

Article

Sources of Discreteness and Gradience in Island Effects

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Abstract: This paper provides an overview of categorical and gradient effects in islands, with a focus on English, and argues that most islands are gradient. In some cases, the island is circumvented by the construction type in which the extraction takes place, and there is growing evidence that the critical factor is pragmatic in nature, contrary to classic and categorical accounts of island effects that are favored in generative circles to this day. In other cases, the island effect is malleable and can weaken with increased exposure to the extraction pattern, a phenomenon traditionally referred to as ‘syntactic satiation’. However, it is not clear what satiation consists of. Some argue that it is nothing more than task adaptation (mere increased familiarity with the experimental paradigm, impacting difficult sentences more than easy ones), whereas others propose that it consists of a form of error-driven structure-dependent form of learning. The present paper discusses this controversy, and the broader adaptation debate, and argues that both task adaptation and grammatical adaptation are taking place during the processing of complex sentences, and that both frequency and attention are plausible factors to stimulate adaptation.

Keywords: Islands; satiation; frequency; adaptation



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1. Introduction

There is growing evidence that repeated exposure to infrequent syntactic structures can lead to adaptation, as measured in faster reading times and/or increased acceptability. For example, certain illicit *wh*-movement structures known as ‘islands’ (Ross 1967) can become more acceptable, and are processed faster, with increased repeated exposure, a phenomenon often referred to as *syntactic satiation* (Snyder 1994, 2000; Stromswold 1986). The precise nature of syntactic satiation is not known. It could be an instance of *task adaptation* (Heathcote et al. 2000) (i.e., mere increased familiarity with the experimental paradigm, perhaps impacting difficult sentences more than easy ones as argued by Prasad and Linzen (2021)). Alternatively, it could be *syntactic adaptation* (Chang et al. 2006, 2012; Fine et al. 2010, 2013; Fine and Jaeger 2013; Sikos et al. 2016) (an error-driven structure-dependent form of statistical learning, whereby unexpected structures cause the processor to adapt to the contingencies of the input), or a combination of the two. Such changes in behavior are important because they can shed light on whether grammar is gradient, and fundamentally probabilistic, or categorical after all. This in turn is connected to broader questions about how language changes, and how it is learned by children as well as adults.

In Section 2 I provide an overview of the evidence suggesting that there are two major kinds of island phenomena. On the one hand we have categorical effects, which are due to some strict (syntactic or semantic) grammatical constraint, and in the other we have gradient effects, which are to a large extent caused by contextual or expectation-based factors. In some islands, there is a confluence of both types of phenomena, which are difficult to disentangle. In Section 3 I turn to amelioration effects caused by repeated exposure, which is a selective phenomenon, as certain island violations are more susceptible than others to amelioration than others. Several kinds of account for this effect are surveyed, and it is argued that Brown et al. (2021) are incorrect in regarding all satiation as a form of task adaptation having nothing to do with grammar or island phenomena. To further disentangle task adaptation from syntactic adaptation, I describe a self-paced reading

experiment, using a classic garden-path effect, to show that increased reward leads to more adaptive behaviour in the critical region. The experiment suggests that fine-grained error-driven learning is taking place, and that frequency can compound with reward to and speed up sentence processing of complex sentences, over and above task adaptation.

2. Discreteness and Gradience

It has become increasingly clear that island effects are not created equal, and lie on a continuum constrained by multiple factors. At one end, we have islands that are categorical and exceptionless. These are construction-invariant (i.e., are active in any construction that involves unbounded extraction), immune to any form of principled circumvention (e.g., parasitism), insensitive to contextualization, and do not weaken with repeated exposure (i.e., satiation).¹

A good example of how disparate island phenomena can be is the Coordinate Structure Constraint (Ross 1967), which is composed of two separate parts. One bans extraction *from* conjuncts, called the Element Constraint (Grosu 1973), and the other one bans extraction *of* conjuncts, named the Conjunct Constraint (Grosu 1973). There is good evidence that the two constraints are due to fundamentally different factors. Let us focus on the Conjunct Constraint first, illustrated in (1). This constraint is construction-invariant, since it arises in any kind of filler-gap dependency construction, be it interrogative, declarative or subordinate.

- (1) a. *Who did you see Robin and _ yesterday?
 b. *Who did you see _ and Robin yesterday?
 c. *It was Alex who you saw Robin and _ yesterday.
 d. *It was Alex who you saw _ and Robin yesterday.
 e. *The person who you saw _ and Robin yesterday was Alex.
 f. *The person who you saw Robin and _ yesterday was Alex.

All of the sentences in (1) become acceptable if the conjunction 'and' is replaced with a comitative like 'with', which serves to indicate that it is the coordination that hampers extraction. To my knowledge, nothing can improve the acceptability of Conjunct Constraint violations. This includes Across-the-Board (ATB) extraction, as in (2).²

- (2) a. *Who did you see _ and _ yesterday?
 b. *It was Alex who you saw _ and _ yesterday.

The insensitivity to ATB extraction is noteworthy because ATB extraction circumvents the part of the Coordinate Structure Constraint that bans extraction from conjuncts, the Element Constraint. This is illustrated in (3).

- (3) a. *Who did you say Alex dislikes Robin and Mia absolutely loves _ ?
 b. *Who did you say Alex dislikes _ and Mia absolutely loves Robin?
 c. Who did you say Alex dislikes _ and Mia absolutely loves _ ?

What is more, filler-gap dependencies like (3a,b) can become more acceptable if the conjunction is interpreted asymmetrically (Kehler 2002; Lakoff 1986; Na and Huck 1992), as illustrated in (4). Here, the order of the conjuncts matters for the interpretation. For example, in (4a) the first conjunct is a preparatory action for the second conjunct, which expresses the main assertion. In (4b) the second conjunct is a consequence of the first, and in (4) we have a more complex case of the same kind of pattern. No such meaning-based amelioration can salvage Conjunct Constraint violations.

- (4) a. Who did Sam pick up the phone and call _ ?
 b. How much can you drink _ and still stay sober?
 c. What did Harry buy _, come home, and devour _ in thirty seconds?

Taken together, the foregoing data tell us that the Conjunct Constraint and the Element Constraint are due to very different factors. The former constraint is brought about by coordination itself (conjuncts cannot be extracted), which can be explained if conjunctions are markers that attach to heads rather than heads that select arguments (Abeillé and Chaves 2021; Chaves 2007). The Element Constraint, in contrast, seems to be caused by the symmetric interpretation of coordination, which can be predicted by independently motivated pragmatic factors; see Kehler (2002, chp. 5) and Kubota and Lee (2015) for a more detailed discussion.

Another island type that resists any form of amelioration is the Left Branch Condition (LBC). This prohibits the extraction of determiner expressions in languages like English, as seen in (5). Nothing can ameliorate the effect, including repeated exposure (Francom 2009; Goodall 2011; Hiramatsu 2000; Snyder 2000, 2017; Sprouse 2009, 2007).

- (5) a. *Whose did you meet _ friend?
 (cf. 'Whose friend did you meet _ ?')
 b. *Which did you buy _ book?
 (cf. 'Which book did you buy?')
 c. *It was Robin's I liked _ painting the most.
 (cf. 'It was Robin's painting I liked _ the most.')

Since English LBC effects appear in any construction (relative clauses, declaratives, and interrogatives), and are not subject to contextual amelioration of any kind, they are a good candidate for a syntactic constraint on extraction.

Languages that apparently allow LBC violations, like most Slavic languages, don't have determiners (Uriagereka 1988, p. 113), and therefore the extracted phrase is in apposition to the nominal head. No LBC violation occurs. This is best illustrated by languages, like French, that obey the LBC but have a special construction in which such extractions are apparently possible (Corver 2014). Consider the contrast illustrated by (6a,b).

- (6) a. **Quels* *avez-vous acheté* _ *livres*?
 how-many have-you bought books
 'How many books have you bought'
 b. *Combien* *a-t-il vendu* _ *de livres*?
 how-many has-he sold of books
 'How many books did he sell?'

There are good empirical reasons to believe that there is no LBC violation in (6b). The phrase *de livres* is a post-verbal NP in French, and *combien* behaves more like a nominal than a canonical quantifier (Abeillé et al. 2004; Kayne 1981), since the former can appear without the latter in the presence of other licensors, including the preposition *sans* ('without') or negation, e.g., *Paul n'a pas lu [de livres]* ('Paul did not read any books'). If *combien* and the *de*-phrase are autonomous, then that means that no LBC violation occurs in (6b). I suspect something analogous occurs in Slavic languages.

There are other construction-invariant and categorical island effects, to be sure, such as the Preposition Stranding Ban in most languages that have prepositions, with the exception of some Germanic languages (including Danish, Dutch, English, Frisian, Norwegian and Swedish), as well as Berber, Hungarian, and Zoque (Emonds and Faarlund 2014, pp. 84–96).

At the other end of the spectrum we have island effects that are construction specific (i.e., are only active in certain types of unbounded dependency construction), permit systematic circumvention, exhibit varying degrees of acceptability depending on the exact wording (e.g., the plausibility of the content expressed, parsing difficulty caused by lexical ambiguity, garden paths, infrequent words, and/or stylistic issue), and can weaken with repeated exposure. According to the survey in [Chaves and Putnam \(2021\)](#), this is the true of the majority of known island effects; cf. with [Szabolcsi and Lohndal \(2017\)](#). In what follows I provide a brief overview of a number of island effects which are graded, malleable, and construction-specific.

2.1. Subject Islands

Subject Island violations, like the one in (7a), famously vanish with the presence of a second gap ([Engdahl 1983](#)) as illustrated by (7b), but see [Chaves and Dery \(2019\)](#) for concerns about such a paradigm.

- (7) a. *Who did [the opponents of _] assassinate Castro?
 b. Who did [the opponents of _] assassinate _ ?

The standard view that the second gap rescues the first by virtue of being outside the island is dubious, as [Levine and Sag \(2003\)](#), [Levine and Hukari \(2006, p. 256\)](#), and [Culicover \(2013, p. 161\)](#) note, because of examples like (8) in which both gaps are Subject Island violations. Such constructions should be completely ungrammatical.

- (8) This is a man who [friends of _] think that [enemies of _] are everywhere.

More recently it has also been shown that Subject Island effects can vanish if the extraction is from a relative clause, as in (9), which are attestations found by [Culicover and Winkler \(2022\)](#); see also [Abeillé et al. \(2020\)](#) for supporting experimental evidence.

- (9) a. There are some things which_i [fighting against __i] is not worth the effort. Concentrating on things which can create significant positive change is much more fruitful.
 [<https://news.ycombinator.com/item?id=13946026>, accessed on 7 January 2020]
 b. I'm looking for someone who I click with. You know, the type of person who_i [spending time with __i] is effortless.
 [<https://3-instant.okcupid.com/profile/mpredds>, accessed on 7 January 2020]
 c. Survived by her children, Mae (Terry), Dale (Andelyn), Joanne (Gary), Cathy (Jordan), George, Betty (Tim), Danny (Angela); a proud grandmother of 14 grandchildren and 16 great-grandchildren, who_i [spending time with __i] was one of her finest joys;
 [<http://www.mahonefuneral.ca/obituaries/111846>, accessed on 7 January 2020]

Attestations involving extraction from subject-embedded verbal structures are shown in (10). To my knowledge, there are no attested Subject Island violations that do not involve extraction from relative clause subjects.

- (10) a. The eight dancers and their caller, Laurie Schmidt, make up the Farmall Promenade of nearby Nemaha, a town_i that [to describe __i as tiny] would be to overstate its size.
 ([Huddleston et al. 2002](#), pp. 1094, ft.27)
 b. In his bedroom, which_i [to describe __i as small] would be a gross understatement, he has an audio studio setup.
 ([Chaves 2012](#), p. 471)

- c. Leaving the room, she is quick to offer you some Arabic coffee and dates which_i [to refuse __i] would be insane because both are delicious, and an opportunity to relax and eat is welcome when working twelve hours.
[www.thesandyshamrock.com/being-an-rt-in-saudi-arabia/, accessed on 7 January 2020]

Still, various authors such as Ross (1967, p. 242), Kluender (1998, p. 268), Hofmeister and Sag (2010, p. 370), Sauerland and Elbourne (2002, p. 304), Jiménez–Fernández (2009, p. 111), and Chomsky (2008, pp. 160, ft. 39), among others, have noted that slight rewording can attenuate Subject Island effects in interrogatives, as (11) illustrates.

- (11) a. What did [the attempt to find _] end in failure?
(Hofmeister and Sag 2010, p. 370)
- b. Which President would [the impeachment of _] not shock most people?
(Chaves and Putnam 2021, p. 80)
- c. Which problem will [a solution to _] never be found?
(Chaves and Dery 2014)

Interrogative Subject Island violations like the above sometimes ameliorate with repetition (Chaves and Dery 2014; Clausen 2011; Francom 2009; Goodall 2011; Hiramatsu 2000; Lu et al. 2021). According to Chaves and Dery (2019), extractions from subjects like (12a) are initially less acceptable than their object counterparts in (12b), but as the experiment progressed the former became more acceptable, and by 12 exposures the two types of extraction were equally acceptable. This was replicated by Chaves and Putnam (2021, p. 213).

- (12) a. Which stock does [the value of _] often parallels the price of the dollar?
b. Which stock does the value of the dollar often parallels [the price of _]?

The authors ensured that the acceptability differences in (12) were due to extraction (rather than to lexical biases, semantic plausibility, complexity, pragmatics, etc.), by making sure that their declarative counterparts shown in (13) were truth-conditionally near synonymous and expressed highly plausible propositions to begin with. This was done via a sentence acceptability norming experiment, with different participants.

- (13) a. The value of this stock often parallels the price of the dollar
b. The value of the dollar often parallel the price of this stock.

Since the items expressed essentially the same proposition, this design avoided the concern raised by Kim (2021) about the factorial design adopted by Sprouse (2007), which does not control for important non-syntactic factors and therefore has limited ability to identify the exact nature of island effects. Chaves and Dery (2019) also compared acceptability and the online processing of near-synonymous sentence pairs like (12), which express essentially the same proposition. Any acceptability differences must come from the extraction itself.

The fact that no such dramatic acceptability increase was observed in the ungrammatical controls (including in a later replication by the same authors) suggests that Subject Island effects can vanish, in ideal conditions. That is, if the items are not too complex, express highly plausible propositions, and participants are sufficiently exposed to such structures. A similar effect was also observed in terms of reduced reading times around the gap site on a subsequent experiment in Chaves and Dery (2014). In other words, speakers can adjust to unusual gaps and the associated semantic-pragmatic consequences. The asymmetry between subject and object subextraction is not categorical, and can be countered in ideal conditions.

The conclusion is that English Subject Islands are most likely not purely syntactic phenomena. The effect is not present in relative clauses, and is sometimes graded elsewhere. But what, then, is behind such otherwise strong islands? One possibility is that extraction from subject phrases is dispreferred when the subject is expected to be discourse-old. Subject phrases are used typically used for topic continuity (Chafe 1994; Kuno 1972; Lambrecht 1994). For example, subject phrases are more likely to be pronominal or elliptical than objects (Michaelis and Francis 2007). Consequently, there is a conflict between the discourse function of the extracted element (focus) and the discourse function of the subject phrase itself (Abeillé et al. 2020; Erteschik-Shir 2006b; Goldberg 2006; Takami 1988; Van Valin 1986). Extracting from a discourse-old subject not only involves a structurally unexpected move, so to speak, but also contextually unusual state-of-affairs, one in which a discourse-old referent is linked to a subordinate referent that can be the focus. No such contradiction arises in relative clauses, because their subjects are under no obligation to be a main topic or focus.

According to Kluender (2004, p. 495), ‘Subject Island effects seem to be weaker when the *wh*-phrase maintains a pragmatic association not only with the gap, but also with the main clause predicate, such that the filler-gap dependency into the subject position is construed as of some relevance to the main assertion of the sentence’. In other words, the subject-embedded referent must contribute to the interpretation of the main predication. For example, in (11a) the extraction is licit because whether or not the attempt to find *x* ends in failure crucially depends on the identity of *x*; the search failed precisely because of the nature of what was sought. Similarly, whether or not an impeachment shocks most people crucially depends on the one that is impeached, and whether or not a solution is found crucially depends on the identity of the problem.

Chaves and Putnam (2021, p. 228) found supporting experimental evidence for such a relevance constraint. A total of 20 experimental items were constructed, each of which had two versions, as seen in (14). The extracted referents in the –Relevant condition are less important for the situation described by the sentence as compared to the items in the +Relevant condition.

- (14) a. Which joke was the punchline of extremely offensive?
(+Relevant)
- b. Which joke was the punchline of overheard by the teacher?
(–Relevant)

To ensure that the +Relevant condition items were indeed more relevant than the –Relevant condition items, a norming experiment in which a different group of participants were asked to use a 5-point Likert scale to state to what extent they agreed with statements like (15), created from the 20 original experimental items.

- (15) Whether the punchline of a joke is [offensive / overheard by the teacher] depends on what the joke is.

To ensure that any difference in acceptability between the item pairs was due to extraction and not to semantic or pragmatic differences between the item pairs, a norming experiment was conducted to measure the acceptability of the declarative counterparts of the 20 items, illustrated in (16). The goal of this task is to ensure that the non-extracted counterparts of the items were equally acceptable to begin with.

- (16) The punchline of this joke was extremely offensive/overheard by the teacher.

After these norming experiments, acceptability ratings were collected for the 20 Subject Island items like (14). A Cumulative Bayesian Linear Regression model with sentence acceptability ratings as a dependent variable and the mean relevance ratings per item from the questionnaire experiment as the independent variable (allowing for the intercept to

vary with items and declarative acceptability ratings as random effects) found a significant effect ($\beta = 0.08$, $SD = 0$, $CI = [0.07, 0.08]$, $P(\beta > 0) = 1$). These results suggest that the more important the extracted referent is for the proposition described by the utterance, the more acceptable the subject subextraction. This is consistent with the view in which not all subject embedded referents are equally biased to be assigned the same pragmatic function as the subject referent. This depends on the predication, the proposition, and the context. Moreover, whether or not a referent embedded in a discourse-old subject is interpreted as new and has an impact on the main predication is a matter of degree, and therefore it is not surprising that with repeated exposure such constructions sometimes become more and more acceptable. To conclude, Subject Islands are not construction-invariant, and even when they are active, their effect is gradient. Although a syntactic account may be possible, stipulating that in certain constructions extraction is allowed, it is unclear how such an account can *explain* why things are the way they are on independently motivated grounds.

2.2. Adjunct Islands

A similar situation arises in connection with Adjunct Islands. First, they can be circumvented by the presence of a secondary gap (Engdahl 1983), as illustrated by (17) and (18). But these sentence pairs have radically different meanings, and therefore it is not clear in which sense the main gap can be said to rescue the secondary gap. Indeed, it is well-known that such environments are not categorical boundaries to extraction, given examples like (19).

- (17) a. *Which printouts_i did Kim discard thumbtacks [without reading _i]?
 b. Which printouts_i did Kim discard _i [without reading _i]?
- (18) a. *Which colleague_i did John slander Robin [because he despises _i]?
 b. Which colleague_i did John slander _i [because he despises _i]?
- (19) a. Who_i did you go to Girona [in order to meet _i]?
 (Hegarty 1990)
 b. What_i do you think Robin computed the answer [with _i]?
 (Bouma et al. 2001, p. 45)
 c. Which movies_i does Sean Bean die [in _i]? (Chaves and Putnam 2021, p. 87)
 d. Which temperature_i should I wash my jeans [at _i]?
 (Chaves 2013)

There is no independently motivated empirical reason to assume that these adjuncts combine with their VP heads in different ways (Truswell 2011), which suggests that syntax is not the source of the island effect. Müller (2017) provides sentence acceptability evidence from Swedish suggesting that extraction from tensed adjuncts is contingent on the degree of semantic-pragmatic cohesion between the matrix, and similar results are reported for Norwegian by Bondevik (2018). More recently, Kohrt et al. (2020) and various others show that semantic factors play a critical role in English Adjunct Islands.

As in the case of Subject Islands, clausal Adjunct Island violations are usually stronger than phrasal violations. Compare (17a) and (18a) with (20).

- (20) a. *Who_i did John come back before I had a chance to talk to _i?
 (Huang 1982, p. 491)
 b. *Who_i did Mary cry after John hit _i?
 (Huang 1982, p. 503)

But Gibson et al. (2021) recently show that if a supporting context is provided, then island effects in tensed adjuncts is significantly ameliorated, suggesting that pragmatics plays a

role as well. Further evidence for the presence of semantic-pragmatic factors comes from the fact that the most acceptable Tensed Adjunct Island violations involve relative clauses which express assertions rather than backgrounded information. This is illustrated in (21).

- (21) a. I got to do things_{*i*} in the film that, if you did _{*i*} on the street they'd send you away Epstein (2013).
(Chaves and Putnam 2021, p. 91)
- b. I called the client who_{*i*} the secretary worries if the lawyer insults _{*i*}.
(Sprouse et al. 2016)
- c. This is the watch_{*i*} that I got upset [when I lost _{*i*}].
(attributed to Ivan A. Sag (p.c.) by Truswell (2011, pp. 175, ft.1))

Indeed, Sprouse et al. (2016) found evidence of an Adjunct Island effect in interrogatives but no such effect in relative clauses like (21b). See also (Kush et al. 2018, 2019), and Müller and Eggers (2022) for similar findings about such relatives in English and other languages. In sum, Adjunct Islands are not construction-invariant, and seem to be sensitive to semantic and pragmatic factors (Kohrt et al. 2018a; Kohrt et al. 2018b; Müller and Eggers 2022). The parallel with Subject Islands does not stop here. Repeated exposure to interrogative Adjunct Islands can lead to amelioration effects (Chaves and Putnam 2021, pp. 232, 238). This includes clausal islands like (22), which by the end of the experiment were as acceptable as grammatical controls.

- (22) Who would Amy be really happy [if she could speak to _{*i*}]?

2.3. Complex NP Constraint

There are various other island effects that are similarly not construction-invariant, and which are attenuated when extraction occurs from structures that do not express backgrounded content. Complex NP Constraint (CNPC) phenomena, illustrated in (23) in one such case.

- (23) a. *Who_{*i*} did Kim believe [the claim that Robin saw _{*i*}]?
b. *Which student_{*i*} should we report [the teacher who punished _{*i*}]?

These islands are graded, as has long been noted (Culicover 1999; Deane 1991; Erteschik-Shir and Lappin 1979; Kluender 1998; Kuno 1987). Compare (23b) with the isomorphic example in (24). Furthermore, CNPC violations ameliorate with repeated exposure, as shown by Snyder (2000), and Goodall (2011).

Erteschik-Shir (1977, chp. 2) first noted that in CNPC exceptions the matrix predicate is in general less informative than the embedded, and main verbs like *hear* and *know* are almost devoid of semantics, which makes it more likely for the main action to be conveyed by the subordinate clause. See Vincent (2021) and Vincent et al. (2022) for experimental evidence confirming that English should be counted among the languages that allow extraction from relative clauses in environments such as the one in (24).

- (24) Which kid_{*i*} did you hear [a rumor that my dog bit _{*i*}]?
(Chaves and Putnam 2021, p. 67)

This also explains why CNPC effects tend to vanish in relative clauses that express the assertion of the utterance, as in (25). See Erteschik-Shir and Lappin (1979), McCawley (1981, p. 108), Chung and McCloskey (1983) for more examples, and Kush et al. (2013) and Sprouse et al. (2016) for supporting experimental evidence. The situation is not unlike that of Subject and Adjunct Islands.

- (25) a. Which diamond ring_i did you say there was [nobody in the world who could buy __i]?
(Pollard and Sag 1994, p. 206)
- b. John is the sort of guy_i that I don't know [a lot of people who think well of __i].
(Culicover 1999, p. 230)

2.4. Factive Islands

Factive Island phenomena exhibit various kinds of circumvention phenomena. As Szabolcsi and Zwarts (1993) originally noted, when a question necessarily has a unique true (and non-negative) answer then the presence of a factive verb hampers extraction, as illustrated in (26). See Oshima (2007), Schwarz and Simonenko (2018), and Abrusán (2014) for elaborations of this conclusion.

- (26) a. #Who did Robin know that [Alex helped _ first]?
b. Who did Robin say that [Alex helped _ first]?

As a consequence, there are two ways to circumvent the effect in (26a). One way is to make the question not have a necessarily unique true answer, which can be achieved by replacing the one-time adverb *first* with any other kind of adverb:

- (27) Who did Robin know that [Alex helped _ yesterday]?

The other way to circumvent the effect is to convert the unbounded dependency to a declarative, as in (28). This means that Factive islands are not construction-invariant, since they disappear in non-interrogative extractions.

- (28) a. It was Kim who Robin knew that [Alex helped _].
b. I met the person who Robin knew that [Alex helped _].
c. KIM, Robin knew that [Alex helped _]. MIA he didn't.

But there are other, more subtle, island effects in clausal complements, illustrated in (29), where the interrogatives are not required to have a unique true answer. Here, it is the mere presence of a factive or manner-of-speaking verb that hampers extraction.

- (29) a. What did John say that Mary bought _? (Bridge verb)
b. ??What did John know that Mary bought _? (Factive verb)
c. ??What did John whisper that Mary bought _? (Manner-of-speaking verb)

Most researchers seem to agree that the explanation for these for Bridge verb effects is at least in part pragmatic, although they disagree in the details (Ambridge and Goldberg 2008; Erteschik-Shir 2006a; Kothari 2008; Liu et al. 2022), and if Tonhauser et al. (2018) and Degen and Tonhauser (2022) are correct about factivity being a matter of degree, this would explain why such island effects are fuzzy.

For example, Ambridge and Goldberg (2008) provide evidence suggesting a pragmatic explanation: the more backgrounded the proposition, the stronger the island effect. Liu et al. (2019) challenge these findings and instead provide evidence suggesting that the frequency with which verbs are used in the clausal complement frame is responsible for acceptability contrasts observed by extracting from factive and manner clausal complements. Liu et al. (2022) conjectures that discourse, semantic, and structural factors might conspire to give rise to the observed frequency distributions, which in turn give rise to acceptability ratings.³

2.5. Interim Summary

Most of the islands discussed above are not construction-invariant. They are stronger in interrogatives than in relative clauses that express assertions, for example. This suggests a common thread between the Element Constraint, Subject Islands, Adjunct Islands, Factive Islands, and the Complex NP Constraint: asserted content more readily allows extraction than backgrounded (non-at-issue content); cf. with [Erteschik-Shir and Lappin \(1979\)](#), [Kuno \(1987\)](#), [Goldberg \(2013\)](#), [Chaves and Dery \(2019\)](#), and [Abeillé et al. \(2020\)](#).

This observation allows us to make further predictions. For example, it means that extraction from parentheticals should be impossible, regardless of the construction, because parentheticals by definition express suppletive information, orthogonal to the main assertion. This prediction is borne out in the contrasts in (30) and (31).

- (30) a. The union leaders—in case you missed that article—refused to sign the contract.
 b. *It was that article that the union leaders—in case you missed _ —refused to sign the contract.
 c. *What the union leaders—in case you missed _ —refused to sign the contract was that article.
- (31) a. David Johnson—I am not sure Robin told you this—refused to sign the contract.
 b. *It was Robin who David Johnson—I am not sure _ told you this—refused to sign the contract.
 c. *Who David Johnson—I am not sure _ told you this—refused to sign the contract was Robin.

Why are island effects gradient, even in interrogative environments? [Tonhauser et al. \(2018\)](#) provides evidence that whether or not speakers commit to the content expressed by subordinate clauses is a matter of degree, as it depends on a number of factors, including the prior probability of the event that is described. If this is correct, then it would provide an explanation for why *wh*-phrases embedded in the subjects of certain interrogatives are more readily interpreted as Foci than others, i.e., more readily extracted, and so on. Another possibility is that the increase in acceptability is due to more general factors, independent of islands, which have more to do with how informants adapt to psycholinguistic tasks. I turn to this matter in the following section.

3. Satiation

As discussed above, even when the filler-gap construction type is island-inducing, it is often the case that the island effect can be attenuated with repeated exposure ([Chaves and Dery 2014, 2019](#); [Clausen 2011](#); [Do and Kaiser 2017](#); [Francom 2009](#); [Goodall 2011](#); [Hiramatsu 2000](#); [Hofmeister 2015](#); [Lu et al. 2021](#); [Snyder 2000, 2017](#)) as discussed above. To be sure, such amelioration is not consistently observed, suggesting that different results arise because different researchers have used different stimuli and different exposure rates ([Chaves and Dery 2019](#); [Hiramatsu 2000](#); [Hofmeister 2011](#); [Snyder 2017](#)). In particular, the role of stimuli design cannot be overstated. If sentences that are too complex or awkward are used, satiation is less likely to be observed ([Hofmeister 2011](#); [Hofmeister and Sag 2010](#)). Consider for example the sample of items in (32), from [Sprouse et al. \(2012\)](#).

- (32) a. *What_i do you faint if the actors forget __i on stage?
 b. *What_i do you sneeze if the dog owner leaves open __i at night?
 c. *What_i do you cough if the tourists photograph __i in the exhibit?
 d. *What_i do you laugh if the heiress buys __i at the auction?
 ([Sprouse et al. 2012](#))

Now contrast these with (33), which [Chaves and Putnam \(2021, p. 238\)](#) found induce satiation. Crucially, the adjunct clause coheres much better with the main predication because it expresses a cause that triggers the state described by the psychological predicate. In contrast, there is no obvious relation between the main predication and the conditional clause in (32).

- (33) a. Who_i would Amy be really happy if she could speak to _i?
 b. What_i would Jill get really angry if she missed _i?
 c. What_i would Allison be really upset if she forgot _i?

The low acceptability of such tensed Adjunct Island violations and their lack of satiation is likely to be due, at least to some extent, to the described propositions. For instance, people don't routinely faint when something is forgotten on stage as in (32a), or typically sneeze if dog owners leave something open at night, as in (32b). These are perfectly possible propositions, but they describe rather unusual situations. The event described by the matrix predication does not cohere particularly well with that of the adjunct's predication. In order to avoid this kind of problem, one would have to norm the declarative counterpart of these items, to ensure that all are equally felicitous and plausible.

The amelioration effect caused by repeated exposure is referred to as *syntactic satiation*, in analogy to the phenomenon of semantic satiation, whereby repetition causes a word or phrase to temporarily lose meaning for the listener. There are two problems with this terminology. First, it is perfectly reasonable that the increase of acceptability is caused by semantic and pragmatic factors, over and above syntactic factors. Second, whereas semantic satiation is a fairly well-understood general reactive inhibition phenomenon (a bottom-up processing process associated with lower level neural mechanisms of inhibition), the increase of acceptability during sentence processing is selective: certain island violations robustly ameliorate with repetition, whereas others simply do not, as discussed above. In contrast, repetition of any lexical item can induce the semantic satiation effect. Syntactic satiation seems to be facilitatory in nature, rather than inhibitory, because repeated exposure to island violations does not lead to loss of sentence meaning. Thus, comprehension question accuracy does not decline as island effects ameliorate.

A more concerning problem is that it remains unclear what syntactic satiation actually amounts to. It could be a form of adaptation, caused by changes in the activation of the representations in declarative memory (i.e., a form of priming), residual activation (the mechanism that accounts for priming), a change in the procedural knowledge required to construct the relevant structures (adaptations to the parsing strategy), or belief-updating (violated expectations lead to probabilistic updates, under a Bayesian interpretation).

3.1. Adaptation

Sensory input is typically noisy and ambiguous, and individuals respond to the challenges created by such variation by using probabilistic expectations ([Anderson 1990](#); [Gigerenzer et al. 1999](#); [Newell and Simon 1972](#)). For example, infants already exhibit the ability to integrate prior beliefs, knowledge, and expectations about human actions with new evidence provided by the environment ([Xu and Kushnir 2013](#)), and use new evidence to modify their prior expectations ([Brandone et al. 2014](#)). Linguistic input is particularly noisy, ambiguous, and variable across individuals and contexts, and therefore it is expected that speakers can adapt to the contingencies of the input. This would enable individuals to make heuristic predictions and robustly cope with such a dynamic linguistic input. For example, it is known that comprehenders create expectations about upcoming words ([Altmann and Kamide 1999](#); [Arai and Keller 2013](#); [Creel et al. 2008](#); [DeLong et al. 2005](#); [Kutas and Hillyard 1984](#); [Metzing and Brennan 2003](#)), about upcoming lexical categories ([Gibson 2006](#); [Levy and Keller 2013](#); [Tabor et al. 1997](#)), and about syntactic structures ([Farmer et al. 2014](#); [Fine et al. 2010, 2013](#); [Fine and Jaeger 2013](#); [Kamide and Mitchell 1997](#); [Lau et al. 2006](#); [Levy 2008](#); [Levy et al. 2012](#); [MacDonald et al. 1994](#); [Malone and Mauner 2018](#); [Stack et al.](#)

2018; Staub and Clifton 2006; Wells et al. 2009), among other modalities of linguistic input. In what follows I will provide a brief survey of this literature and the controversy therein about the nature of adaptation. See Kaan and Chun (2018) for a detailed overview.

3.2. Adaptation in Garden-Path Sentences

Fine et al. (2010), Kamide and Mitchell (1997), Farmer et al. (2014) and others provide evidence suggesting that syntactic expectations are malleable and quickly adapt to changes in the input. Fine and Jaeger (2013) argue that repeated exposure to *a priori* unexpected structures can reduce, and even completely invert, their processing disadvantage, and *a priori* expected structures can become less expected (even eliciting garden paths) in environments where they are hardly ever observed. As illustrated in (34), past participle verb forms often give rise to a temporary ambiguity between a main verb parse like (34a), and a relative verb parse, seen in (34b). However, (34a) and (34b) differ in that the latter consistently elicits a garden-path effect, because the main verb use of *warned* is much more likely than the relative verb use according to corpora evidence (Roland et al. 2007). This effect has been detected by various researchers, including Stack et al. (2018), Malone and Maurer (2018), Prasad and Linzen (2019, 2021), Dempsey et al. (2020).

- (34) The experienced soldiers . . .
 a. . . warned about the dangers before the midnight raid.
 b. . . warned about the dangers conducted the midnight raid.

But by making the relative verb use more frequent than the main verb use in a controlled experiment, Fine and Jaeger (2013) found that the garden-path effect can flip: the relative verb parse becomes the default preferential parse, and the main verb parse becomes dispreferred. By the end of the experiment, sentences like (34b) no longer exhibit a garden-path effect because the relative verb parse is now the most frequent and preferential parse, whereas sentences like (34a) now yield a garden-path effect. The latter is called a *reverse ambiguity effect*. Fine et al. (2013) argue that comprehenders adapt to the statistics of the current linguistic environment by generating expectations that reflect the distribution of actual events in the environment. This rational strategy allows comprehenders to reduce the average prediction error experienced during processing.

More recently, Lu et al. (2021) provide evidence suggesting that comprehenders can exhibit speaker-specific satiation to Subject Islands, and argue that syntactic satiation in island phenomena is a form of Bayesian learning *a la* Fine et al. (2010).

The reverse ambiguity effect that penalizes *a priori* preferred structures found by Fine and Jaeger (2013) seems to be elusive, however. It was replicated by Sikos et al. (2016), but not by Stack et al. (2018). See also Jaeger et al. (2018) for a response. Now, it is worth pointing out that these studies used different experimental items, different numbers of participants, different amounts of exposure, different compensation levels for participants, and different statistical methods. As I will discuss below, at least some of these may play a crucial role in promoting adaptation.

Second, although the reading times of garden-path sentences decreased in all of the aforementioned studies, this also happened for all other sentences, including controls that were not temporarily ambiguous. In fact, there is independent evidence that reading times generally decrease exponentially as a function of practice (Heathcote et al. 2000). Given this evidence, Stack et al. (2018), Prasad and Linzen (2019, 2021), and Dempsey et al. (2020) argue that the reduction in reading time due to syntactic adaptation is confounded with a more general adaptive phenomenon, called *task adaptation*: adaptation driven instead by increased familiarity with the experimental procedure, rather than by syntactic structure. For Dempsey et al. (2020), task adaptation is what is commonly referred to as syntactic satiation. The latter does not directly depend on the syntactic structure of the sentence, and could be due to a number of factors, such as word frequency, plausibility, predictability, and syntactic disambiguation difficulty.

3.3. Syntactic Satiation as Adaptation in Islands

For [Brown et al. \(2021\)](#) syntactic satiation in islands is a form of task adaptation, and has nothing to do with grammar or island phenomena. In their experiments, only the items with intermediate acceptability became more acceptable, and they did so only at the beginning of the experimental session, regardless of syntactic construction. However, other island satiation studies find different patterns. For example, [Hiramatsu \(2000\)](#) found Subject Island satiation with 7 exposures but not with 5. This should be impossible if satiation mainly occurred at the beginning of the experiment. Similarly, [Hofmeister \(2015\)](#) found that Adjunct Islands satiate after 8 exposures but not before (this experiment replicated); see [Chaves and Putnam \(2021\)](#), p. 232) for details. None of these results are expected if satiation is mainly located at the beginning of the experiment.

What is more, different conditions usually satiate at different rates, contrary to the generalization put forth by [Brown et al. \(2021\)](#). In (35) are examples of item types used by [Hofmeister \(2015\)](#).

- (35) a. Just a few years ago, Mosul was a city which terrorists would have thought twice before attacking.
[Adjunct Island condition]
- b. Just a few years ago, terrorists would have thought twice before attacking the city of Mosul.
[Non-island condition]
- c. The rebels in the jungle captured the diplomat who pleaded with the villagers after they threatened to kill his family for not complying with their demands.
[Right-branching]
- d. The diplomat who the rebels who were in the jungle captured pleaded with the villagers after they threatened to kill his family for not complying with their demands.
[Center-embedded]

Linear Mixed-Effect models with acceptability as the dependent variable and the presentation order as the predictor (allowing the intercept to be adjusted by list and item, as random effects) reveal that the acceptability center-embedding condition increased significantly as the experiment progressed ($\beta = 0.02$, $SD = 0.005$, $t = 4.042$, $p < 0.0001$), as did the adjunct island condition ($\beta = 0.01$, $SD = 0.004$, $t = 3.89$, $p = 0.0001$), whereas the right-branching condition did not ($\beta = -0.01$, $SD = 0.005$, $t = -0.19$, $p = 0.84$). The non-island condition improved as well, but the effect size was much the smallest ($\beta = 0.007$, $SD = 0.002$, $t = 2.66$, $p = 0.007$). This is seen in [Figure 1](#).

Crucially, the right-branching condition received middle ratings, and yet did not experience any acceptability changes. Moreover, adjunct island items (at the very bottom of the acceptability range) only rise sharply and consistently in the last two thirds of the experiment. These results are unexpected for [Brown et al. \(2021\)](#).

As a final example, consider the satiation patterns of three different types of clausal adjuncts from the data in [Chaves and Putnam \(2021\)](#), p. 238), shown in [Figure 2](#). Again, extractions from one item type (in this case, conditional clauses like (22) above) exhibit a more consistent trajectory than the others. Again, these results challenge the generality of the conclusions of [Brown et al. \(2021\)](#).

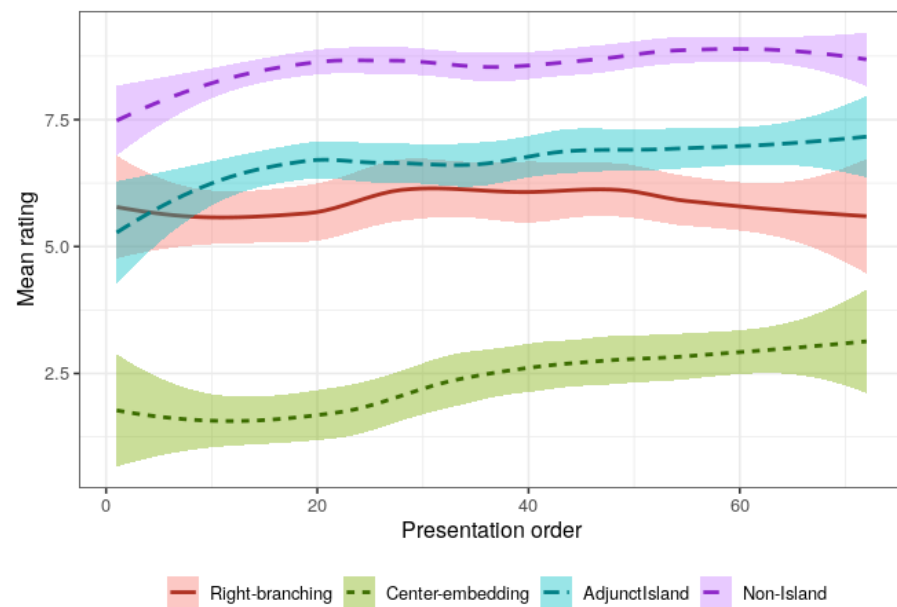


Figure 1. Differential effect of repeated exposure in Hofmeister (2015).

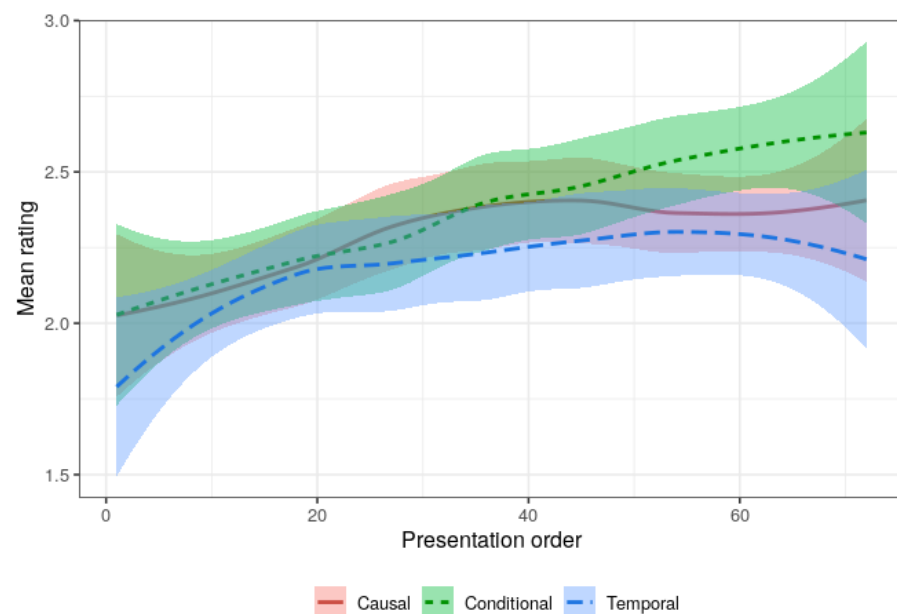


Figure 2. Effect of repeated exposure in Clausal Adjuncts in Chaves and Putnam (2021, p. 238).

Prasad and Linzen (2021) suggest that sentences that are difficult to process undergo a sharper rate of task adaptation than easier sentences, which in turn overwhelms the effect of syntactic adaptation, if any exists. They argue that the effect of syntactic adaptation is very small, and required very large numbers of participants (around 1000). If this is the case, then there should be a correlation between acceptability and the satiation coefficient. To test this hypothesis, data from three separate experiments was used. First, the clausal adjunct island satiation data mentioned above (Chaves and Putnam 2021, p. 238) were obtained and the (significant) satiation coefficients, per item, were compared with the respective mean acceptability ratings. The correlation was not significant ($t = 2.06, p = 0.13$), and had it been significant, it would have been positive, not negative. Next, the significant satiation coefficients from the Adjunct Island violations in Hofmeister (2011) were also computed, by item, as above, and correlated with the respective mean acceptability ratings. Again, no

significant correlation was found ($t = -0.28, p = 0.79$). The same was done for the Subject Island satiation data from [Chaves and Dery \(2019\)](#), [Chaves and Putnam \(2021, p. 212\)](#), and again the correlation was not significant ($t = 1.12, p = 0.34$). These results are the opposite of what [Prasad and Linzen \(2021\)](#) would predict if these island satiation effects affected low acceptability sentences more than high acceptability sentences. And if more extreme island violations do not satiate more, then island satiation cannot amount to just task adaptation, according to the logic of [Prasad and Linzen \(2021\)](#).

3.4. Disentangling Task Adaptation from Syntactic Adaptation

[Malone and Maurer \(2020\)](#) develop a new approach to decoupling syntactic adaptation from task adaptation, and show that the former is detectable without large numbers of participants, and robust. In a nutshell, they propose that the effect of task adaptation is dealt with by using *Task-Adapted Reading Times* (TART). These are conceptually similar to residual reading times that correct for the effect of word length on reading speed within individual participants. The TART procedure uses the speed-up in reading times in the distractor items as a proxy for task adaptation. The assumption is that as distractors are structurally unambiguous, uncomplicated sentences, any reduction in reading times over the course of the experiment should (i) not be due to syntactic adaptation, and (ii) be due to task adaptation, as participants mechanically or cognitively adjust to the task. Distractor regions 4 through 11 were selected, and regressed onto stimulus order (not critical item order) for each participant. Because these regressions do not include critical items, and no learning should occur in distractors, this method can measure task adaptation, unconfounded with syntactic adaptation.

As TART involves regressing reading times over distractor item order, the first step is to correct reading times in the selected region of analysis by residualizing reading times to correct for word length. The second step is to then regress item order over the length-corrected distractor reading times discussed above, with participant as a random factor. The result should be a model that captures the unique rate of increase in reading time over the course of the experiment for each participant. These TART values are then subtracted from the reading times of each of the critical item regions, and the resulting reading times are residualized based on word length, per region and participant, as is standard ([Trueswell and Tanenhaus 1994](#)). The new reading times, now adjusted for both character length and participants' unique increase over time due to irrelevant task adaptation, are now ready to be fit in the primary analytic regression model. If distractors are structurally diverse, unambiguous, and uncomplicated sentences, then all syntactic adaptation must come from the regularities in the critical items.

3.5. The Role of Reward

It is now well-known that learning requires attention, alertness, and focus, and that predicted reward (dopamine) can not only help engage these systems but also promote synaptic plasticity by enhancing long-term potentiation and depression ([Legenstein et al. 2008](#); [Otmakhova and Lisman 1996](#); [Reynolds et al. 2001](#); [Schultz 1998](#)). It follows that adaptation in language processing should be sensitive to the predicted reward, not just to structural frequency and task adaptation. There is currently no standard for the compensation of participants in psycholinguistics experiments, and perhaps this is a problem. For example, [Fine et al. \(2010\)](#) compensated participants with course credit, [Fine and Jaeger \(2013\)](#) paid participants \$10, [Stack et al. \(2018\)](#) paid \$4, [Dempsey et al. \(2020\)](#) paid \$3, and [Prasad and Linzen \(2021\)](#) paid \$6.51 per hour. It is therefore possible that these participants experienced different levels of motivation and focus while performing this task, which had an effect on the probability of learning regularities in the items. As [Christianson et al. \(2022\)](#) show, both online and offline measures of processing and comprehension are susceptible to focus and motivation levels, leading to results that are not reflective of normal human language processing.

To probe for the effect of the predicted reward and provide independent support for the TART methodology, an experiment was designed and conducted to determine whether syntactic adaptation is sensitive to the predicted reward, over and above structural frequency. I focused on a garden-path effect rather than on an island because there is no question that such constructions are grammatical, and all of the literature on task adaptation has focused on garden-paths. Future work should probe island constructions.

4. TART Reward Experiment: Adaptation to Complex Sentences

4.1. Methods

Subjects

In this between-subjects experiment, 100 participants with US-based IP addresses were recruited via the Amazon Mechanical Turk marketplace, all of which self-reported as having grown up speaking English as a first language via a language questionnaire conducted after the experiment concluded. Participants were informed that their responses to the language questionnaire had no bearing on their compensation.

Only subjects with at least 98% approval rating from previous jobs and with over 10k previous tasks approved were allowed to participate. Participants were told the experiment consisted of reading 32 sentences and answering yes/no comprehension questions correctly. Participants were compensated with \$2.4 for their participation.

Participants were randomly assigned to either the Control group or the Bonus group. All participants were informed that the experimenters might not be able to compensate them if their comprehension accuracy dipped significantly below 70%, although in practice no participants were excluded from compensation. The individuals from the Bonus group saw additional text and instructions informing them that if their comprehension question accuracy was above 75%, they would receive a bonus of \$4.80, for a total of \$7.2. The participants from each group saw the same stimuli.

Ethics statement

This study was conducted with the approval of the Institutional Review Board of the University of the State of New York at Buffalo. All participants gave their informed written consent.

Materials

A total of 16 items were constructed, all of which exhibited the classic subject/object ambiguity in (36), whereby a noun phrase (underlined) is a temporally plausible object of the preceding verb, but is in fact the subject of the following main verb (bold font) (Christianson et al. 2001; Ferreira and Henderson 1990; Frazier and Rayner 1982; Jacob and Felser 2016).⁴ This late closure parse is well-known to be susceptible to priming, as reflected behaviorally by decreased reading times (Noppenny and Price 2004; Traxler 2015), and physiologically by attenuated responses in the left temporal pole (Noppenny and Price 2004).

- (36) a. After ₁ | the ₂ | Mayor ₃ | visited ₄ | the ₅ | patients ₆ | **were** ₇ | moved ₈ | to ₉ | different
₁₀ | rooms. ₁₁ |
 [The Mayor paid a visit after the patients were moved. True or False?]
- b. While ₁ | the ₂ | customers ₃ | ate ₄ | some ₅ | food ₆ | **was** ₇ | cooking ₈ | on ₉ | the ₁₀ |
 grill. ₁₁ |
 [The customers ate only after all the cooking was done. True or False?]

Half the items were disambiguated by 'was'; the other half by 'were'. The prepended adverbs were 'after', 'although', 'as', 'though', 'when' and 'while', evenly distributed across items. To maximize the garden path effect, the subordinate verbs came from a subset of verbs from Ferreira and Henderson (1991) and Staub (2007) that had the highest proportion of transitive uses relative to intransitive uses, according to both (Gahl et al. 2004) and to a corpus study using the Corpus of Contemporary American English (Davies 2008). The 16 items were pseudo-randomized and interspersed with 16 distractors, illustrated in (37). The

latter used the same prepended adverbs (plus the adverbs ‘because’, ‘if’ and ‘whenever’), evenly distributed across distractors, and a variety of verbal structures different from the items. Across items and distractors, no two stimuli contained the same verb, as to avoid priming effects caused by verb repetition (Fine and Jaeger 2016; Traxler and Pickering 2005). Although all participants in the experiment saw the same stimuli, no two participants saw the same order of stimuli.

- (37) a. Though₁ | the₂ | bus₃ | driver₄ | missed₅ | a₆ | street₇ | Sue₈ | was₉ | at school₁₀ | on time.₁₁ |
[Sue brought a child home after the bus missed its stop. True or False?]
- b. If₁ | the₂ | radar₃ | is₄ | correct₅ | the₆ | storm₇ | will₈ | be₉ | here₁₀ | tomorrow.₁₁ |
[The radar data can be used to make predictions about the weather. True or False?]

Procedure

Subjects read sentences in a self-paced moving window display (Just et al. 1982), using the self-paced reading mode of the PCIBex platform (Zehr and Schwarz 2018). Three practice trials were conducted before the experiment proper started. All experimental items were followed by a Yes/No comprehension question probing the lingering of the initial interpretation. The form of the comprehension questions varied from item to item, to prevent participants from strategizing how to answer the comprehension questions. The correct answer was “yes” half of the time, and after submitting each answer participants were informed about whether their selection was correct or not. The stimuli were pseudo-randomized so that no two participants saw the items in the same order and no more than two critical items were allowed to immediately follow each other. Participants took an average 15 min to complete the experiment, meaning that Control group participants were paid at an hourly rate of about \$9.4 while the Bonus group participants were paid at a \$28.8 hourly rate.

Filtering

Participants with comprehension question accuracy below 75% were excluded, resulting in 12% of data loss (11.3% data loss for the Control group, and 11.2% for the Bonus group). Only distractors were used for this participant exclusion criterion, since it is expectable that comprehension questions about garden-path sentences are harder to answer than comprehension questions about non-ambiguous sentences (Dempsey et al. 2020). Finally, all observations with reading times lower than 100ms and longer than 2000ms were removed, excluding 1% of all observations. The results are qualitatively similar if reading times are unfiltered, or if reading times are log-transformed.

4.2. Results

The mean accuracy of the Control group was 89% (SD = 0.3) and 90% (SD = 0.29) for the Bonus group. Logit models with accuracy as the dependent variable and item order as the predictor were fit for each participant group, revealing that item accuracy increased for the Bonus group during the experiment ($\beta = 0.04$, SE = 0.01, $z = 3.73$, $p = 0.0001$), but not for the Control group ($\beta = 0.01$, SE = 0.006, $z = 1.67$, $p = 0.09$). This suggests that the Bonus group participants became better at interpreting the sentences in the experiment correctly, but Control group participants did not. Also, the control group read distractors about 10 ms faster than the Bonus group, per exposure.

In order to avoid the usual convergence problems of Linear Mixed-Effect models, power concerns, and the well-known limitations of frequentist significance testing (Kruschke 2015; Lavine 1999; Sorensen et al. 2016), Bayesian Linear-Mixed effect models were fit, using the BRMS package (Bürkner 2017). The dependent variable was the task-adapted length-corrected residual reading times (TART), with item presentation order, participant group and their interactions as predictors, allowing for the intercept to be adjusted by

participant and item. The model had a flexible threshold and weakly informative priors, and was checked for convergence ($\hat{R} = 1$) after fitting with four chains and 2000 iterations, half of which were the warm-up phase. A significant interaction between participant group and item order (1–16) was found at the spill-over region 8 (see Table 1):

Table 1. Coefficients for the effect on TARTs from the interaction between Control/Bonus reward group and the item order, per region, according to Bayesian Mixed-effect models.

Region	$\beta_{item.order \times group}$	Estimated Error	95% Credible Interval	$P(\beta < 0)$
7 (was/were)	0.06	1.05	[−1.71, 1.78]	0.48
8 (V)	−1.49	0.96	[−3.11, 0.08]	0.94
9 (P)	−0.13	0.68	[−1.25, 1]	0.57

Plots illustrating the TART values in regions 7 through 10 are shown in Figure 3.

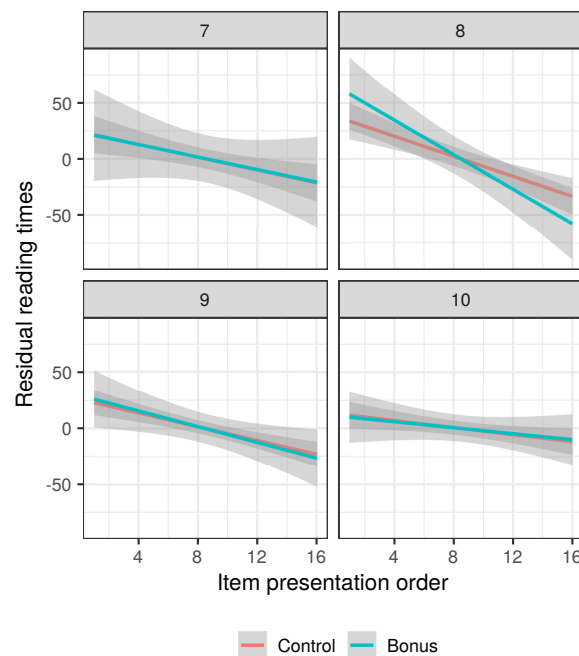


Figure 3. Effect of repeated exposure and reward differential in spill-over region 8.

For completeness, a region-by-region plot with the plain residual reading times is provided in Figure 4. The behaviour of the two groups of participants was generally the same, except that the Bonus group slowed down at region 5 (approaching the critical region), and exhibited greater variability than the Baseline group, which is consistent with participants being more attentive and taking greater care to perform the task.

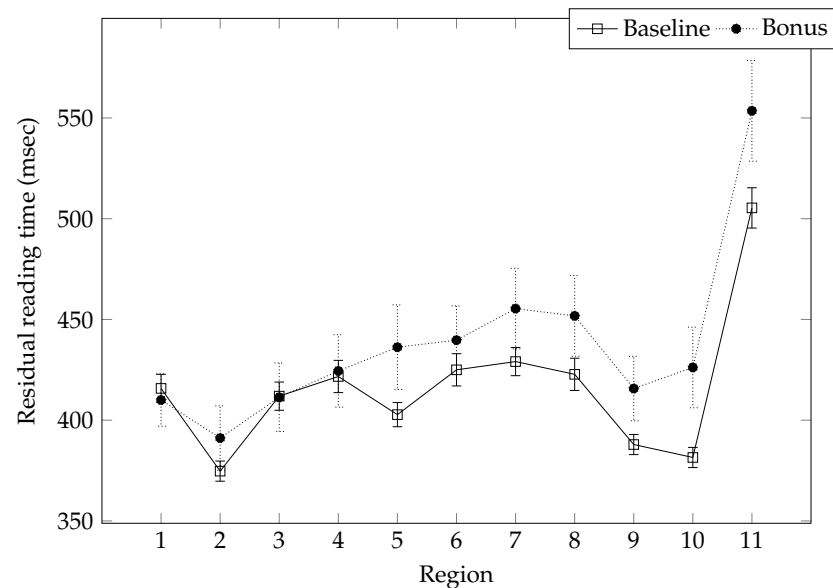


Figure 4. Mean residual reading times for all sentence regions.

4.3. Discussion

The results suggest that participants in the Bonus group used cues in the input to predict the upcoming structure and adapted strategically to the critical items faster than the Control group participants did. Frequency can compound with reward, and speed up sentence processing of complex sentences, in this case, a classic garden-path construction.

It is possible that studies that found null effects in garden-path adaptation (and in island adaptation) were caused by factors that usually are not controlled for: the complexity of the items, their naturalness (norming their non-extracted counterparts would address that), the motivation and focus that participants experience when performing a rather repetitive and artificial task (assigning numbers to sentences, or reading sentences in moving displays), as pointed out by [Christianson et al. \(2022\)](#). To be sure, further research is necessary in order to investigate this matter in more detail, but if it turns out that reward does in fact modulate syntactic adaptation, then a new tool can be added to experimenter's toolkit, which can reduce the chances of null effects caused by low motivation and focus, due to low perceived reward.

5. Conclusions

It is increasingly clear that most island effects are not construction-invariant ([Abeillé et al. 2020](#)). Constructions that express assertions tend to yield weaker island effects, for example. Moreover, even in constructions where strong island effects are observed, these are far from categorical. In the present work I have drawn attention to a wide range of factors that likely contribute to that gradience. First, the complexity of the items and the plausibility of the expressed propositions likely plays a role ([Hofmeister and Sag 2010](#)). Second, the number of exposures often has an effect, in that it can sometimes cause acceptability ratings to rise. Sometimes that acceptability increase is restricted to the first exposures, sometimes it is not. It is a highly dynamic phenomenon. The acceptability increase instigated by repeated exposure is also selective, in that it does not always affect all sentence types equally. In particular, there is no correlation between sentence acceptability and rate of acceptability change.

The mechanism that drives the amelioration effects remains poorly understood, but extant evidence suggests that speakers are highly sensitive to the items themselves, so that sentences that are excessively complex, or lack semantic plausibility, or require unusual contexts in order to be felicitous in discourse are less likely to improved with repeated

exposure. The amount of exposure also seems to matter, since a number of studies found thresholds after which acceptability increases are observed (Snyder 2021). A survey of the literature on syntactic/task adaptation suggests that syntactic satiation is likely to consist, at least in part, of syntactic adaptation (Fine et al. 2010). This is consistent with the notion that the grammar is gradient and flexible (Francis 2022).

Finally, the present paper puts forth a new factor that can promote adaptation to complex syntactic structures: predicted reward. The underlying mechanism is straightforward: the more motivated and focused the comprehenders are, the faster they can adapt to unusual and complex input, over and above the effect of frequency and task adaptation. This can shed light on why syntactic adaptation – in garden-paths and in certain islands – is not systematically observed in experimental research (Christianson et al. 2022; Kaan and Chun 2018).

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Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Notes

- ¹ The traditional view whereby islands are categorical and construction-invariant is still the norm in generative circles, e.g., Željko Bošković (2017), Shafiei and Graf (2020), and many others, though some researchers have more recently come to embrace gradience, like Villata et al. (2019).
- ² Levine (2017, pp. 309–13) points out a possible counterexample to the Conjoint Constraint, shown in (i), in which *succeed* is extracted from the first conjunct VP. But attestations like (j) suggest that (i) may be a special asymmetric disjunction construction in which the reference of the missing subject in the second conjunct is determined anaphorically, rather than via VP coordination.
 - i. [Succeed] he [[must _] or [be forever shamed]].
 - j. [[Choose wisely] or [be forever shamed]].
- ³ If pragmatics plays a role, this would explain the puzzle raised by Liu et al. (2022) that the matrix verb seems to play a larger role in acceptability than the embedded verb. That is, *What did John say that Mary muttered?* is more acceptable than *What did John mutter that Mary said?* because the latter requires a more unusual context in which John muttered that Mary said something is part of the common ground. This is may be simply a matter of contextualization difficulty (Erteschik-Shir 2006a; Kothari 2008).
- ⁴ All stimuli are available at ...

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