slower in the Parallel condition, but faster in the Non-parallel condition. However, further subset analysis revealed no main effect of Connective in either Parallel or Non-parallel conditions. In the TFT measure, a main effect of Parallelism was also observed such that the Non-parallel conditions were read significantly slower than Parallel conditions.

Table 7. Statistical analysis for the Eye-Tracking Experiment on the Verb region.

		Verb region: *hid*		
		Estimate	*t* value	*p* value
FFD	Intercept	5.36 (0.02)	252.06	
	Parallelism	0.00 (0.03)	0.05	>.05
	Connective	−0.03 (0.03)	−0.96	>.05
	Parallelism × Connective	0.02 (0.06)	0.32	>.05
RPD	Intercept	5.81 (0.07)	88.65	
	Parallelism	0.02 (0.08)	0.31	>.05
	Connective	0.05 (0.09)	0.52	>.05
	Parallelism × Connective	−0.33 (0.19)	−1.74	>.05
TFT	Intercept	5.90 (0.05)	126.46	
	Parallelism	**0.10** (0.04)	**2.28**	**<05***
	Connective	0.07 (0.06)	1.29	>.05
	Parallelism × Connective	0.08 (0.09)	0.94	>.05

FFD: first fixation duration; RPD: regression path duration; TFT: total fixation time.
*$p < .05$. Bold indicates the significant main effect and significant interaction.

Spillover region 1 (*from the*)

A main effect of Parallelism was observed in the TFT (see Figure 5), such that the Parallel conditions were read significantly slower than Non-parallel conditions. This may have been driven by the Parallel/Coordinate condition, as further subset analysis showed that there was a main effect of Parallelism in the Coordinate conditions ($\beta = 0.22$, $SE = 0.06$, $t = 3.74$, $p < .001$) but not in the Subordinate conditions ($\beta = .00$, $SE = 0.06$, $t = 0.05$, $p > .05$). An interaction between Parallelism and Connective was also observed in the TFT such that the Parallel/Coordinate

condition was read significantly slower than the Parallel/Subordinate condition (β = −0.14, *SE* = 0.06, *t* = −2.21, *p* < .05), but no differences were found between Non-Parallel/Coordinate and Non-parallel/Subordinate conditions (β = 0.09, *SE* = 0.06, *t* = 1.62, *p* > .05).

In the RPDs, a main effect of Parallelism was observed such that Parallel conditions were read significantly slower than Non-parallel conditions.

Table 8. Statistical analysis for the Eye-Tracking Experiment on Spillover Region 1.

		Spillover Region 1: *from the*		
		Estimate	*t* value	*p* value
FFD	Intercept	5.39 (0.02)	264.88	
	Parallelism	−0.00 (0.03)	−0.15	>.05
	Connective	−0.01(0.03)	−0.35	>.05
	Parallelism × Connective	−0.00 (0.05)	−0.02	>.05
RPD	Intercept	6.49 (0.09)	68.44	
	Parallelism	**0.43 (0.11)**	**3.98**	**<.001*** **
	Connective	0.06 (0.11)	0.58	>.05
	Parallelism × Connective	−0.23 (0.19)	−1.22	>.05
TFT	Intercept	6.11(0.05)	127.23	
	Parallelism	**0.11**(0.05)	**2.41**	**<.05**
	Connective	−0.02 (0.05)	−0.40	>.05
	Parallelism × Connective	**−0.23** (0.08)	**−2.75**	**<.05**

FFD: first fixation duration; RPD: regression path duration; TFT: total fixation time.
*$p < .05$, ***$p < .001$.

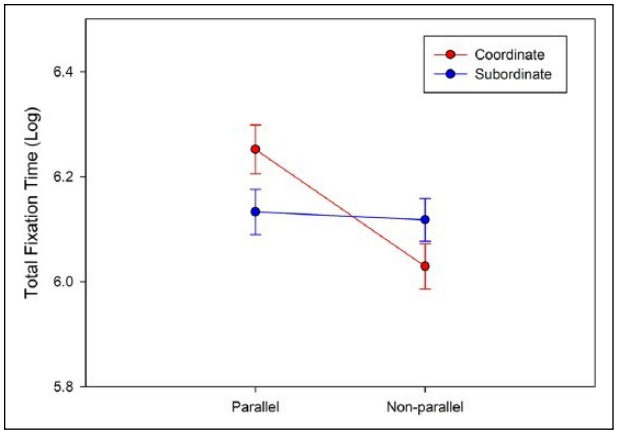


Figure 5. Total fixation time (TFT) at Spillover Region 1 (*from the*).

Spillover Region 2 (*sneaky photographers*)

In the RPDs (see Figure 6), a main effect of Parallelism was observed such that the Parallel conditions were read significantly slower than Non-parallel conditions. A main effect of Connective was also observed such that the Coordinate conditions were read significantly slower than Subordinate conditions. An interaction between Parallelism and Connective was also observed such that the Parallel/Coordinate condition was read significantly slower compared with other conditions. Further subset analysis showed that the Parallel/Coordinate condition was read significantly slower than the Parallel/Subordinate condition within the Parallel conditions (β = −0.28, *SE* = 0.08, *t* = −3.33, *p* < .01), but the Coordinate condition was not significantly slower than the Subordinate condition within the Non-parallel condition (β = −0.07, *SE* = 0.08, *t* = −0.88, *p* > .05).

Table 9. Statistical analysis for the Eye-Tracking Experiment on Spillover Region 2.

		Spillover region 2: *sneaky photographers*		
		Estimate	*t* value	*p* value
FFD	Intercept	5.42 (0.02)	332.6	
	Parallelism	0.02 (0.02)	1.1	>.05
	Connective	−0.02 (0.02)	−0.9	>.05
	Parallelism × Connective	−0.02 (0.04)	−0.4	>.05
RPD	Intercept	7.88 (0.08)	96.58	
	Parallelism	**0.12** (0.05)	**2.41**	**<.05**
	Connective	**−0.17** (0.06)	**−2.94**	**<.01**
	Parallelism × Connective	**−0.22** (0.10)	**−2.25**	**<.05**
TFT	Intercept	6.35 (0.07)	94.82	
	Parallelism	**0.09** (0.03)	**2.91**	**<.01**
	Connective	**−0.07** (0.03)	**−2.29**	**<.05**
	Parallelism × Connective	−0.06 (0.06)	−1.09	>.05

FFD: first fixation duration; RPD: regression path duration; TFT: total fixation time.
**$p < .01$. *$p < .05$.

In TFTs (see Figure 7), a main effect of Parallelism was observed such that the Parallel conditions were read significantly slower than the Non-parallel conditions. A main effect of Connective was observed such that Coordinate conditions were read significantly slower than Subordinate conditions. A main effect of Connective was also observed in the Parallel conditions (β = −0.10, *SE* = 0.04, *t* = −2.36, *p* < .05) but not in Non-parallel conditions (β = −0.05, *SE* = 0.04, *t* = −1.23, *p* > .05). A main effect of Parallelism was also observed in the Coordinate condition (β = 0.12, *SE* = 0.04, *t* = 3.01, *p* < .01) but not in the Subordinate conditions (β = 0.06, *SE* = 0.04, *t* = 1.30, *p* > .05).[9]

Discussion. The results revealed that the parser inserts the gap (assigns a Gapping analysis) when there is structural parallelism between two coordinated (but not

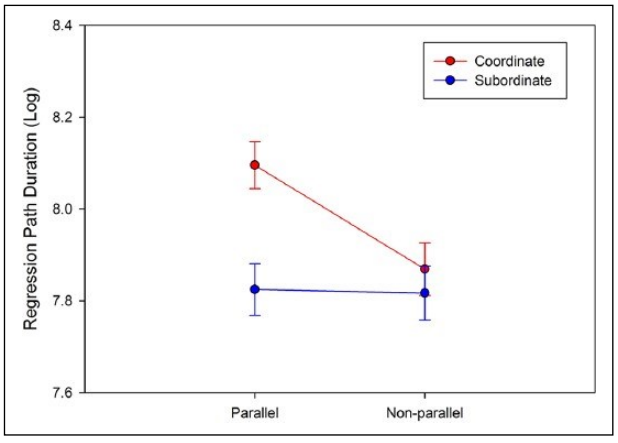


Figure 6. Regression path duration (RPD) at Spillover Region 2 (*sneaky photographers*).

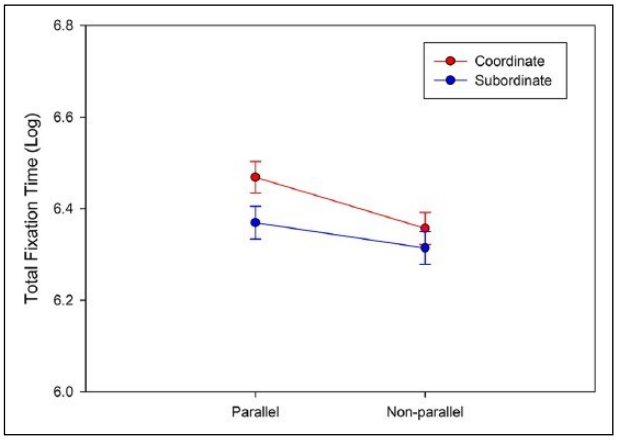


Figure 7. Total fixation time (TFT) at Spillover Region 2 (*sneaky photographers*).

subordinated) clauses. This was reflected at Spillover Region 1 in TFT and Spillover Region 2 in RPD, where we observed longer reading times in the Parallel/Coordinate condition. Specifically, at Spillover Region 1, TFT showed an interaction between Parallelism and Connective, and further subset analysis showed a main effect of Connective only in Parallel conditions. Furthermore, at Spillover Region 2, RPD showed an interaction between Parallelism and Connective and further subset analysis showed a main effect of Connective only in Parallel conditions.

We also examined the reading times before the verb at the second conjunct.[10] At the point of *behind*, there was an interaction between Parallelism and Connective such that the Parallel/Coordinate condition was read significantly faster than other conditions in the RPD measure ($\beta = 0.28$, $SE = 0.13$, $t = 2.19$, $p < .05$). This suggests that the parser is expecting to observe the PP right after the NP in Parallel/Coordinate conditions. However, there is a main effect of Parallelism at the verb and at the PP after the verb (spillover regions). This might be due to the reanalysis of the verb from the end of the sentence, and thus the post-verbal PP is read slower in the Parallel/Coordinate condition. The question is why the verb is read slower in the Parallel/Subordinate condition. One possibility could be that the effect of reanalysis is not sufficiently strong and also the repetition of the verb contributes to the reading slowdown. It is plausible that readers might expect to have different verbs in the second clause, that is, a condition of less parallelism of structure to match the subordinating conjunction, and observing exactly the same verb itself creates processing costs.

The NP-PP sequence is compatible with both NP-attachment and Gapping structures. When the parser encounters the verb which appears after the PP, the parser should be surprised to see the verb only if the parser inserted Gapping as a first resort. This is reflected in the longer reading time for the region where Gapping should be possible. Thus, the longer reading time for the Parallel/Coordinate structure compared with other conditions is an indication of the parser's reanalysis process due to the initial preference for Gapping structures as a first resort (the Incremental Ellipsis Hypothesis).

Note that this effect cannot be solely explained by accounts claiming that Gapping is licenced in all parallel clauses. Rather, these results suggest that the gap is inserted only when the grammatical Coordination Constraint is not violated. Both the TFT and RPD subset analyses showed a main effect of Coordinate only in Parallel conditions, not in Non-parallel conditions. Note that the TFT at the spillover region suggests that the parser may have looked for Parallelism first, such that the Gapping structure may have been considered briefly in the Parallel/Subordinate condition. However, grammatical constraints are then taken into consideration, leading the parser to abandon the Gapping parse in subordination. In other words, the extra-grammatical parallelism preference might affect the processing of Gapping constructions early in processing. Furthermore, a main effect of Parallelism was observed only in Coordinate conditions but not in Subordinate conditions. This suggests that the parser prefers connected clauses that respect parallelism but only when the clauses are connected by a coordinate conjunction, and Gapping is then an allowable structure which the parser could build.

General discussion

The purpose of this article was to systematically test the contribution of parallelism and connective types to the distribution of Gapping. Ellipsis constructions such as Gapping pose some challenges to incremental parsing because only at the second verb in the second conjunct is the parser able to recognise the ellipsis. In an eye-tracking experiment and a number of associated offline experiments, we showed that the parser employs Gapping as a

first resort when the second conjunct is fully parallel to the first conjunct, and that this preference appears only in coordinated clauses.

First, acceptability judgement tasks showed that the second conjunct containing Gapping is understood as a complete clause when the clauses are joined by a coordinating connective and when they obey parallelism. Next, we conducted a completion task where we showed that readers overwhelmingly preferred NP-attachment structures for Parallel/Subordinate, Non-parallel/Coordinate, and Non-parallel/Subordinate conditions, but that both Gapping and NP-attachment structures were equally available in the Parallel/Coordinate condition. Finally, we compared the online processing of coordinated and subordinated clauses with or without parallelism to investigate whether the parser inserts an ellipsis site as a first resort. Crucially, these tests were only possible because the NP-PP sequence in the second clause was structurally ambiguous: it could be analysed either as a Gapping structure with a hidden verb or a simple NP with a PP modifier.

The results of the eye-tracking experiment revealed that Parallel/Coordinate conditions were read significantly slower than the Parallel/Subordinate, Non-parallel/Coordinate, and Non-parallel/Subordinate conditions at some regions and in some measures. This can be explained by the parser's reanalysis process of converting the Gapping structure to the NP-attachment structure when faced with the overt verb in the second conjunct. Given that reanalysis exacts a processing cost (Schneider & Phillips, 2001; Sturt et al., 2001), it was plausible that the parser would insert an ellipsis site only when there is no other option (the Ellipsis as a Last Resort Hypothesis). Under this view, Gapping should have been the least preferred structure in cases of structural ambiguity. This is not compatible with our results.

However, an alternative possibility was that the parser inserts a gap when an ellipsis can be licenced, even without any confirming evidence for ellipsis (the Incremental Ellipsis Hypothesis). We expected that if structural parallelism facilitates building the Gapping analysis online, the NP-PP string should be preferentially analysed as Gapping after a coordinating conjunction. The parser should then attempt reanalysis at the second verb, resulting in longer reading times at the verb in the second clause. However, when parallelism does not hold between the clauses and the Coordination Constraint is not satisfied, the Gapping analysis should not be available. In this case, we expected the PP should be analysed as a modifier for the NP instead of as involving a Gapping structure, and no surprise at the following verb should be observed.

The results of the eye-tracking study revealed an interaction of Parallelism and Connective at Spillover Regions 1 and 2, suggesting that the parser first uses a Gapping structure which respects structural parallelism between two coordinated clauses. The effect does not appear at the verb itself, where the disambiguation takes place, but in the spillover regions. This suggests that the effect of reanalysis shows up later as the verb is the trigger of reanalysis. It is only at the verb where the parser rules out the Gapping structure and realises that the NP-attachment structure is needed. In fact, the interaction of Parallelism and the Connective was only revealed in later measures (RPD and TFT) but not in early measures.

Note that at Spillover Region 1, in both RPD and TFT measures, the parallel structures were read significantly slower than non-parallel structures. We speculate that this arises from the parser's preference only to consider parallel structures as possible Gapping-licencing environments. When the parallelism constraint is not met in the first place, the reader would regard the PP in the second conjunct as a modifier of the NP, ruling out the possibility of a Gapping parse already. This explains why parallel structures were read significantly slower than non-parallel structures in general.

These results are compatible with the idea that Gapping is possible and pursued to some extent, provided that the grammatical constraints are met. Although Parallelism may play a role at first, permitting both the parallel and non-parallel conditions to allow for Gapping, it is the syntactic constraint on the licencing of Gapping (a grammatical constraint) that truly permits the Gapping. In this sense, the Gapping structure's licencing can be understood as the interplay between parallelism (an extra-grammatical constraint) and coordination con- straint (a grammatical constraint).

An alternative possibility raised by an anonymous reviewer is that the slight non-parallelism between the subjects of the first and second conjuncts in the Parallel/Coordinate condition affected reading times once the matching verb was read. The subject in the first conjunct (*the guitarist*) has no PP modifier, but the subject of the second clause (*the singer behind the stage*) turns out to have one once the following verb confirms that Gapping is not present. The Parallel/Coordinate condition is the one where parallelism is most expected, while the Non-parallel/Coordinate condition could still show some effects of parallelism expectations due to the conjunction. This explanation is plausible, and the fact that sentence completions in which a verb was provided did not use the same verb the majority of the time is consistent with it. Our explanation, though, is more consistent with the Gapping preference shown overall in the sentence completion experiment.

Why do we observe the effects only in late measures in the eye-tracking study? First, we have to note that the verb region is very small, and the skipping rate for the verb region was high. This could be one of the reasons why we do not detect the effect right at the verb region. Furthermore, it is also possible that the parser is strongly affected by the extra-grammatical parallelism considerations. The absence

of an interaction between Parallelism and Connective at the verb region and the observation that parallel structures were slower than non-parallel structures may suggest the parser can initially be guided by extra-grammatical considerations and consider a Gapping structure in the subordinate clauses when parallelism is met (Sturt et al., 2010). However, the fact that the slowdown associated with the reanalysis is observed only in the Parallel/Coordinate conditions in the spillover regions indicates that the parser respects the grammatical constraints and does not maintain a Gapping structure in the subordination condition. This is potentially another reason why we observe the effects in late measures and at spillover regions.

These results are compatible with previous studies on online ellipsis resolution (Kaan, Wijnen, & Swaab, 2004; Martin & McElree, 2018; Yoshida, Dickey, & Sturt, 2013). Specifically, Kaan et al. (2004) showed that in Gapping sentences such as *Ron took/sanded the planks for the bookcase* and *Bill the hammer with the big head*, readers immediately recognise the Gapping structure even at the point of the determiner following *Bill*. An implausibility effect between the verb in the first conjunct and the object in the second conjunct, *the hammer*, yielded an N400 effect which suggests that the Gapping structure is interpreted and analysed immediately.

Overall, the results of our experiments suggest that Gapping is allowed when there is structural parallelism, but only between two coordinated clauses. The parser's preference for postulating or inserting a gap can be understood as not just a byproduct of a parallelism preference. This is similar to what is observed in wh-gap dependency formation processes. The incremental insertion of the ellipsis site that we have seen has some resemblance to the incremental long-distance dependency formation that we see in the processing of wh-gap dependencies. Resolving long-distance dependencies involves linking the dependent element (e.g., a wh-phrase) to the controlling element (e.g., a verb), and the parser tries to resolve the wh-gap dependency as soon as possible. Thus the parser posits the gap early, without any confirming evidence for the gap (Aoshima, Phillips, & Weinberg, 2004; Omaki et al., 2015; Stowe, 1986; Traxler & Pickering, 1996). At the same time, even though the parser tries to minimise the distance between the wh-phrase and the gap, the parser does not posit a gap in a position that is not grammatically sanctioned; for example, within syntactic islands, even positing a gap within an island may accomplish the shortest dependency length (Phillips, 2006; Stowe, 1986; Traxler & Pickering, 1996). Similarly, in Gapping, the parser inserts an ellipsis site without any confirming evidence of the presence of an ellipsis site, but only in coordinated structures. The parser is putting in a silent verb between the N and the PP, even though if it waits, it will find out that it is not needed. Furthermore, the parser seems to prefer the Gapping structure while there is a perfectly reasonable alternative structure, an N with a PP modifier, available. It is not that the Gapping structure is the only way forward with no alternative syntactic options. It has to have been predicted because the disconfirming verb is not very far in the future.

Even though the insertion of an ellipsis as a first resort could be risky, the parser seems to incrementally postulate the ellipsis site when grammatically possible before waiting for the disambiguation site. Although there is a debate with regard to whether parallelism is considered as a grammatical constraint or an extra-grammatical constraint (Parker, 2017), we argue that its operations are strongly constrained by grammatical constraints (see Phillips, 2006, for a similar point in the context of syntactic islands). At the same time, our study also provides evidence that the insertion of the gap is clearly strongly influenced by extra-grammatical information such as the parser's preference for parallelism (Carlson, 2001; Eastwick & Phillips, 1999; Frazier et al., 2000; Knoeferle & Crocker, 2009; Sturt et al., 2010; Trueswell, Tanenhaus, & Garnsey, 1994).

Acknowledgements

We thank several anonymous reviewers for very helpful comments. We also thank Shayne Sloggett and Roger Levy for their feedback and helpful comments.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: M.Y. and N.K. would like to thank the NSF DDRI (National Science Foundation Doctoral Dissertation Research Improvement) for partial financial support under grant number BCS-1749580, and K.C. would like to acknowledge partial financial support from the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD) of the National Institutes of Health (NIH) under grant number R15HD072713 and the National Institute of General Medical Sciences (NIGMS) of the NIH under grant number 5P20GM103436-13. M.D.'s contributions to this work were supported with resources and the use of facilities at the VA Pittsburgh Healthcare System. The contents of this article do not represent the views of the Department of Veterans Affairs of the United States.

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Supplementary material

The supplementary material is available at qjep.sagepub.com

Notes

1. Following the convention in linguistics literature, we are indicating the elided portion of the sentence by strike-outs.
2. A note is in order in terms of the analysis of Gapping. In the syntactic literature, there has been a debate whether Gapping is ellipsis or not. Some of the dominant theories of Gapping (Johnson, 1994, 2000, 2004, 2006, 2009) suggest that Gapping is not ellipsis, but there are other papers that claim that Gapping should be analysed as ellipsis (Coppock, 2001; Potter, Frazier, & Yoshida, 2017; Vicente, 2010, among others). We will not argue for either view, as offering the right syntactic analysis of Gapping is beyond the scope of this project. But we use the term *ellipsis* to refer to any construction like Gapping that involves apparent omission of some part of a sentence.
3. First of all, the Noun Phrase (NP) is the most recently processed node. Furthermore, attaching the PP (Prepositional Phrase) to the NP does not require any other structure to be built, whereas attaching the PP to the VP (verb phrase) requires analysing the NP as the subject, thus building the IP node, and building the VP structure attached to the IP. It may be that a VP will need to be built later, but at the point of PP attachment, the NP structure is smaller.
4. We remain agnostic about the ultimate explanation of the Coordination Constraint; for another analysis of Gapping, refer to Potter et al. (2017).
5. We checked the residuals for normality to make sure whether the residuals were symmetrical across the whole distribution of fitted values. The quantiles of residuals in general looked normal (the distribution of residuals: minimum: −4.18, median: 0.13, maximum = 3.60). We also fitted a cumulative logit model (proportional odds model). The results of the cumulative logit model were similar to the results of the linear mixed model where we found no main effect of Parallelism ($\beta = -0.08$, $SE = 0.18$, $z = -0.44$, $p > .05$), a main effect of Adverb Placement ($\beta = -1.41$, $SE = 0.33$, $z = -4.30$, $p < .001$), and no interaction between these two ($\beta = -0.12$, $SE = 0.37$, $z = -0.32$, $p > 0.05$).
6. We checked the residuals for normality to make sure whether the residuals were symmetrical across the whole distribution of fitted values. The quantiles of residuals in general looked normal (the distribution of residuals: minimum: −4.01, median: −0.08, maximum = 3.77). We also fitted a cumulative logit model (proportional odds model). The results of the cumulative logit model were similar to the results of the linear mixed model where we found a main effect of Parallelism ($\beta = 1.84$, $SE = 0.27$, $z = 6.89$, $p < .001$), Connective Type ($\beta = 0.63$, $SE = 0.18$, $z = 3.50$, $p < .001$), and an interaction between these two ($\beta = 1.01$, $SE = 0.28$, $z = 3.61$, $p < .001$).
7. We thank an anonymous reviewer for suggesting this analysis of the results.
8. We checked the residuals for normality to make sure whether the residuals were symmetrical across the whole distribution of fitted values. The quantiles of residuals in general looked normal (the distribution of residuals: minimum: −3.30, median: 0.03, maximum = 2.95). We also fitted a cumulative logit model (proportional odds model). The results of the cumulative logit model were similar to the results of the linear mixed model where we found no main effect of Parallelism ($\beta = 0.22$, $SE = 0.13$, $z = 1.71$, $p > .05$), no main effect of Connective ($\beta = 0.19$, $SE = 0.12$, $z = 1.53$, $p > .05$), and no interaction between these two ($\beta = -0.34$, $SE = 0.26$, $z = -1.31$, $p > .05$).
9. We did not observe an order effect at the verb, Spillover Region 1 or 2. There was no interaction between Parallelism × Trial order nor Connective × Trial order. There was also no three-way interaction between Parallelism × Connective × Trial order. For example, at Spillover Region 1 in RPD, no interaction between Parallelism and Connective ($\beta = -0.22$, $SE = 0.18$, $t = -1.18$, $p > .05$), Connective and Trial order ($\beta = -0.19$, $SE = 0.18$, $t = -1.07$, $p > .05$), nor three-way interaction ($\beta = 0.11$, $SE = 0.35$, $t = 0.32$, $p > .05$) was observed. The lack of the order effect suggests that the participants did not learn the task, become used to the lack of Gapping structures in the critical items, or employ strategies to carry out the tasks, over the course of experiment.
10. Thanks to an anonymous reviewer who directed our attention to the analysis of the regions before the verb region.

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