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REGULAR ARTICLE

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Abstract

Recent research in psycholinguistics supports the hypothesis that retrieval from working memory is a key component of establishing syntactic dependencies in comprehension. This can result in so-called grammatical illusions. These illusions have been modeled as the result of a content-addressable retrieval process in sentence comprehension that allows grammatically inaccessible licensing elements to be reactivated, creating a spurious perception of acceptability. This article reports five studies that establish the existence of a new grammatical illusion involving quantification at a distance and the licensing of so-called *de* NPs in French. Our results suggest that this grammatical illusion is interestingly constrained by syntactic properties of the licensors. Specifically, quantifiers that independently participate in quantification-at-a-distance constructions were seen to create grammatical illusions to a greater extent than quantifiers that do not participate in that construction. Consistent with previous work on the nature of cues in memory retrieval, we suggest that this is the result of fairly specific abstract syntactic cues that guide retrieval of a licensing element. This article thus

brings further evidence that syntax is crucially used to structure working memory over the course of a parse.

KEYWORDS
quantification at a distance, grammatical illusions, cue-based parsing

1 | INTRODUCTION

One of the central tasks in language comprehension is the process of establishing linguistic dependencies between elements in a sentence. For example, to understand the sentence *Linda, whose office is near room N400, often drinks herbal tea*, it is necessary to integrate the subject phrase *Linda* with the verb *drinks*. Psycholinguistic research into this basic process suggests that the process of establishing dependencies in comprehension relies on *memory retrieval*: upon reaching the verb, the comprehender uses a set of *retrieval cues* that reactivate the desired dependent in working memory. Generally, this process of cue-based retrieval works via a process of feature matching against the contents of working memory (R. Lewis & Vasishth 2005, R. Lewis et al. 2006, Vasishth et al. 2008, Van Dyke & McElree 2011). This often means that syntactic constraints on dependency formation are deployed alongside semantic constraints, although there remain substantial open debates about the priority of syntactic cues over semantic or morphological cues (Dillon et al. 2013, Jäger et al. 2020).

This mechanism of establishing linguistic dependencies predicts the existence of *illusions of grammaticality*, otherwise known as *grammatical illusions* (Phillips et al. 2011). Such an illusion occurs when an ungrammatical dependency appears well formed due to the presence of a syntactically inaccessible but semantically appropriate licensing element (Vasishth et al. 2008). Grammatical illusions are a case of misalignment between grammaticality and acceptability, and as such, they have been argued to provide a window into the architecture of the language system (Phillips et al. 2011).

In this article we use offline-judgment methodology to establish the existence of a new grammatical illusion, illusory *de*-NP licensing in French. Across four studies we show that illusory *de*-NP licensing in French arises when a licensing quantifier linearly precedes but does not c-command the *de* NP. We hypothesize that licensing *de* NPs in processing involves a memory-retrieval operation to identify a licensor. We propose that this retrieval may reactivate a nonlocal quantifier even if the quantifier does not c-command the *de* NP. However, our results suggest that this grammatical illusion only arises for quantifiers that, among other things, independently participate in quantification-at-a-distance (QAD) constructions in French. Our results from *de*-NP illusions thus suggest that these memory-retrieval operations are guided by fairly abstract syntactic cues, despite their lack of sensitivity to c-command relations. Building on work on the structure of QAD and quantifiers in French, we propose that these syntactic cues index the structure of some (but not all) *de*-NP-licensing quantifiers. This thus allows us to tie the varying degrees to which quantifiers give rise to intrusive licensing to other asymmetries in the syntax of these quantifiers.

We now turn to a discussion of grammatical illusions and present the specific construction we investigate in this article. Because we will show that syntax is key to understanding our results, we review both descriptive and theoretical work on the relevant grammatical construction. Finally,

we discuss relevant approaches to how grammatical illusions have been argued to arise. In sections 2–7, we present our experimental results, which (i) establish the existence of this novel grammatical illusion, and (ii) show that it only arises in certain syntactic conditions. In section 8, we discuss our results against the background of previous models of grammatical illusions and the grammatical properties of this construction. This leads us to build on previous accounts to construct our own analysis of how the grammatical illusion we observed arises. Section 9 concludes.

1.1 | What is a grammatical illusion?

Broadly speaking, grammatical illusions arise when an ungrammatical sentence sounds acceptable, at least at first blush (Phillips et al. 2011). For instance, consider the sentences in (1). On standard treatments of negative-polarity items (NPIs; Ladusaw 1979), (1a) is grammatical because the NPI *ever* is in the scope of a downward-entailing operator *no* (i.e., *no* c-commands the NPI). This is not true in (1b); hence the sentence is predicted to be ungrammatical. However, the sentence in (1b) is judged more acceptable than the minimally different ungrammatical sentence without *no*, namely (1c); compare the grammatical sentence in (1a). Similarly in event-related-potential measures (Drenhaus et al. 2004) and eye-tracking measures (Vasishth et al. 2008), less disruption is seen at the NPI in (1b) than (1c).

(1) NPI illusions
   a. **No** man who had a beard was **ever** thrifty.
   b. *A man who had **no** beard was **ever** thrifty.
   c. *A man who had a beard was **ever** thrifty.
   (Vasishth et al. 2008)

The finding of increased acceptability and concomitant eased processing is the evidence for an illusion of grammaticality in (1b).

This phenomenon is not limited to NPI licensing. Similar effects obtain with subject–verb agreement in a range of languages (English: Wagers et al. 2009, Dillon et al. 2013; Spanish: Lago et al. 2015; Arabic: Tucker et al. 2015) and with reflexive licensing (Parker & Phillips 2017, Sloggett 2017, Jäger et al. 2020). Other potentially similar grammatical illusions are comparative illusions (Wellwood et al. 2018) and the so-called missing-VP illusion (Frazier 1985, Gibson & Thomas 1999).

One way of understanding the NPI illusion, descriptively, is that an item in need of licensing, for example, *ever* in (1b), spuriously appears to be licensed because the presence of a grammatically inaccessible licensor, for example, *no* in (1b) somehow creates the illusion of a well-formed dependency between the NPI and the quantifier. One hypothesis for the underlying source of this phenomenon attributes it to a memory-retrieval process that is used to establish the dependency between the NPI and its licensor. This hypothesis is rooted in the observation that working-memory-retrieval processes form an integral part of incremental language processing (McElree et al. 2003, R. Lewis et al. 2006, McElree 2006, Phillips et al. 2011, Parker & Phillips 2017). Broadly speaking, these models adopt a content-addressable-memory architecture for the parser and propose that the retrieval mechanism that activates representations when they are necessary during processing operates in a cue-based fashion. This means that in order to retrieve or reactivate some encoding from earlier in the sentence, all representations

stored in memory are probed simultaneously to evaluate how well they match a set of features specified by the retrieval "cues." The degree of match between the retrieval cues determines which representations are likely to be reactivated, as well as how easily this process will proceed.

Content-addressable models of cue-based retrieval have been successful at accounting for many types of grammatical illusions. For example, suppose that the NPI *ever* initiates retrieval in working memory of a licensing element. Plausible retrieval cues for this process are [+downward entailing] (i.e., a semantic constraint) and [+c-commanding] (i.e., a syntactic constraint).[1] In (1b) there is a situation of partial cue match: the inaccessible licensor *no* has the correct semantic feature, but it does not match the syntactic cue. However, this partial feature match makes it possible that the inaccessible licensor will be retrieved from time to time. When it is, the sentence will appear well formed, at least temporarily. There are multiple distinct implementations of this core idea: we refer the reader to Van Dyke 2007 and Vasishth et al. 2008 for two different formalizations of this process.

Because these models attribute the NPI illusion in (1b) to a feature of the working-memory systems used to establish linguistic dependencies during parsing, they lead us to expect that these effects should be fairly general across languages and across constructions. For instance, the ungrammatical sentence in (2b) is consistently rated higher than the ungrammatical sentence in (2c) (Wagers et al. 2009, Parker & Phillips 2017, Hammerly et al. 2019).

(2) a. The keys to the cabinet are on the table.
b. *The key to the cabinets are on the table.
c. *The key to the cabinet are on the table.

The explanation for this grammatical illusion under the cue-based account is the same: the parser initiates retrieval at the verb for a plural-marked, grammatically available agreement controller. In (2b) we find a partial feature match to this retrieval probe with the word *cabinets*, thus making the sentence more acceptable even though the word bearing the cue is not in a grammatically accessible position. Similar effects have been reported across a range of languages, including Spanish (Lago et al. 2015), Turkish (Lago et al. 2019), Armenian (Avetisyan et al. 2020), Arabic (Tucker et al. 2015), and Russian (Slioussar 2018).

Work on grammatical illusions has explored the conditions that give rise to these effects: see Parker & Phillips 2016 and Orth et al. 2021. For example, Parker & Phillips showed that NPI illusions can be turned on or off by modulating the linear distance/time between intrusive licensor and NPI. In (3b), for instance, illusory licensing was not observed when a parenthetical, such as *as the editors mentioned*, intervened between *no* and *ever*, but it was observed when the parenthetical was sentence initial, in (3a).

(3) a. *As the editors mentioned, the authors [that **no** critics recommended for the assignment] have **ever** received a pay raise.
b. *The authors [that **no** critics recommended for the assignment] have, as the editor mentioned, **ever** received a pay raise.

[1]We set aside here the question of whether configurational cues such as [+c-commanding] can be straightforwardly specified in a cue-based architecture, but we refer the reader to Cunnings & Sturt 2014, Dillon 2014, Kush et al. 2015, and Kush et al. 2018 for further discussion.

Interestingly, Parker & Phillips found that linear distance/time did not have any effect on agreement attraction: increased acceptability was observed in both (4a) and (4b).

(4) a. *According to the janitor, the key to the **cabinets** probably **were** destroyed by the fire.
b. *The key to the **cabinets,** according to the janitor, probably **were** destroyed by the fire.

They propose that the difference in illusion profile comes down to a difference in memory encoding between syntactic and semantic/pragmatic representations. But they note that grammatical illusions could, in principle, reflect either an error in how we mentally encode structured linguistic representations in memory or an error in how we later access information in those representations.

As mentioned, one important feature of the cue-based model is that it predicts that these effects should be rather pervasive across constructions and languages. This is the starting point for our investigation. We look at ungrammatical constructions like (5b) in French. As in (1), in the examples in (5) there is an element that needs to be licensed; here it is the *de* NP *de livres* 'de books'. As we detail in section 1.2, this *de* NP needs to be licensed by a quantifier, as it is in (5a). The ungrammatical sentence in (5b), on the other hand, is superficially analogous to the ungrammatical NPI sentence in (1b). In (5b) and in the more acceptable (1b), there is an element that needs to be licensed—*ever* or *de livres*—but the licensor—*no* or *beaucoup*—though present, is in a grammatically inaccessible position.

(5) a. J' ai donné à des associations **beaucoup de livres.**
I have given to INDF.PL charities a_lot *DE* books
'I gave away a lot of books to charities.'
b. *J' ai donné à **beaucoup** d' associations **de livres.**
I have given to a_lot *DE* charities *DE* books

The analogy between NPI illusions and the configuration in (5b) is not perfect, however. While in an intrusive-NPI sentence there is one NPI that needs to be licensed but no accessible licensor, in the French examples here there are two *de* NPs in need of licensing and only one licensor.[2]

In this study, our main empirical question is whether speakers of French find the ungrammatical sentence in (5b) significantly more acceptable than the following unacceptable and ungrammatical sentence.

(6) *J' ai donné à des associations **de livres.**
I have given to INDF.PL charities *DE* books

Such an effect would constitute a grammatical illusion for *de* NPs analogous to NPI illusions, insofar as it is the presence of the structurally inaccessible quantifier *beaucoup* that is responsible for this effect. To preview our findings, we find that this is indeed the case, and we further ask under what conditions this grammatical illusion arises. We explore how current models of sentence processing might explain this finding.

However, we first turn to a description of the grammatical phenomenon under consideration, because this provides important linguistic context for the studies that follow.

[2]We are grateful to an anonymous reviewer for highlighting this fact.

1.2 | Quantification at a distance: generalizations and analyses

Like many languages, French has several types of NPs: for example, definite NPs, as in (7a), indefinite NPs, as in (7b), and quantificational NPs, as in (7c).

(7) a. Francis a écrit la lettre.
Francis has written the letter
'Francis wrote the letter.'

b. Francis a écrit une lettre.
Francis has written a letter
'Francis wrote a letter.'

c. Francis a écrit **beaucoup de lettres.**
Francis has written a_lot *DE* letters
'Francis wrote a lot of letters.'

Consider the type of NP instanced in (7c). In French, nominal quantifiers are, at least on the surface, different from many of their English counterparts in that their restrictor is an NP that is necessarily, as (8a) shows, marked with the particle *de*—a *de* NP—and that needs to be licensed by a quantifier; this is shown by the unacceptability of (8b).[3]

(8) a. *Francis a écrit **beaucoup lettres.**
Francis has written a_lot letters
Intended: 'Francis wrote a lot of letters.'

b. *Francis a écrit **de lettres.**
Francis has written *DE* letters
Intended: 'Francis wrote letters.'

It will be important to bear in mind that restrictors marked with *de* (*d'* if followed by a vowel) contrast with phrases headed by an indefinite determiner (e.g., *des*), illustrated by (9a), which do not need to be licensed by a quantifier. The determiner *des* does not license *de* NPs on its own, as (9b) shows.

(9) a. Francis a écrit **des lettres.**
Francis has written INDF.PL letters
'Francis wrote letters.'

b. *Francis a écrit **des de lettres.**

In (10) we list quantifiers that license *de* NPs.[4]

[3]Noun phrases with *de* are also found under negation:

(i) Je n' ai pas envoyé de lettres.
I NEG have NEG sent *DE* letters
'I did not send letters.'

However we follow Milner 1978 in assuming that *de* NPs licensed by quantifiers and *de* NPs licensed by negation should be distinguished on the grounds that they have different properties (e.g., locality restrictions).

[4]The categorial status of what we call *(licensing) quantifiers* is not uncontroversial: for instance Kayne 2002 suggests that they may always be adverbs involved in a complex DP structure. Whatever the correct status of the lexical items listed in (10), we continue to use the descriptive term *quantifiers* to refer to them.

(10)	assez	'enough'
	suffisamment	'enough'
	trop	'too many/much'
	beaucoup	'a lot'
	énormément	'a great deal of'
	pas mal	'quite a few/some'
	peu	'little'
	un peu	'a little'
	vachement	'a lot' (familiar)
	sacrément	'a lot'
	drôlement	'a lot'
	guère	'little'
	tant	'so many/much'
	de plus en plus	'more and more'
	de moins en moins	'less and less'
	tellement	'so many/much'
	le plus	'the most'
	le moins	'the least'
	plus	'more'
	davantage	'more'
	moins	'less'
	autant	'as many/much as'
	plein	'a lot'
	quantité	'many'
	nombre	'many'

French allows some of these quantifiers to be separated from (nonadjacent to) their *de*-NP restrictor, in the construction known as quantification at a distance (QAD; Kayne 1975, Milner 1978, Kayne 1981, Obenauer 1983, Obenauer 1985, Azoulay-Vicente 1989, Rizzi 1990, Valois 1991, Obenauer 1994, Doetjes 1995, Doetjes 1997, Boivin 1999, Kayne 2002, Mathieu 2002, Heyd 2003, Labelle & Valois 2004, Mathieu 2005, Burnett 2009, Burnett 2012, Pasquereau 2015, Authier 2016, Pasquereau 2016, Pasquereau 2018). For example, in (11a) the quantifier *beaucoup* 'many' appears separated from *de livres* 'books'; compare (11b).[5]

(11) a. Des gens ont **beaucoup** lu **de livres.** — QAD
INDF.PL people have many read *DE* books
'Some people have read many books.'

b. Des gens ont lu **beaucoup de livres.** — Local quantification
INDF.PL people have read many *DE* books
'Some people have read many books.'

[5]Obenauer 1983 and subsequent work report that a QAD construction requires multiple events distributed over the temporal axis, much like a construction with a VP adverb like *souvent* 'often' or *intensément* 'intensely' (see Burnett 2009 for more detail), whereas local quantification does not have such a requirement. However see Doetjes 1995 and 1997 for arguments against this position.

However, mere linear precedence does not suffice to license QAD in French. The syntactic position of the potential licensor prior to the *de* NP is critical: if the licensing quantifier fails to c-command the *de* NP, as in (12a), or if it is (also) already associated with another *de* NP, as in (12c), then the sentence is reliably judged to be significantly less acceptable than a counterpart with *des*, as in (12b) and (12d) respectively, when speakers are given sufficient time to make their judgment.

(12) a. *Les enfants [que je vois **peu**] lisent **de livres.**
the children that I see little read *DE* books
Intended: 'The children that I seldom see read books.'
b. Les enfants [que je vois peu] lisent des livres.
the children that I see little read INDF.PL books
'The children that I seldom see read books.'
c. ***Peu de gens** ont lu **de livres.**
few *DE* people have read *DE* books
Intended: 'Few people have read books.'
d. Peu de gens ont lu des livres.
few *DE* people have read INDF.PL books
'Few people have read books.'

Based on these observations, we may formulate the generalization concerning *de*-NP licensing as follows.

(13) Grammatical-*de*-NP-licensing generalization
For every *de* NP, there must be one licensing quantifier, such that:
• it c-commands the *de* NP it licenses and
• it licenses exactly one *de* NP.

The generalization in (13) correctly rules out (12a, c) as ungrammatical: (12a) is ruled out because the licensing quantifier *peu* does not c-command the *de* NP *de livres*, and (12c) is ruled out because there are two *de* NPs but only one licensing quantifier.

To what extent is the licensing dependency between a quantifier and the *de* NP it licenses similar to the licensing dependency between a negative element and the NPI it licenses? Consider the examples in (14) and (15). The first repeats the example of the NPI-illusion effect from Vasishth et al. 2008. The second repeats an example of a comparable configuration with a *de* NP.

(14) a. *A man who had **no** beard was **ever** thrifty.
b. *A man who had a beard was **ever** thrifty.
= (1)

(15) a. *J' ai donné à **beaucoup** d' associations **de livres.**
I have given to a_lot *DE* charities *DE* books
b. *J' ai donné à des associations **de livres.**
I have given to INDF.PL charities *DE* books
= (5b), (6)

If we suppose that the process of licensing a *de* NP that does not have an adjacent quantifier (i.e., one in a QAD configuration) involves a memory-retrieval process to identify a licensor, then there

TABLE 1 Properties of *beaucoup*- and *plein*-type quantifiers

	Beaucoup	***Plein***
Quantify at a distance	✓	✗
Can be used as an object pronoun	✓	✗
Can be used as an adverb	✓	✗

is a clear parallel between the two cases. In (15a), the licensor *beaucoup* should match whatever features code for appropriate quantifiers, but it will not match the appropriate structural features. Therefore, it may be considered a *partial match* for the retrieval cues that a *de* NP uses to find a long-distance quantifier as a licensor.

The cue-based-retrieval model of dependency resolution thus predicts that we should see an increase in acceptability in the ungrammatical sentence in (15a) compared to a relevant ungrammatical control sentence, just as we see one in (14a) when the negative element *no* is present albeit in an inaccessible position for the NPI *ever*. Testing this prediction is our first empirical question. There are several other features of the French QAD construction, however, that raise very interesting questions from the point of view of real-time dependency resolution. Any of the quantifiers listed in (10) can license an immediately adjacent *de* NP, as in (7c) and (12d). However, we might also ask: are all of these *de*-NP-licensing quantifiers equally capable of creating illusions of grammaticality? This is our second empirical question, and here we draw our inspiration from Xiang et al. 2009 and Xiang et al. 2013, which ask a similar question with NPI licensors. If the answer to our second question is negative, then, the final question we would like to answer is: what are the properties that make a quantifier eligible to create illusory licensing of *de* NPs?

It is important to note that not all the *de*-NP-licensing quantifiers listed in (10) are created equal: these quantifiers are differentiated syntactically in three critical ways, listed in table 1. As indicated, these quantifiers may be divided into two classes, which we will call the *beaucoup* class and the *plein* class, using a prototypical example of each class as its label. The three differences are not apparent in the (simple) cases where quantifier and *de* NP are immediately adjacent but instead become visible in other contexts. We now discuss each of these three differences.

The first crucial difference among *de*-NP-licensing quantifiers is that only some of them can take part in QAD constructions. As previously mentioned, constructions where the *de*-NP-licensing quantifier is not immediately adjacent to the *de* NP it licenses are known as QAD. Most of the quantifiers in (10) can quantify at a distance; for ease of exposition, we will refer to these as +QAD quantifiers. The *beaucoup* class is +QAD, as illustrated in (16). However, others cannot quantify at a distance and must be strictly local to the *de* NP: they are −QAD. The *plein* class is −QAD, as illustrated in (17).

(16) a. Francis a écrit beaucoup de lettres.
Francis has written a_lot *DE* letters
'Francis wrote a lot of letters.'
b. Francis a beaucoup écrit de lettres.

(17) a. Francis a écrit plein de lettres.
Francis has written a_lot *DE* letters
'Francis wrote a lot of letters.'
b. *Francis a plein écrit de lettres.

The second crucial difference is that only *beaucoup*-type quantifiers may be used as object pronouns. In that case, they can appear in the standard postverbal object position, as in (18a), or preverbally, as in (18b).

(18) a. J' ai fait beaucoup/*plein pour les pauvres.
I have done a_lot for the poor
'I did a lot for the poor.'
b. J'ai beaucoup/*plein fait pour les pauvres.

The third crucial difference among *de*-NP-licensing quantifiers is that some are (also) VP adverbs while others are not. Kayne 1975 noticed that this property correlated with the ability to participate in QAD constructions. We illustrate this generalization in (19) and (20). As (19) shows, *beaucoup* may be used as a VP adverb and as a quantifier licensing its *de*-NP restrictor at a distance. On the other hand, *plein* cannot be used as a VP adverb and cannot quantify at a distance, as (20) shows.

(19) a. J' ai beaucoup dormi.
I have a_lot slept
'I slept a lot.'
b. J' ai acheté beaucoup de pommes.
I have bought a_lot *DE* apples
'I bought many apples.'
c. J' ai beaucoup acheté de pommes.
I have many bought *DE* apples
'I bought many apples.'

(20) a. *J' ai plein dormi.
I have a_lot slept
Intended: 'I slept a lot.'
b. J' ai acheté plein de pommes.
I have bought a_lot *DE* apples
'I bought many apples.'
c. *J' ai plein acheté de pommes.
I have many bought *DE* apples
Intended: 'I bought many apples.'

The adverb–quantifier generalization has motivated an analysis that takes the correlation between the possibilities of being used as a VP adverb and as a distant quantifier at face value. Under this analysis, the quantifier is base generated in the position where it appears, and a dependency is established between it and the *de* NP. In other words, the local-quantification construction and the QAD construction have different underlying structures: the quantifier is a determiner when it appears adjacent to the *de* NP and an adverb when it appears in preverbal position. This type of analysis, known as the base-generation analysis, is defended or assumed in most work on this construction (Kayne 1975, Obenauer 1983, Azoulay-Vicente 1989, Rizzi 1990, Valois 1991, Obenauer 1994, Doetjes 1995, Doetjes 1997, Heyd 2003, Labelle & Valois 2004, Mathieu 2005, Burnett 2009, Burnett 2012).

An alternative type of account is one in which the QAD structure is derived from the structure where quantifier and *de* NP are adjacent. Under the derivational analysis, the quantifier is generated next to *de* NP and can be pronounced there or can feed a movement rule and end up being pronounced (and possibly interpreted) in the preverbal position (Milner 1978, Boivin 1999, Kayne 2002, Pasquereau 2015, Authier 2016, Pasquereau 2016, Pasquereau 2018). Crucially, the underlying structure of QAD is one in which the quantifier is adjacent to the *de* NP. Authier 2016 offers one such movement account. In that account, *beaucoup* optionally undergoes head movement to spec,vP from the position where it is merged into the structure.[6]

Kayne 1975 notes a variety of problems for such movement accounts, but we believe that they can be overcome by integrating insights from Kayne's later work. Kayne 2002 and 2008 make the proposal that a sentence like (21a) has the underlying structure in (21b). That is, Kayne proposes that the phrase *beaucoup de livres* contains an adverb *beaucoup* that modifies a silent adjective that itself modifies a silent noun that denotes a quantity.[7,8]

(21) a. J' ai lu beaucoup de livres.
I have read many *DE* books
'I read many books.'
b. J'ai lu beaucoup MANY NUMBER de livres.

Kayne does not specify what the exact structure of this sentence is, and we do not commit to a particular structure either. In accord with Kayne 2002, all we commit to is that *beaucoup*-type quantifiers involve a silent adjective and a silent noun. For the sake of making more concrete the

[6]In line with Fukui & Takano 1998, Nakamura 2000, and Matushansky 2006, Authier assumes that head movement is movement of a head to *the specifier* of another head, possibly followed by m-merger of the two heads.

[7]Kayne 2002: 98 notes that an alternative to this hypothesis is to posit that *peu* (and, we assume, *beaucoup*, *trop*, and so on) are themselves nouns. It is not clear, though, how this alternative hypothesis would handle the fact that *peu* (and the others in this class) are also all adverbs. We refer the interested reader to Kayne's discussion.

[8]We do not pursue Kayne 2002's movement analysis of QAD since it predicts that *plein* can quantify at a distance, which is strongly unacceptable for our informants and the participants in our experiments. Kayne reports that (i) is judged "passably acceptable" by his informant.

(i) (?) Elle a tout plein acheté de bouquins.
she has every many bought *DE* books
(Intended:) 'She has bought a great many books.'

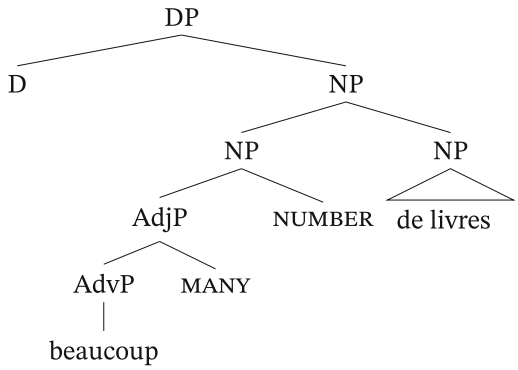
Notice that the sentence does not contain just *plein* but *tout plein*. There are a number of expressions in French that are perfectly acceptable with *tout plein* but not with *plein* or *tout* on their own:

(ii) a. Merci tout plein / *plein / *tout.
thanks every a_lot a_lot every
'Thanks a lot.'
b. Il est mignon tout plein / *plein / *tout.
He is cute every a_lot a_lot every
'He's very cute.'

In any case, as our experiments repeatedly show, sentences where *plein*-type quantifiers are separated from *de* NP are judged unacceptable.

discussion and the representations used to illustrate it, we will use the structure in (22) for +QAD quantifiers, where the *de* NP is an NP constituent.[9]

(22)

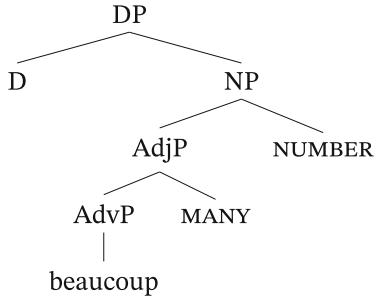


We now show how this structure captures the three differences in table 1.

First, with regard to the third property, *beaucoup*-type quantifiers are always adverbs, whether they appear in local quantification, in QAD, or as adverbs.

With regard to the second property, *beaucoup*-type quantifiers have the same distribution as object pronouns because, we assume, in an example like (18), the structure of "bare" *beaucoup* is as follows.[10]

(23)



In (18b), where bare *beaucoup* appears to the left of the verb, we assume in accord with Authier 2016 that Adv has undergone head movement to spec,VP (or to spec,vP, to be more specific, though we do not represent the v layer).[11]

[9]In fact, Pesetsky 2013: 100 proposes to treat *de* NPs in French as genitive-case NPs, which happen to be realized at the constituent level in French via the preposition *de*.

[10]The adverb *beaucoup* might undergo head movement to D, as in Russian (Pesetsky 2013). We leave this issue for further work.

[11]Alternatively, it could be that the *whole DP* has moved to spec,VP. This would be consistent with the observation that the phrase *un peu* 'a little' can quantify at a distance—and be used pronominally in object position and as an adverb:

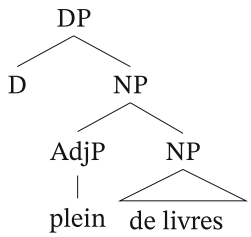
(i) a. J' ai un peu fait de repassage.
I have a little done *DE* ironing
'I did a little bit of ironing.'

b. J' ai fait un peu pour cette cause, mais pas beaucoup.
I have done a little for this cause but not much
'I did a little for this cause but not much.'

Finally, *beaucoup*-type quantifiers can quantify at a distance for the same reason that they can appear without an (overt) restrictor, as in (23). In QAD, we assume that just the adverb has moved to spec,VP.

Kayne does not treat *plein*-type quantifiers as different from *beaucoup*-type quantifiers, which is probably because he assumes that they can quantify at a distance too. However, as our results will show, this is clearly not the case for the participants we tested. We assume that *plein*-type quantifiers are adjectives that directly modify *de* NPs:

(24)



This explains why they cannot be used as VP adverbs, why they cannot appear without a *de* NP (at least in object position), and, assuming that adjectives cannot move in French, why they cannot quantify at a distance.

This concludes our review of the grammatical properties of the QAD construction in French, the analyses they have been given, and those they could be given. We do not intend to argue for a specific analysis. Instead, we simply want to make use of the insights of these analyses when interpreting the results of our studies.

1.3 | The present study

To summarize, in the present study we are interested in asking whether *de*-NP-licensing quantifiers can intrusively license *de* NPs, drawing an analogy between this construction and the more widely studied NPI-illusion effects. We investigate the acceptability of *de* NPs by comparing different kinds of similar dependencies in an attempt to create configurations parallel to those involving NPIs. Across five experiments, we attempt to address the three central questions discussed in section 1.2:

(25) Three questions
- a. Can *de*-NP-licensing quantifiers intrusively license *de* NPs?
- b. Can all *de*-NP-licensing quantifiers intrusively license *de* NPs?
- c. What properties of a quantifier are critical for intrusive licensing?

In addressing these three questions in French, we aim to bring a new construction to bear on our understanding of grammatical illusions and on the debate concerning how

c. J' ai un peu dormi.
I have a little slept
'I slept a little.'

TABLE 2 Design

Description	Label
Grammatical, quantifier present	Gram
Ungrammatical, quantifier present	Int (Intrusion)
Ungrammatical, quantifier absent	Ungram

grammatical illusions arise. We now turn to our experimental investigations. Experiment 1 investigates question 1, and experiments 2–4 investigate questions 2 and 3 by testing intrusive structures with different types of *de*-NP-licensing quantifiers. Experiment 5 explores question 3.

2 | EXPERIMENT 1

2.1 | Methods

2.1.1 | Participants

A total of 48 subjects participated in this experiment (30 females, 18 males, aged 15 to 68). They were recruited by word of mouth or via Facebook. Prior to participation in the experiment, participants filled out a questionnaire aimed at assessing their language background and where they were from. We required that all participants (i) self-report as a native speaker of a variety of French spoken in continental France, (ii) be less than 70 years old, and (iii) judge control grammatical sentences higher than control unacceptable ungrammatical sentences. These exclusion criteria were identical across all experiments. In experiment 1, seven participants were excluded: four were not native speakers of French and three did not perform well on the control items. All 41 remaining participants self-reported as native speakers of French, and all 41 indicated that French was their dominant daily language. Completion of the survey took approximately 10 minutes.

2.1.2 | Materials

We developed 18 sets of experimental items, each set consisting of the three experimental conditions shown in table 2. The experiment involved three conditions varying along two factors: grammaticality and presence of a quantifier. The 18 critical experimental items were combined with 23 filler sentences. Fillers included nine control grammatical sentences with an NPI, nine ungrammatical control sentences with an NPI, and five ungrammatical sentences containing quantifiers of the kind used in the experimental items.

The particle *de* in *de* NPs has two forms: *de* before a word starting with a consonant and *d'* before a word starting with a vowel. To block for a potential effect of this difference, half of the items contained a quantifier followed by a *de* NP in the reduced form, as in (26), and the other half contained a quantifier followed by a *de* NP in the full form, as in (27). (We omit the usual judgment marks for ungrammatical sentences.)

(26) Items with reduced *de* (i.e., *d'*)

a. Gram
J' ai donné à **beaucoup d' amis** des livres sur
I have given to many *DE* friends INDF.PL books about
la vie de mon oncle qui a passé 20 ans au Vietnam.
the life of my uncle who has spent 20 years at.the Vietnam
'I gave many friends books about the life of my uncle who spent 20 years in Vietnam.'

b. Int
J'ai donné à **beaucoup d'amis de livres** sur la vie de mon oncle qui a passé 20 ans au Vietnam.

c. Ungram
J'ai donné à des amis **de livres** sur la vie de mon oncle qui a passé 20 ans au Vietnam.

(27) Item with full *de*

a. Gram
Michel a demandé à **beaucoup de gens** des conseils
Michel has requested to many *DE* people INDF.PL advice
concernant le discours qu' il doit prononcer le 14 juillet.
about the speech that he must pronounce the 14 July
'Michel requested from many people advice concerning the speech that he must make on July 14.'

b. Int
Michel a demandé à **beaucoup de gens de conseils** concernant le discours qu'il doit prononcer le 14 juillet.

c. Ungram
Michel a demandé à des gens **de conseils** concernant le discours qu'il doit prononcer le 14 juillet.

Six different quantifiers licensing *de* were used in the study:

(28) Quantifiers used in the study

beaucoup	'a lot'
trop	'too many/much'
énormément	'a great deal of'
suffisamment	'enough'
pas mal	'quite a few/some'
de plus en plus	'more and more'

Each quantifier occurred in three item sets.

All sentences used ditransitive verbs such that the goal or addressee (encoded by a PP headed by *à*) preceded the direct object. The more standard order (object–PP) was not used, to avoid having the preposition intervene between the two *de* NPs.

2.1.3 | Procedure

The experiment was developed in Ibex and deployed on the Ibex Farm online platform (Drummond 2013). The experimental items were distributed into three Latin-square lists, and

each participant was assigned to a different list. For each participant, the order of presentation was randomized.

Each trial consisted of a sentence presented on the screen followed by a question with two response options. Sentences were cut up in chunks. Each chunk appeared for 350 ms, and a 100 ms pause separated each chunk. Participants responded by choosing their desired response using the F and J keys or the mouse. Participants were given two seconds to give their judgments. Reaction times were recorded. Participants were instructed to judge whether a sentence was 'acceptable' by replying *oui* 'yes' or *non* 'no' to the question *Avez-vous trouvé cette phrase acceptable?* 'Did you find this sentence acceptable?' They were first given two examples to introduce them to the task. Then they were given several examples with feedback to illustrate the difference between acceptability and grammaticality—this is important given the strong prescriptive tradition of European French.

Chunked presentation was chosen, as opposed to word-by-word presentation, in an attempt to not draw attention to the critical word *de*. We reasoned that displaying *de* on its own would make comprehenders prosodify it differently than if it were displayed next to the NP it was part of, which could interfere with the results. The following is an example of how items were chunked.

(29) a. Gram
J' ai donné / à beaucoup / d' amis / des livres / sur la
I have given to many *DE* friends INDF.PL books on the
vie / de mon oncle / qui a passé / 20 ans / au Vietnam.
life of my uncle who has spent 20 years at.the Vietnam

b. Int
J'ai donné / à beaucoup / d'amis / de livres / sur la vie / de mon oncle / qui a passé / 20 ans / au Vietnam.

c. Ungram
J'ai donné / à / des amis / de livres / sur la vie / de mon oncle / qui a passé / 20 ans / au Vietnam.

2.1.4 | Analysis

The acceptance-rate data were analyzed using a mixed-effects logistic-regression model including condition as a fixed effect. In this experiment and later ones, we attempted to fit the maximum random-effects structure justified by the design and simplified the random-effects structure until the model converged (Matuschek et al. 2017). All of our code and data are freely available in an Open Science Framework repository.[12] Helmert contrast coding was used to decompose the three conditions into two comparisons (table 3): a grammaticality contrast that compares Gram against Int plus Ungram and an intrusion contrast that compares Int against Ungram.

2.1.5 | Predictions

We expect to see clear sensitivity to grammatical licensing of *de* NPs in the task. Statistically this should result in a significant effect of the grammaticality contrast. If *de* NPs are subject to licensing

[12]The link for the repository is https://osf.io/sgw48/?view_only=1ff62b0d0ed04467b68ba8f773052013.

TABLE 3 Helmert contrast coding

	Grammaticality	Intrusion
Gram	2	0
Int	−1	1
Ungram	−1	−1

TABLE 4 Acceptability ('yes' responses), results of experiment 1

Condition	Mean	SE
Gram	0.94	0.01
Int	0.44	0.04
Ungram	0.24	0.04

TABLE 5 Acceptability, result of model for yes responses

	β estimate	SE	z value	p value
Grammaticality	1.41	.12	11.74	$< 2 \times 10^{-16}$
Intrusion	.60	± .12	5.13	< .001

by grammatically inaccessible licensors, we further predict a significant effect of the intrusion contrast.

2.2 | Results

By-condition average acceptance rates are presented in table 4, along with by-participant standard errors.

The model revealed a significant effect of grammaticality and a significant effect of intrusion (table 5).

2.3 | Discussion

We may sum up the results of this experiment as follows. First, we observed a significant effect of grammaticality: only the grammatical baseline does not violate the grammatical rule in (13), and so we expected that it would be accepted at the highest rate in the experiment.

In addition, we observed a significant effect of intrusion when comparing the two ungrammatical conditions, Int and the ungrammatical baseline. This suggests that even if a sentence violates the grammatical constraint on licensing *de* NPs (13), its acceptability is improved when a grammatically inaccessible quantifier precedes it. The results of this experiment suggest that *de*-NP licensing is subject to an illusion-of-grammaticality effect.

In this experiment, we only used *beaucoup*-type quantifiers that can take part in the QAD construction. Based on the results of this experiment alone, we are unable to generalize the grammatical-illusion effect. It remains unclear if all licensors can create

illusions of grammaticality or if different licensor types behave differently. We test this in experiment 2 by comparing the ability of +QAD and −QAD licensors to create grammatical illusions.

3 | EXPERIMENT 2

3.1 | Methods

3.1.1 | Participants

A total of 74 people participated in this experiment (60 females, 14 males, aged 18 to 63). Participants for this experiment and subsequent ones were recruited via the mailing list of the French National Center for Scientific Research's Cognitive Science Information Relay, which has a recruitment pool. We aimed for a specific number of subjects, but our recruitment method did not allow us to set a precise number of subjects. This led to inconsistent sample size across experiments, but we decided to analyze everyone who managed to take the experiment in the allotted portion of time. Of the 74 participants, 15 were excluded according to the exclusion criteria. All 59 remaining participants self-reported as native speakers of French, and all 59 indicated that French was their dominant daily language. Completion of the survey took approximately 15 minutes.

3.1.2 | Materials

We developed 30 sets of experimental items, each consisting of five experimental conditions: Gram +QAD, Gram −QAD, Int +QAD, Int −QAD, and Ungram. These five conditions vary along three factors: grammaticality, intrusion, and whether the quantifier can quantify at a distance (+QAD; e.g., *beaucoup*) or not (−QAD; e.g., *plein*). While there are two Gram conditions and two Int conditions, there is just one Ungram condition, because in that condition, no quantifier is present; manipulation of the ±QAD factor would therefore be meaningless.

Samples of the experimental items are given in (30) and (31). To counterbalance a potential effect of the form of the particle *de* (i.e., *de* or *d'*), half of the items contained a quantifier followed by a *de* NP in the reduced form, and the other half contained a quantifier followed by a *de* NP in the full form.

(30) Items with reduced *de*

a. Gram +QAD
J' ai donné à **beaucoup d'** amis des livres sur la
I have given to many *DE* friends INDF.PL books on the
vie de mon oncle qui a passé 20 ans au Vietnam.
life of my uncle who has spent 20 years at.the Vietnam
'I gave many friends books about the life of my grandfather who spent 20 years in Vietnam.'

b. Int +QAD
J'ai donné à **beaucoup d'**amis de livres sur la vie de mon oncle qui a passé 20 ans au Vietnam.

c. Ungram
J'ai donné à des amis de livres sur la vie de mon oncle qui a passé 20 ans au Vietnam.
d. Gram −QAD
J'ai donné à **plein d'**amis des livres sur la vie de mon oncle qui a passé 20 ans au Vietnam.
e. Int −QAD
J'ai donné à **plein d'**amis de livres sur la vie de mon oncle qui a passé 20 ans au Vietnam.

(31) Items with full *de*
a. Gram +QAD
Michel a demandé à **beaucoup de** gens des conseils
Michel has requested to many *DE* people INDF.PL advice
concernant le discours qu' il doit prononcer le 14 juillet.
concerning the speech that he must pronounce the 14 July
'Michel requested from many people advice concerning the speech that he must make on July 14.'
b. Int +QAD
Michel a demandé à **beaucoup de** gens de conseils concernant le discours qu'il doit prononcer le 14 juillet.
c. Ungram
Michel a demandé à des gens de conseils concernant le discours qu'il doit prononcer le 14 juillet.
d. Gram −QAD
Michel a demandé à **plein de** gens des conseils concernant le discours qu'il doit prononcer le 14 juillet.
e. Int −QAD
Michel a demandé à **plein de** gens de conseils concernant le discours qu'il doit prononcer le 14 juillet.

Six different quantifiers licensing *de* were used in the study:

(32) Quantifiers used in the study

+QAD		−QAD	
beaucoup	'much'	plein	'much'
suffisamment	'sufficiently many/much'	quantité	'much'
de plus en plus	'more and more'	nombre	'much'

Each quantifier occurred in 10 item sets.

As in experiment 1, all sentences used ditransitive verbs such that the goal or addressee (encoded by a PP headed by *à*) preceded the direct object.

The 30 critical experimental items were combined with 40 filler sentences. Fillers consisted of 15 grammatical sentences with an NPI, 15 ungrammatical, unacceptable sentences with an NPI, six ungrammatical, unacceptable sentences containing quantifiers of the kind used in the experimental items, and four sentences that the experimenters were interested in having rated for independent reasons.

TABLE 6 Condition means and standard errors

	Acceptability	
Condition	**Mean**	**SE**
Gram +QAD	.87	.02
Gram −QAD	.89	.02
Ungram	.22	.03
Int +QAD	.35	.04
Int −QAD	.25	.03

TABLE 7 Contrast coding, model 1

	Grammaticality	QAD
Gram +QAD	.5	.5
Gram −QAD	.5	−.5
Int +QAD	−.5	.5
Int −QAD	−.5	−.5

3.1.3 | Predictions

It is expected that the results from experiment 1 will be replicated. Furthermore, if the type of quantifier matters, then we expect to see more illusions for +QAD quantifiers than for −QAD quantifiers.

3.1.4 | Procedure

The same procedure as in experiment 1 was used.

3.2 | Results

By-condition average acceptance rates for all experimental conditions are presented in table 6 along with by-participant standard errors.

We performed two statistical analyses on this design, each addressing a different research question, as outlined below. We ran mixed-effects models with response as dependent variable and fitting random slopes/intercepts by subject and item following the method outlined for experiment 1 (Matuschek et al. 2017).

The first question was whether the type of quantifier (±QAD) had a differential effect on acceptability in grammatical and ungrammatical sentences. To test this question, we left out the nonillusory ungrammatical baseline condition and analyzed the remaining four conditions as a 2×2 design crossing quantifier type (±QAD) with grammaticality (grammatical/ungrammatical). We fit a single logistic-regression model with each of these factors (sum coded as in table 7) and their interaction as fixed effects using the GLMER optimizer BOBYQA.

TABLE 8 Results of the mixed-effects logistic regression testing for an interaction of grammaticality and quantifier type

	β estimate	SE	*z* value	*p* value
Grammaticality	3.53	.34	10.42	$< 2 \times 10^{-16}$
±QAD	0.23	.17	1.31	0.19
Grammaticality × ±QAD	−.8	.34	−2.37	< .05

TABLE 9 Contrast coding, model 2

	Gram +QAD	Int +QAD	Gram −QAD	Int −QAD
Gram +QAD	1	0	0	0
Gram −QAD	0	0	1	0
Ungram	0	0	0	0
Int +QAD	0	1	0	0
Int −QAD	0	0	0	1

TABLE 10 Results of the mixed-effects logistic regression testing for differences from the Ungram baseline condition

	β estimate	SE	*z* value	*p* value
Gram +QAD > Ungram	3.57	.23	15.68	$< 2 \times 10^{-16}$
Gram −QAD > Ungram	3.72	.23	15.79	$< 2 \times 10^{-16}$
Int +QAD > Ungram	.73	.18	3.95	< .001
Int −QAD > Ungram	.16	.19	.84	.40

This model revealed a significant effect of grammaticality and an interaction of grammaticality and QAD (table 8). Descriptively, the interaction appears to be driven by the lower average acceptance rate in the −QAD intrusive condition relative to the +QAD intrusive condition.

The second question was whether there was illusory licensing present in both the +QAD and −QAD intrusive-licensing conditions. To test this question, we used treatment contrasts (table 9) to compare each of the four quantified conditions to the ungrammatical baseline.

We fit a single logistic-regression model with condition as fixed effect and random intercepts by subject and item using the GLMER optimizer BOBYQA. According to this model, while we find evidence of intrusive licensing in the Int +QAD condition, there is no such evidence in the Int −QAD condition (table 10).

3.3 | Discussion

The results of experiments 1 were replicated. Quantifiers gave rise to intrusive licensing of *de* NPs. However experiment 2 revealed an interaction of intrusion and ±QAD: intrusive sentences containing a +QAD quantifier were judged acceptable significantly more frequently than those

containing a −QAD quantifier, which were not themselves judged acceptable significantly more frequently than the Ungram sentences.

The absence of a significant difference between the Int −QAD and Ungram conditions does not necessarily mean that only +QAD quantifiers display illusions of grammaticality. Rather, this result shows that the observed boost in acceptability is stronger with +QAD quantifiers than with −QAD quantifiers. Importantly, we cannot conclude that there is no illusion of grammaticality at all for −QAD quantifiers.

In experiment 3, we confirmed that this pattern holds in offline judgments using Likert-scale responses.

4 | EXPERIMENT 3

4.1 | Methods

Experiment 3 is an offline replication of experiment 2. Sentences were presented whole. Subjects read them for as long as they wanted and took as long as they wanted to judge them. A Likert scale was used from 1 to 7.

4.1.1 | Participants

A total of 57 people participated in this experiment (43 females, 14 males, aged 18 to 69). They were recruited via the mailing list of the French National Center for Scientific Research's Cognitive Science Information Relay. Four participants were excluded according to the same criteria as in experiments 1 and 2. Prior to participation in the experiment, participants filled out a questionnaire aimed at assessing their language background and where they were from. All 53 remaining participants self-reported as native speakers of French, and all 53 indicated that French was their dominant daily language.

4.1.2 | Materials

The materials and design were identical to those used in experiment 2.

4.1.3 | Predictions

The predictions were identical to experiment 2.

4.1.4 | Procedure

Sentences were presented whole and with no time limit. Participants had to press the space bar to get to the next screen, where a Likert scale was given. Participants could click on any one number from 1 to 7 to rate the acceptability of the sentence they had just seen on the previous screen.

TABLE 11 Condition means and standard errors

	Acceptability	
Condition	**Mean**	**SE**
Gram +QAD	5.73	.11
Gram −QAD	5.87	.14
Ungram	2.49	.18
Int +QAD	2.87	.17
Int −QAD	2.62	.17

TABLE 12 Results of the mixed-effects regression testing for an interaction of grammaticality and quantifier type

	***β* estimate**	**SE**	***z* value**	***p* value**
Grammaticality	2.25	.19	11.79	$< 2 \times 10^{-16}$
± QAD	.01	.12	.08	.93
Grammaticality × ±QAD	−.39	.14	−2.68	< .05

4.2 | Results

By-condition average ratings for all experimental conditions are presented in table 11, along with by-participant standard errors.

We performed two statistical analyses on this design, each addressing a different research question. We ran two mixed-effects models with response as dependent variable and fitting random slopes/intercepts by subject and item. Both models were implemented with a cumulative logistic regression using the Ordinal package in R.[13]

The first question was whether the type of quantifier (±QAD) had a differential effect on acceptability in grammatical and ungrammatical sentences. To test this question, we left out the nonillusory ungrammatical baseline condition and analyzed the remaining four conditions in a 2 × 2 design crossing quantifier type (±QAD) with grammaticality. We fit a single regression model with each of these factors (sum coded as in table 7) and their interaction as fixed effects. The results of this model (table 12) revealed a significant effect of grammaticality and an interaction of grammaticality and QAD. Descriptively, the interaction appears to be driven by the lower ratings in the −QAD intrusive condition relative to the +QAD intrusive condition.

The second question was whether there was illusory licensing present in both the +QAD and −QAD intrusive-licensing conditions. To test this question, we used the same treatment-coding scheme we used in experiment 2. The results of this model (table 13) suggest that there is intrusive licensing in both Int conditions.

[13] Liddell & Kruschke 2018 points out that ordinal data such as Likert-scale acceptability judgments should not be analyzed with models that assume continuous underlying distributions (thanks to an anonymous reviewer for bringing this to our attention).

TABLE 13 Results of the mixed-effects logistic regression testing for differences from the Ungram baseline condition

	β estimate	SE	z value	p value
Gram +QAD > Ungram	2.44	.23	10.78	$< 2 \times 10^{-16}$
Gram −QAD > Ungram	2.65	.24	10.95	$< 2 \times 10^{-16}$
Int +QAD > Ungram	.46	.14	3.32	< .001
Int −QAD > Ungram	.25	.11	2.24	< .05

4.3 | Discussion

In experiment 3, the results of experiment 1 and 2 were replicated in offline judgments. If grammatical illusions are acceptability boosts that are observable online but disappear offline, as has been observed repeatedly for intrusive NPI licensing, for instance (Parker 2014: 270), then this result is quite surprising.

However, there are reasons to doubt that such an asymmetry between online and offline judgments is a necessary condition for a contrast in acceptability to qualify as a grammatical illusion. First, other mismatches between ungrammaticality and unacceptability have been observed offline, for example, with logophlexives (Sloggett 2017) and comparative illusions (Wellwood et al. 2018). Second, more recent discussions of the offline–online distinction cast it primarily as a difference in the signal-to-noise ratio of different judgment modes, with faster judgments being more prone to errors (S. Lewis & Phillips 2015, Parker 2019). On this view, we might not expect illusions to always disappear in offline (e.g., "untimed") judgment tasks. What matters for whether an illusory pattern is revealed is the relative signal-to-noise ratio in the judgments. This can vary as a number of factors: strength of the illusion (Dillon et al. 2017) and time taken to process the sentence (Parker 2019), to name two.

To summarize the first three experiments, we observed in experiment 1 that the presence of an intrusive quantifier in an ungrammatical sentence, as in (33), significantly improves its acceptability, but we found in experiments 2 and 3 that this effect is stronger with +QAD quantifiers than with −QAD quantifiers.

(33) Int +QAD

J' ai donné à **beaucoup** d' amis de livres sur la
I have given to many *DE* friends *DE* books on the
vie de mon oncle qui a passé 20 ans au Vietnam.
life of my uncle who has spent 20 years at.the Vietnam
Intended: 'I gave many friends books about the life of my grandfather who spent 20 years in Vietnam.'

In all three experiments, we used ditransitive verbs and a marked word order where the indirect object preceded the direct object. Although we attempted to justify this word order by making the direct object heavy, it remains somewhat marked. In experiment 4, then, we tested for grammatical-illusion effects in a different, less marked construction, to check whether the marked word order influenced our results. An example is given in (34). In this configuration, the intrusive quantifier is associated with the subject of the sentence.

(34) Int +QAD
Beaucoup de gens ont lu de livres sur la vie
many *DE* people have read *DE* books on the life
de mon oncle qui a passé 20 ans au Vietnam.
of my uncle who has spent 20 years at.the Vietnam
Intended: 'Many people read books about the life of my uncle who spent 20 years in Vietnam.'

5 | EXPERIMENT 4

In this section, we report both our original experiment 4 and a direct replication that we ran in response to concerns that our original study was underpowered. In what follows, we will refer to our original experiment as run 1 and the direct replication as run 2. Given this, we will first present the design of the experiment, which is shared across both runs. Then we will report the participants and results separately for each run.

5.1 | Methods

5.1.1 | Materials

We developed 30 sets of experimental items, each consisting of five experimental conditions, exemplified in (35). The five conditions again vary along three factors: grammaticality, intrusion, and whether the quantifier used can move (+QAD) or not (−QAD). The design is the same as experiment 2 except that the quantifier phrases are in subject position and the unlicensed *de* NP is in object position:

(35) a. Gram +QAD
Beaucoup de gens ont envoyé [**des** invitations] pour mon anniversaire.
many *DE* people have sent INDF.PL invitations for my birthday
'Many people have sent out invitations for my birthday.'
b. Int +QAD
Beaucoup de gens ont envoyé [**d'** invitations] pour mon anniversaire.
c. Ungram
Des gens ont envoyé [**d'** invitations] pour mon anniversaire.
d. Gram −QAD
Plein de gens ont envoyé [**des** invitations] pour mon anniversaire.
e. Int −QAD
Plein de gens ont envoyé [**d'**invitations] pour mon anniversaire.

We used the same quantifiers as in experiments 2 and 3.

The 30 critical experimental items were combined with 37 filler sentences. Fillers consisted of 12 grammatical sentences with an NPI, six ungrammatical, unacceptable sentences containing quantifiers of the kind used in the experimental items, and 19 sentences from an unrelated experiment.

TABLE 14 Condition means and standard errors

	Acceptability	
Condition	**Mean**	**SE**
Gram +QAD	.87	.02
Gram −QAD	.90	.01
Ungram	.33	.03
Int +QAD	.42	.04
Int −QAD	.33	.04

5.1.2 | Predictions

The predictions were identical to those in experiments 2 and 3.

5.1.3 | Procedure

We used the same procedure as in experiment 2.

5.2 | Run 1

5.2.1 | Participants

A total of 62 people participated in this experiment (49 females, 13 males, aged 16 to 67). They were recruited via the mailing list of the French National Center for Scientific Research's Cognitive Science Information Relay. Six participants were excluded according to the same criteria as the previous experiments. Prior to participation in the experiment, participants filled out a questionnaire aimed at assessing their language background and where they were from. All 56 remaining participants self-reported as native speakers of French, and all 56 indicated that French was their dominant daily language.

5.2.2 | Results

By-condition average acceptance rates for all experimental conditions are presented in table 14, along with by-participant standard errors.

We conducted the same two analyses as in experiment 2. The model that tested for an interaction of grammaticality and quantifier type revealed a significant effect of grammaticality and a marginal interaction of ±QAD and grammaticality (table 15).

We then asked whether there was illusory licensing present in both the +QAD and −QAD intrusive-licensing conditions. To test this question, we used the same treatment-coded mixed-effects logistic-regression analysis as in experiments 2 and 3. This model revealed a significant effect of intrusion in the Int +QAD condition but no reliable effect in the Int −QAD condition (table 16).

TABLE 15 Results of the mixed-effects logistic regression testing for an interaction of grammaticality and quantifier type

	β estimate	SE	z value	p value
Grammaticality	3.68	.37	9.86	$< 2 \times 10^{-16}$
±QAD	0.14	.27	.53	.59
Grammaticality × ±QAD	−0.87	.45	−1.92	.05

TABLE 16 Results of the mixed-effects logistic regression testing for differences from the Ungram baseline condition

	β estimate	SE	z value	p value
Gram +QAD > Ungram	3.57	.25	14.06	$< 2 \times 10^{-16}$
Gram −QAD > Ungram	3.92	.27	14.28	$< 2 \times 10^{-16}$
Int +QAD > Ungram	.46	.19	2.42	< .02
Int −QAD > Ungram	.01	.19	.07	.94

Run 1 found only a marginal interaction of grammaticality and QAD, which is neither strong evidence for nor strong evidence against the presence of this interaction. It seems likely that run 1 was simply too underpowered to detect an interaction. Because of the theoretical importance of this effect, we ran a direct replication.

5.3 | Run 2

5.3.1 | Participants

A total of 126 people participated in this experiment (106 females, 20 males, aged 18 to 67). Participants were recruited from among first-year students at the University of Poitiers. Of the 126 participants, 24 were excluded according to the same criteria as before. As in other experiments, participants filled out a questionnaire prior to taking the experiment. All 102 remaining participants self-reported as native speakers of French, and all 102 indicated that French was their dominant daily language.[14]

5.3.2 | Results

By-condition average acceptance rates for all experimental conditions are presented in table 17, along with by-participant standard errors.

[14]The large difference between the number of participants in run 1 and run 2 is due to the way participants were recruited. For run 1, participants were all recruited, as mentioned, using the Cognitive Science Information Relay mailing list. Anyone can sign up to this list. Participation plateaued at 62 after a few weeks. For run 2, participants were initially recruited by word of mouth from among one of the authors' family. Participation plateaued at 36 participants after a few weeks. Participants were then recruited from among this author's students, which increased the number of participants to 126 overnight, at which point the experiment was stopped.

TABLE 17 Condition means and standard errors

	Acceptability	
Condition	**Mean**	**SE**
Gram +QAD	.94	.01
Gram −QAD	.93	.01
Ungram	.32	.02
Int +QAD	.51	.03
Int −QAD	.34	.03

TABLE 18 Results of the mixed-effects logistic regression testing for an interaction of grammaticality and quantifier type

	β estimate	SE	z value	p value
Grammaticality	3.91	.32	12.31	$< 2 \times 10^{-16}$
±QAD	0.61	.17	3.45	$< .001$
Grammaticality × ±QAD	−0.70	.34	−2.1	$< .05$

TABLE 19 Results of the mixed-effects logistic regression testing for differences from the Ungram baseline condition

	β estimate	SE	z value	p value
Gram +QAD > Ungram	4.23	.23	19.11	$< 2 \times 10^{-16}$
Gram −QAD > Ungram	4.00	.21	19.40	$< 2 \times 10^{-16}$
Int +QAD > Ungram	.98	.14	7.23	$< .001$
Int −QAD > Ungram	.13	.14	.98	.33

We performed the same statistical analyses as in run 1. The model testing for an interaction of grammaticality and quantifier type revealed a significant effect of grammaticality, a significant effect of ±QAD, and a significant interaction of grammaticality and ±QAD (table 18). Descriptively, the interaction appears to be driven by the lower ratings in the −QAD intrusive condition relative to the +QAD intrusive condition.

The model testing for differences from the Ungram baseline condition revealed evidence of intrusive licensing in the Int +QAD condition but, again, no such evidence in the Int −QAD condition (table 19).

5.4 | Discussion

Overall, the two experiments reported here suggest that *de* NPs can be intrusively licensed by a subject quantifier and that this effect is significantly stronger if the quantifier is +QAD.[15]

[15]An anonymous reviewer of a conference abstract suggested that perhaps the interaction we observed was due to the type of variable that *beaucoup*- and *plein*-type quantifiers can bind. The reviewer did not elaborate further, but we

However, this effect was only marginal in run 1. It is not clear why run 1 did not show the effect. In all likelihood, it was simply too underpowered to detect the effect. Note that we used a different construction in experiment 4 than previously, which could have contributed to a smaller effect size by putting more linear or syntactic distance between the intrusive quantifier and the *de* NP.

Stepping back, four out of five experiments (experiments 1, 2, and 3 and run 2 of experiment 4) revealed statistically significant evidence that +QAD quantifiers cause more interference than −QAD quantifiers. A simple memory-retrieval account such as the one sketched in section 1.2 cannot derive this asymmetry given that −QAD and +QAD quantifiers occupy the same position in the string, are in the same constituent, and have the same +*de* NP cue (since they both license *de* NPs). Because the *de*-NP-illusion effect is stronger with +QAD quantifiers, we next explore the possibility that the observed effect is the result of a repair process that capitalizes on their ability to quantify at a distance.

6 | INTERIM DISCUSSION: *DE*-NP ILLUSORY LICENSING AND RETRIEVAL

6.1 | Retrieval hypothesis

Our experiments until now suggest two empirical generalizations. One, *de*-NP licensing is subject to illusions of grammaticality in a way that mirrors NPI illusions, at least in judgment measures. Two, we saw larger *de*-NP-illusion effects for +QAD quantifiers than for −QAD quantifiers. This pattern may be accommodated in the cue-based-parsing framework, with certain modifications.

A memory-retrieval account for these *de*-NP grammatical illusions might go as follows. If the parser reaches a *de* NP that has an immediately preceding licensor, no memory retrieval is necessary. However, when the parser encounters a *de* NP that does not have an immediately local quantifier licensing it, the parser executes a memory-retrieval operation to find a licensing quantifier that matches the retrieval cues. When the target of the retrieval matches the retrieval cues, it is activated. If the target is not in a structural position to grammatically license the *de* NP, as in our intrusive conditions, a partial match with the features may nevertheless give rise to the illusion of licensing and grammaticality. A pressing question for this account, however, is what exactly these retrieval cues are. A different but perhaps equally well-motivated hypothesis is repair.

6.2 | Alternative hypothesis: repair

Until now, we have largely focused on the hypothesis that grammatical-illusion effects are driven by memory-retrieval errors. However, competing hypotheses exist that merit consideration. One alternative explanation for our grammatical illusions is based on the idea that comprehenders receive imperfect input and may use information beyond the grammar per se (e.g., knowledge of the speech-production system, knowledge of real-world plausibility and probability) to arrive at

suppose that they had the following idea in mind. In Obenauer 1983 and Burnett 2009 (among others), it is argued that +QAD quantifiers bind an event variable when they appear preverbally.

It is not clear how the possibility of binding event variables would give rise to *de*-NP-licensing illusions: no linking hypothesis has been proposed. But even if this were a viable idea, the fact that quantifiers in indirect-object position, as in experiments 1–3, and in subject position, as in experiment 4, can give rise to *de*-NP illusions would be unpredicted.

an understanding of the speaker's intended message (Frazier & Clifton 2015). A similar idea is at the core of the so-called noisy-channel model of sentence comprehension (Levy 2008, Gibson et al. 2013), although the two approaches differ in the implementation of this leading idea and in what factors are presumed to be relevant for the covert repair process.

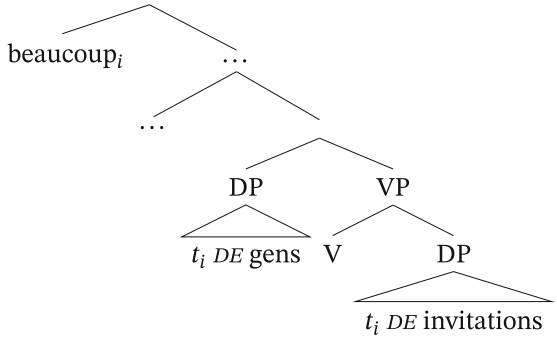
Support for this view comes from findings that suggest that comprehenders are at times willing to consider certain imperfect input (mismatch ellipsis, doubled quantifiers, doubled negation) as syntactic blends and to assign the input both a relatively acceptable rating (compared to undiagnosable or irreparable ungrammatical counterparts) and an interpretation supported by the repair (see Frazier 2015 for an overview). For instance Arregui et al. 2006 found that speakers rated the ellipsis cases in (36b–d) as a function of the number of repairs necessary to repair the would-be antecedent so that it may serve as the antecedent for VP ellipsis. (We omit the usual judgment marks for ungrammatical sentences.)

(36) a. Available verb phrase
None of the astronomers saw the comet, / but John did.
b. Embedded verb phrase
Seeing the comet was nearly impossible, / but John did.
c. Verb phrase with trace
The comet was nearly impossible to see, / but John did.
d. Negative adjective
The comet was nearly unseeable, / but John did.

From this perspective, we could imagine an alternative account of our core findings. When processing ungrammatical sentences containing a *de* NP and a quantifier in an inaccessible position, comprehenders first recognize that the sentence is ill formed and attempt to repair the input to yield a form that licenses two *de* NPs. Subsequent to this repair, comprehenders interpret the repaired structure. We discuss another type of repair account in section 8.4.

The correlation we observe between participating in QAD constructions and spurious licensing receives a natural interpretation from this perspective. One repair account of Int +QAD sentences might go as follows. +QAD quantifiers are covertly reanalyzed as binding both *de* NPs. On the basis of the work in Burnett 2012 on QAD, we illustrate one way this (re)analysis can be implemented:

(37) Quantifier in subject position, reanalyzed structure after repair



This explains the correlation between +QAD quantifiers and *de*-NP illusions, because only +QAD quantifiers can establish long-distance dependencies whereas −QAD quantifiers cannot.

The repair account makes a signature, distinct prediction: *de*-NP illusions should be assigned a particular interpretation such that *beaucoup* modifies both *de* NPs. Here again we propose to illustrate one way such a reanalysis could be implemented, modifying Burnett's semantics of *beaucoup* when it occurs at a distance.[16] Accordingly, the meaning of reanalyzed *beaucoup* would be as follows.[17]

(38) $[\![\text{beaucoup}_{\text{reanalyzed}}]\!]$ = the function Bcp, defined as follows.
Let $s, t \in \mathbb{N}$ such that $0 < s, t < |E|$, where E is the universe of discourse.
For all $R \in \mathcal{P}(E \times E)$, $\text{Bcp}_{s,t}(R) = 1$ iff $|\text{Dom}(R)| > s$ & $|\text{Ran}(R)| > t$.
(Extension based on the analysis of *beaucoup* in Burnett 2009: 88)

Our specific hypothesis predicts that a spuriously licensed *de* NP is interpreted as bound by the quantifier. That is, according to the repair hypothesis, each *de* NP is indexed to the quantifier, which leads us to expect an interpretation where each of the *de* NPs is interpreted as a restrictor of the quantifier it is bound by. In other words, a sentence like (39) should be given a doubly quantified interpretation.[18]

(39) J' ai donné à beaucoup d' associations de livres.
I have given to a_lot *DE* charities *DE* books
Predicted interpretation: 'I gave many books to many charities.'

According to our extension of Burnett 2009's analysis, the truth conditions of (39) would be as follows.[19]

(40) $[\![\text{J'ai donné à beaucoup}_{s,t}\text{ d' associations de livres}]\!] = 1$ iff
$|\{x : \exists y(\text{giving}(I, x, y) \,\&\, \text{charities}(y) \,\&\, \text{books}(x))\}| > s$ &
$|\{y : \exists x(\text{giving}(I, x, y) \,\&\, \text{charities}(y) \,\&\, \text{books}(x))\}| > t$.

We now turn to an experiment that tests whether this predicted interpretation occurs with *de*-NP illusions.

7 | EXPERIMENT 5

7.1 | Methods

We used the same methods as for experiments 1, 2, and 4. In addition, we asked participants to choose between two paraphrases of the sentence they had just seen: one corresponding to a

[16]Burnett assumes, following Obenauer, that the QAD construction in European French requires multiple events and analyzes *beaucoup*-type quantifiers, in the QAD construction, as polyadic (adverbial) quantifiers that bind an event variable and an object variable at the same time. In accord with Doetjes 1997, we do not think *beaucoup*-type quantifiers require multiple events, but we modify Burnett's proposal to implement our own.

[17]In other words, reanalyzed *beaucoup* takes a set of ⟨individual, individual⟩ pairs and yields true just in case the cardinality of the set of first coordinates, $|\text{Dom}(R)|$, is a lot (i.e., more than the contextual parameter s), and the cardinality of the set of second coordinates, $|\text{Ran}(R)|$, is also a lot (i.e., more than the contextual parameter t).

[18]There are of course a number of alternative ways that a repair operation might apply to an ungrammatical structure without actually predicting a doubly quantified interpretation. We discuss these in section 8.

[19]Space prevents us from detailing how the meaning would be derived compositionally; for more detail see Burnett 2012: 58–60, 73–75.

sentence where the object is quantified and one corresponding to a sentence where the object is interpreted as a plural indefinite. This reformulation-judgment task was inspired by the methodology used in a study reported in Frazier & Clifton 2011 and 2015, on the interpretation of sentences containing doubled quantifiers, for example, *many* and *often* in *Many students often turn in their assignments late*.[20] We adopted this methodology because our study was very similar to Frazier & Clifton 2011 and 2015.

Each sentence was presented, again, in chunks in the center of the screen. We allowed more time (440 ms per chunk with a 150 ms pause in between) because the task was different and because, after receiving feedback from participants, we decided that it was necessary for them to have more time to be able to form a meaning for the sentences. After the sentence to be judged had been displayed, two paraphrases were displayed and the participant had two seconds to choose the better paraphrase (see section 7.1.2 for more detail). In addition, for each experimental item, we added an acceptability-judgment question so that we could check whether the acceptability of an illusory *de*-NP structure and its interpretation are correlated.

7.1.1 | Participants

A total of 135 people participated in this experiment (104 females, 31 males, aged 18 to 72). They were recruited via the mailing list of the French National Center for Scientific Research's Cognitive Science Information Relay, via social media, and by word of mouth. We excluded six people because they did not meet our exclusion criteria (the third criterion, judging control grammatical sentences higher than control unacceptable ungrammatical sentences, did not apply here). The remaining 129 all reported that they spoke French natively.

7.1.2 | Procedure and materials

In this experiment, participants were asked to give two judgments for each sentence that they had seen: one reformulation judgment, where they had to choose between two paraphrases of the sentence they had just seen, and one acceptability judgment. After a sentence from one of the experimental conditions exemplified in (41) was displayed, a blank screen was displayed for two seconds (in an effort to prevent rote learning), and then a screen with the question and the reformulation choices exemplified in (42) appeared. The B choice was designed to evoke the doubly quantified interpretation. Participants had been instructed that each displayed sentence was an utterance said by one of two characters, Jean or Marie. The name of the speaker was displayed at the beginning of each sentence.

(41) a. Gram

Marie: Michel a demandé à beaucoup de gens **des** conseils
Michel has requested to a_lot *DE* people INDF.PL advice
à propos du discours qu' il doit faire le 14 juillet.
to purpose *DE*.the speech that he must make the 14 July
'Michel requested from a lot of people advice about the speech that he must make on July 14.'

[20] In Frazier & Clifton's experiments, subjects were asked to choose one of two paraphrases, for example, *The number of students who turn in their assignments late is large* or *The number of students who frequently turn in their assignments late is large*.

b. Int
Marie: Michel a demandé à beaucoup de gens **de** conseils à propos du discours qu'il doit faire le 14 juillet.

(42) D'après ce que vous avez compris de l'énoncé de Marie:
'According to your interpretation of what Marie said:'
A. Michel a demandé **au moins un** conseil à chaque personne.
'Michel requested **at least one** piece of advice from everyone.'
B. Michel a demandé **une grande quantité de** conseils à chaque personne.
'Michel requested **a great deal of** advice from everyone.'

Before the experiment started, participants were given two practice examples; they had to choose the best paraphrase of each and say whether it was acceptable or not. After their answer, they were given feedback. Neither of the two examples used in the training phase had to do with quantification or phrase licensing.

Then the experiment started. The experimental phase proper consisted of six examples: three initial examples plus two experimental items proper (see below for why we chose to have only two items tested per participant) plus one filler.

The three initial (grammatical) examples (43)–(45) were given (in the same order) to all participants at the beginning. They were designed to calibrate the judgment scale.

(43) Marie: M. Dupont a distribué à plein d' étudiants
Mr. Dupont has distributed to many *DE* students
plein de tracts pour les prochaines élections présidentielles.
many *DE* leaflets for the next elections presidential
'Mr. Dupont distributed to a lot of students a lot of leaflets for the upcoming presidential elections.'
a. D'après ce que vous avez compris de l'énoncé de Marie:
'According to your interpretation of what Marie said:'
A. Chaque étudiant a reçu au moins un tract.
'Each student received at least one leaflet.'
B. Chaque étudiant a reçu une grande quantité de tracts.
'Each student received a large quantity of leaflets.'
b. Trouvez-vous l'énoncé de Marie acceptable?
'Do you find Marie's utterance acceptable?'
A. Oui.
'Yes.'
B. Non.
'No.'

(44) Jean: Tous les élèves ont fait signer
all the students have made sign
leur photo de classe à des professeurs.
their photo of class to INDF.PL professors
'All the students got their class photo signed by some professors.'
a. D'après ce que vous avez compris de l'énoncé de Jean:
'According to your interpretation of what Jean said:'
A. Chaque élève a fait signer sa photo de classe à au moins un professeur.
'Each student got their class photo signed by at least one professor.'

B. Chaque élève a fait signer sa photo de classe à un grand nombre de professeurs.
'Each student got their class photo signed by a large number of professors.'

b. Trouvez-vous l'énoncé de Jean acceptable?
'Do you find Jean's utterance acceptable?'
A. Oui.
'Yes.'
B. Non.
'No.'

(45) Jean: Le professeur a distribué à plein d' étudiants
The professor has distributed to many *DE* students
des affiches faisant la publicité d' un forum professionnel.
INDF.PL posters making the publicity *DE* a forum professional
'The professor distributed to many students posters publicizing a professional forum.'

a. D'après ce que vous avez compris de l'énoncé de Jean:
'According to your interpretation of what Jean said:'
A. Chaque étudiant a reçu au moins une affiche.
'Each student received at least one poster.'
B. Chaque étudiant a reçu une grande quantité d'affiches.
'Each student received a large quantity of posters.'

b. Trouvez-vous l'énoncé de Jean acceptable?
'Do you find Jean's utterance acceptable?'
A. Oui.
'Yes.'
B. Non.
'No.'

Then participants saw two experimental items (one Gram and one Int) and one filler item containing a completely different structure.[21] We developed 20 sets of experimental items that each consisted of the two experimental conditions, Gram and Int.

[21]The extra item, exemplified in (i), contained the phrase *je doute que oui*, lit. 'I doubt that yes'. For a different project, we were interested in knowing whether there was a correlation between the acceptability of the sequence *je doute que oui* and the interpretation of *je doute* 'I doubt' as *je ne suis pas sûr* 'I am not sure' as opposed to *je ne pense pas* 'I don't think'.

(i) Jean: Louise pense que Thomas a bien pensé à
Louise thinks that Thomas has well thought to
envoyer son dossier à temps mais je doute que oui.
send his file on time but I doubt that yes

a. D'après ce que vous avez compris de l'énoncé de Jean:
'According to your interpretation of what Jean said:'
A. **Je ne suis pas sûr** que Tom ait pensé à envoyer son dossier à temps.
'I am not sure that Tom thought to send his file on time.'
B. **Je pense** que Tom **n'**a **pas** pensé à envoyer son dossier à temps.
'I think Tom didn't think to send his file on time.'

b. Trouvez-vous l'énoncé de Jean acceptable?
'Do you find John's utterance acceptable?'
A. Oui.
'Yes.'
B. Non.
'No.'

TABLE 20 Condition means and standard errors for number of doubly quantified (B) responses

	Doubly quantified interpretation	
Condition	**Mean**	**SE**
Gram	.43	.04
Int	.53	.04

Five different *de*-phrase-licensing +QAD quantifiers were used in the study, each occurring in four item sets. They are listed in (46) along with the corresponding phrases that were used in the B alternatives on the question screen to test for the doubly quantified interpretation.

(46) Quantifiers used in the study

beaucoup	'a lot'	une grande quantité de	'a large quantity of'
trop	'too many/much'	un nombre excessif de	'an excessive number of'
énormément	'a great deal of'	un très grand nombre de	'a very large number of'
suffisamment	'enough'	une quantité raisonnable de	'a reasonable quantity of'
pas mal	'quite a few/some'	un nombre conséquent de	'a significant number of'

Whereas in previous experiments, we compared grammatical items both to their Ungram counterparts and to their intrusive counterparts—across +QAD and −QAD levels in experiments 2–4—here we chose to only compare +QAD grammatical and +QAD intrusive items; that is, we chose to design an experiment with just two conditions. Furthermore, we chose to have just one observation per condition.

We chose to only present two conditions because our repair hypothesis makes interpretive predictions for grammatical and intrusive +QAD sentences only (not for ungrammatical sentences of the type we used in previous experiments). As for the number of observations, after receiving feedback from participants in a test run of the experiment, we chose to present only one item per condition because we did not want participants to develop a response strategy. Hence the high number of participants for this experiment.

7.1.3 | Predictions

The repair hypothesis predicts that the illusory *de*-NP conditions should be interpreted as doubly quantified.

7.2 | Results

By-condition average number of doubly quantified interpretations for all experimental conditions is presented in table 20, along with by-participant standard errors.

We ran a mixed-effects model with response as dependent variable, taking condition as a fixed effect (sum coded as in table 21) and fitting random intercepts by subject. The difference was not significant at the 0.05 level ($\beta = .21$ ($\pm .13$), $z = 1.62$, $p = .1$).

TABLE 21 Contrast coding

	Grammaticality
Gram	−1
Int	1

TABLE 22 Condition means and standard errors for number of doubly quantified (B) responses, for items judged acceptable only

	Doubly quantified interpretation	
Condition	**Mean**	**SE**
Gram	.51	.06
Int	.59	.06

7.3 | Post-hoc analysis

It is possible that the predicted interpretation only arises when participants experience a grammatical illusion. To test this possibility, we ran a post-hoc analysis on only those items that were judged acceptable. We report in table 22 the interpretation results for items that were judged acceptable only ($N = 59$).[22]

We ran a mixed-effects model with response as dependent variable, taking condition as a fixed effect (sum coded as in table 21) and fitting random intercepts by subject. Again, the difference between the two conditions was not significant ($\beta = .28$ ($\pm .16$), $z = 1.7$, $p = .08$).

7.4 | Discussion

While experiment 5 had no clear outcome, we report it in the interest of fully documenting the results of our research project.We saw an effect in the predicted direction: the doubly quantified interpretation was chosen more for the intrusive condition than for the grammatical condition. This is compatible with the predictions of the repair hypothesis in section 6.2. However the effect was not statistically significant, and so we cannot draw clear conclusions.[23] As a consequence, we continue to develop the cue-based account to model our findings, while bearing in mind that future work might yet provide evidence for a repair-based account.

[22]Only 59 participants (out of 129) judged both the Gram and Int sentences acceptable *and* responded to the interpretation question for both items within the two-second time window.

[23]An anonymous reviewer stresses that experiment 5 has very low statistical power and that consequently a null result is not entirely surprising. Heather Burnett (personal communication) commented that perhaps the failure to obtain a significant contrast is to be blamed on the vagueness of *beaucoup* and that perhaps further work could use quantifiers that have linguistically instanced points of comparison (i.e., *plus que* 'more than'), which yield sharper truth conditions for the doubly quantified meaning and might therefore provide a better test.

8 | GENERAL DISCUSSION

8.1 | Our findings in light of the debate between retrieval and repair

We repeat the three central questions that guided our investigation:

(47) Three questions
   a. Can *de*-NP-licensing quantifiers intrusively license *de* NPs?
   b. Can all *de*-NP-licensing quantifiers intrusively license *de* NPs?
   c. What properties of a quantifier are critical for intrusive licensing?
   = (25)

We found a grammatical illusion in four experiments: the presence of a *de*-NP-licensing quantifier raises the acceptability of an ungrammatical sentence even if the quantifier is not accessible grammatically. However we found that not all *de*-NP-licensing quantifiers give rise to the grammatical illusion to the same extent. We established that quantifiers that can be grammatically separated from their *de*-NP restrictor (i.e., +QAD quantifiers) intrusively license grammatically unlicensed *de* NPs to a significantly greater extent than quantifiers that must appear adjacent to the *de* NP they license in the grammar (−QAD quantifiers).

We entertained two hypotheses for the mechanism that underlies this effect. Under the cue-based-retrieval account (sketched in section 6.1), nonlocally licensed *de* NPs trigger retrieval from memory of a licensing quantifier that matches the retrieval cues. When an element in memory matches the retrieval cues, it may be reactivated. If a licensing element is not in a structural position to grammatically license the *de* NP, as in our intrusive conditions, a partial match may suffice for it to be reactivated, giving rise to the illusion of licensing and grammaticality. In addition to this account, we explored a repair-based account in terms of structural reanalysis (section 6.2). This account has the strength of correctly predicting the interaction between quantifier type (+QAD or −QAD) and improved acceptability of Int sentences, but in experiment 5 we failed to observe clear evidence for the predicted interpretive effect.[24]

On a cue-based account, one important question is how the difference between +QAD and −QAD quantifiers arises. Our finding that the magnitude of illusory licensing is smaller with −QAD quantifiers suggests that they do not constitute a strong partial match for the features demanded by an unlicensed *de* NP. In the next section, we suggest that this supports a view of memory-retrieval processes where what guides the retrieval is the structure of the quantifiers themselves.

[24]Of course there are alternative repair accounts, and our failure to observe the predicted effect does not falsify repair accounts in general. A repair account with no interpretative prediction might go as follows. The processor first indexes the first *de* NP it encounters as the restrictor of the quantifier, and, when it encounters the second *de* NP, it revises that assignment to assign the quantifier to the second restrictor. This reassignment mechanism would be similar to the one Fodor 1978 proposes to explain the interpretive ambiguity of English examples like the following.

(i) **To whom** did you say that Father wrote?
   a. You said to whom [that Father wrote]?
   b. You said [that Father wrote to whom]?
   c. To whom$_i$ did you say t$_i$ [that Father wrote t$_i$]?

8.2 | Parsing *de* NPs in a cue-based architecture

We interpret the *de*-NP-illusion effect as a grammatical illusion arising from the dynamics of a cue-based processing system. We turn now to a more detailed sketch of the process of parsing *de* NPs, from this perspective.

We couch our account in the cue-based parsing model of R. Lewis & Vasishth 2005. This is one prominent account of cue-based parsing, implemented in the ACT-R cognitive architecture (Adaptive Character of Thought–Rational; Anderson 1990, R. Lewis & Vasishth 2005, Vasishth et al. 2008). The R. Lewis & Vasishth model proposes that the parser proceeds in a left-corner fashion, that is, encoding constituents into working memory as soon as any bottom-up evidence for those constituents becomes available. As the parser proceeds through a sentence, the corresponding phrase marker is split into its major constituents, which are subsequently encoded as "chunks" in working memory. These chunks encode the major features of each constituent (such as its major syntactic category, its lexical head, and any relevant morphosyntactic features), along with the links between constituents in the parse tree. On this model, one of the key processing bottlenecks during incremental syntactic processing is reaccessing or retrieving these constituent encodings from working memory when they are necessary. Retrieval, in this context, refers to the process of reactivating a constituent from working memory and moving it into an active working-memory store or *focus of attention*, where it can undergo active processing. Retrieval of constituents from working memory proceeds via the use of retrieval cues, features of the to-be-retrieved constituent. A core component of this model and others like it is the claim that the size of the focus of attention is limited, that is, that only some of the information processed up to a certain point can be maintained in an active state (McElree et al. 2003, R. Lewis & Vasishth 2005). Older information is stored in a passive-memory store and must therefore be retrieved if needed. Parsing in this model involves continuously shunting information in and out of active-memory stores in order to form dependencies during processing. In this model grammatical illusions arise as a result of the retrieval of irrelevant chunks that partially match the retrieval cues of the item in the focus of attention.

In such a model, one possibility is that *de* NPs licensed by a string-adjacent quantifier, as in (48), are special because, in that case, both licensor and licensee are in the focus of attention (boldface), which means that parsing this configuration need not rely on memory-retrieval processes to establish the dependency.

(48) a. J' ai écrit **beaucoup [de lettres].**
I have written a_lot *DE* letters
'I wrote many letters.'
b. *J'ai écrit à **beaucoup [de gens]** de lettres.

In contrast, *de* NPs that are not immediately adjacent to their licensing quantifiers, such as those in (49), should, on this theory, require a cue-based memory-retrieval operation to establish the dependency.

(49) a. J' ai beaucoup écrit **[de lettres].**
I have a_lot written *DE* letters
'I wrote many letters.'
b. *J'ai écrit à beaucoup de gens **[de lettres].**

This follows from the assumption that the material that intervenes between the licensing quantifier and the *de* NP needs to make use of the limited focus of attention and, as a result, the quantifier must be reactivated from memory when it is needed later on to process the dependent *de* NP. On this view, only nonlocally licensed *de* NPs trigger cue-based retrieval.

From this perspective, an important question is what information is used to retrieve the licensing quantifier. The retrieval cues are standardly assumed to involve the grammatical features that are necessary to license the element currently being processed, but they need not stand in a one-to-one relationship with the features necessary to license an element in memory (R. Lewis & Vasishth 2005, Dillon et al. 2013, Dillon 2014, Kush et al. 2015, Kush et al. 2018). For the case at hand, the retrieval cues must minimally distinguish +QAD quantifiers from −QAD quantifiers, such that retrieval operations will selectively activate +QAD quantifiers. On this account, the intrusive +QAD quantifiers in our intrusive sentences partially match the retrieval cues used to reactivate potential *de*-NP licensors in memory, which leads to some probability of accidentally reactivating the intrusive +QAD quantifier. This in turns results in an illusion of grammaticality (Vasishth et al. 2008, Phillips et al. 2011). In contrast −QAD quantifiers do not create a similar grammatical illusion, since they do not match the cues for licensors that can license *de* NPs at a distance.

What cues might plausibly distinguish +QAD from −QAD quantifiers in memory? Recall that *beaucoup*-type quantifiers have a complex underlying structure, namely N+Adj+Adv. This is motivated by the observation that +QAD quantifiers like *beaucoup* have three different uses, as VP adverbs, pronouns, and determiners: this has been argued to reflect an underlying structure where items like *beaucoup* are adverbs that can modify a silent adjective MANY modifying a silent noun NUMBER (Kayne 2002). By contrast, *plein*-type quantifiers are adjectives (e.g., AdjP) that cannot stand on their own and need to modify an NP. A retrieval operation that needs to selectively activate +QAD quantifiers may plausibly index this categorial difference by deploying a categorial retrieval cue such as N+Adj+Adv. With such a cue only *beaucoup*-type quantifiers will be retrieved since only they have an underlying structure that matches it.

It is important to note that the categorial retrieval cue we propose here is related to but distinct from the grammatical constraints on phrases that can license *de* NPs. It is not the case that only quantifiers that match the N+Adj+Adv categorial feature can license *de* NPs: it is possible for −QAD quantifiers that are local to a *de* NP to license it, and those quantifiers do not match this feature. Instead, the suggestion we make here is that the cue is selectively deployed when it is necessary to retrieve a long-distance licensor, because it is a useful feature that the parser can exploit to identify quantifiers that can license at a distance. This gives this cue utility as a feature that is diagnostic of quantifiers that can license at a distance; it could be profitably used by a parser that can recognize when it needs to selectively activate a grammatical element that can license a *de*-NP licensor at a distance.

One outstanding issue is how such a system could distinguish between c-commanding +QAD quantifiers and non-c-commanding, or intrusive, +QAD quantifiers. How to encode relational information like c-command in a cue-based-retrieval architecture remains an outstanding theoretical issue that we cannot resolve on the basis of the present data; see Wagers 2008, Alcocer & Phillips 2012, Franck & Wagers 2020, Kush 2013, Kush et al. 2015 for discussion. For example, Kush et al. propose that the parser can actively track c-commanding quantifier phrases by marking them with a feature that they call ACCESSIBLE, which is dynamically updated on individual quantifier phrases over the course of a parse so that all and only the c-commanding quantifier phrases bear it at any point in an incremental parse (for more details, see Kush 2013, Kush et al. 2015). In the context of the current proposal, ACCESSIBLE could be used to distinguish

grammatical from intrusive +QAD quantifiers. It is also possible that the c-command relationship can be implicitly encoded in the resting activation of different phrases in memory or in some other type of context features that are associated with phrases when they are encoded in memory: see Wagers 2008 and Franck & Wagers 2020 for an in-depth discussion of these issues.

Stepping back, the present data are naturally explained by a cue-based-parsing architecture that attempts to retrieve long-distance quantifiers using both abstract categorial cues (which selectively activate +QAD licensors) and relational cues (which selectively activate c-commanding phrases). Intrusive licensing, on this view, arises as a function of the partial match between non-c-commanding +QAD quantifiers and these retrieval cues. Non-c-commmanding −QAD quantifiers, on the other hand, match neither cue and hence show a much smaller illusion of grammaticality.

8.3 | On the interpretation of illusory structures

One important question concerning the cue-based-retrieval account of illusory *de*-NP licensing is what types of interpretations this parsing process would ultimately license. The question of how illusory licensing relates to interpretation has been studied with regard to agreement-attraction phenomena.

One natural possibility is that if an illusory licensor is retrieved, it is capable of forming a dependency that can then be interpreted. This possibility was investigated in Schlueter et al. 2019. In this study, participants read sentences that contained illusory-agreement configurations, followed by a two-alternative forced-choice judgment about which adjective better continued the sentence. For example, a participant would read *The bed by the lamps undoubtedly were quite …* and then be asked to decide whether *comfortable* or *bright* was a better continuation of the sentence. Schlueter et al. reasoned that if the agreement illusion led participants to treat the distractor *lamps* as the thematic subject of the sentence, then there should be an increase in the rate of *bright* responses in their two-alternative forced-choice task. They found evidence for this prediction, but the overall magnitude of the effect was quite small relative to the rate of agreement attraction. Schlueter et al. concluded that agreement attraction did not routinely result in a direct thematic realignment of the sentence. Instead, they concluded, the retrieval mechanism is often deployed as a "low-level-rechecking" mechanism that monitors the well formedness of the parse and does not generally have interpretive consequences. However, a number of other studies do suggest that the number marking on a distractor can influence the overall interpretation of an agreement-attraction configuration by increasing the probability that participants will interpret a grammatically singular head noun as notionally plural (Patson & Husband 2016, Brehm et al. 2019).

In the case of illusory *de*-NP licensing, we failed to find evidence for the predicted "double-quantification" interpretation of the repair-based account. However, this could be for several reasons. Firstly and perhaps most straightforwardly, we may have simply lacked the statistical power to detect an effect. As an anonymous reviewer correctly points out, this is a live possibility, and so this null result should be interpreted with caution. In addition to this, if Schlueter et al.'s generalization about illusory-agreement phenomena generalizes to *de*-NP illusions, then we might not expect incorrect retrievals to result in any interpretive consequence. It is possible that the retrieval processes we described in section 8.2 are deployed as a superficial or low-level rechecking process, allowing easy integration of the *de* NP and high sentence acceptability but not directly guiding interpretation. In other words, it may be that *de*-NP illusions reflect a process

that monitors well formedness at the syntactic level but does not have any impact on the semantic interpretation of the *de* NP.

8.4 | Alternative approaches to illusory *de*-NP licensing

There are a number of alternative approaches that might account for the data we have presented.

One important alternative analysis is suggested by noisy-channel models of sentence interpretation. As reviewed in section 6.2, the noisy-channel approach allows comprehenders to achieve a nonliteral interpretation of linguistic input and does so by positing that comprehenders may entertain edits to the form of a sentence that strike a balance between faithfulness to the input and plausible, likely analyses of that input. This approach might allow a simple repair strategy for the present cases: participants could simply correct an ungrammatical *de* to a grammatical *des*, which would only require the insertion of a single segment. This would result in an unlicensed *de* NP being converted into an indefinite plural NP.

This repair strategy would apply to both fully ungrammatical sentences and sentences where the ungrammatical *de* NP is subject to illusory-licensing effects. So one challenge for such an approach is to explain why repair is more likely specifically in intrusive contexts. Furthermore, this model must explain why this is more likely with intrusive +QAD quantifiers. It is difficult to see how the presence of an intrusive quantifier makes it more likely that comprehenders will entertain the *de*-to-*des* edit, since indefinite plurals marked with *des* do not need to cooccur with either type of quantifier. Thus, while we certainly cannot rule out the possibility that comprehenders are simply interpreting an ungrammatical *de* NP as an indefinite plural marked with *des*, it is at present unclear how this hypothesis captures the full distribution of illusory *de*-NP licensing.

Another possibility is that comprehenders consider an edit to the input that places the +QAD intrusive quantifier in a c-commanding position where it could license the ungrammatical *de* NP: that is, the input sentence *J'ai donné à **beaucoup** d'amis de livres* = I have given to many *DE* friends *DE* books would be edited to *J'ai **beaucoup** donné à d'amis de livres* = I have many given to *DE* friends *DE* books. This edit would allow the critical quantifier to license the unlicensed *de* NP in the input and would only be possible with +QAD quantifiers. But this edit creates a second unlicensed *de* NP (i.e., *d'amis*). Since this edit does not yield a grammatical sentence, it is unclear how it would explain the intrusive-licensing effects we observed in our experiments. In addition, a noisy-channel correction that places a +QAD quantifier in a c-commanding position predicts that the *de* NPs should be interpreted the same in grammatical sentences and intrusive sentences, which we failed to find any evidence for in experiment 5. While we cannot categorically rule out the possibility of a noisy-channel-style explanation of our results, it also seems fair to say that further elaboration of this model to account for the full range of the present findings is necessary.

8.5 | Avenues for future research

One central contribution of this work is the establishment of illusory *de*-NP licensing in French, which we have analyzed in terms of an independently motivated cue-based-parsing architecture. However, there remain many important questions that are beyond the scope of the present work, which remain for future research.

One of the most important questions is how the distribution of illusory *de*-NP licensing compares to other well-documented grammatical illusions, such as agreement-attraction phenomena and illusory NPI licensing. Of particular importance for future work is a careful comparison of illusory NPI licensing and illusory *de*-NP licensing. Although illusory NPI licensing has sometimes been argued to reflect the cue-driven illusory licensing that we have also advanced here (Vasishth et al. 2008), subsequent research into the mechanisms underlying illusory NPI licensing suggests a different analysis. For example, Xiang et al. 2013 shows that illusory NPI licensing but not agreement attraction correlates across individuals with their score on the Communication Subscale of the Autism Quotient (Baron-Cohen et al. 2001, Xiang et al. 2013); Xiang et al. interpret this as evidence that NPI illusions are driven by a pragmatic-rescuing strategy (for related claims about NPI illusions, see Xiang et al. 2009, Mendia et al. 2018). Importantly, NPI illusions are also observed in contexts where the NPI precedes its illusory licensor, as in Turkish (Yanilmaz & Drury 2018); accounts that rely on memory retrieval do not straightforwardly predict the effect when the NPI precedes the intrusive licensor. More recently, it has been shown that NPI illusions are selectively triggered by intrusive quantifiers, suggesting a more limited distribution of NPI-illusion effects than predicted on cue-based-retrieval accounts of this phenomenon (Muller & Phillips 2020, de Dios Flores 2021, Orth et al. 2021). These relatively restricted distributions suggest a different underlying mechanism for NPI licensing, such as illusory licensing driven by overapplication of a quantifier-raising process (Orth et al. 2021) or difficulty integrating the NPI into the immediately post-relative-clause context (Muller & Phillips 2020). Like NPI illusions, *de*-NP illusions involve intrusion by a grammatically inaccessible quantifier. This similarity suggests that it may be possible to understand both *de*-NP illusions and NPI illusions as reflecting a common underlying source, distinct from the analysis in terms of cue-based retrieval that we offered in section 8.2. For example, Orth et al. 2021's model of NPI illusions that attributes them to fleeting, ungrammatical quantifier-raising processes might extend to cover illusory *de*-NP licensing, if we suppose that only +QAD quantifiers may participate in covert quantifier raising.

Given all of this, a clear direction for future research is determining the scope of *de*-NP illusions, with an eye to establishing whether they are relatively unselective (as predicted on a cue-based-retrieval account) or more selective (as might be expected if they are more similar to NPI illusions). If *de*-NP illusions prove to be a rather general phenomenon, then this would lend support to the cue-based account we have articulated in some detail. However, if the distribution of *de*-NP illusions turns out to be more restricted, this would lend support to other analyses of this effect, for example in terms of a fleeting consideration of an ungrammatical quantifier-raising process (Orth et al. 2021).

One possible way to distinguish these broad approaches is to investigate how many *de* NPs a single intrusive licensor can license. In our experiments we only tested sentences with two *de* NPs, one grammatically licensed and one not. But it is possible to create such sentences with three or even four *de* NPs, only one of which is actually licensed:

(50) Three *de* NPs

a. Beaucoup **de gens** ont laissé des enfants utiliser des armes à feu.
a_lot *DE* people have let INDF.PL children use INDF.PL firearms
'Many people have let children use firearms.'

b. *Beaucoup **de gens** ont laissé **d'enfants** utiliser **d'armes à feu**.

c. *Des gens ont laissé **d'enfants** utiliser **d'armes à feu**.

(51) Four *de* NPs

a. Beaucoup **d' hommes politiques** ont laissé des
a_lot *DE* men political have let INDF.PL
gens laisser des enfants utiliser des armes à feu.
people let INDF.PL children use INDF.PL firearms
'Many politicians have let people let children use firearms.'

b. *Beaucoup **d' hommes politiques** ont laissé **de gens** laisser **d'enfants** utiliser **d' armes à feu.**

c. *Des hommes politiques ont laissé **de gens** laisser **d' enfants** utiliser **d' armes à feu**.

On a cue-based approach, each nonlocally licensed *de* NP launches its own retrieval operation to identify a quantifier. Without any constraints on the number of times a quantifier can be partially matched by these retrieval operations, this approach predicts that each *de* NP should be subject to illusory licensing on its own. On the other hand, if this effect reflects fleeting uncertainty about the structure (Orth et al. 2021) or the context (Muller & Phillips 2020), then we might expect that unlicensed *de* NPs after the first would be less subject to illusory licensing, as the structure and incremental context of the unfolding sentence becomes clearer.

9 | CONCLUSION

We have presented the results of five studies that demonstrate the existence of a novel grammatical illusion in French. The distribution of *de*-NP illusions in French demonstrates that illusory-licensing phenomena are not triggered to the same magnitude by the presence of lexical *de*-NP licensors in linearly preceding material. Instead, we have observed that structural conditions had an effect on spurious *de*-NP licensing: the quantifiers must be, in principle, able to participate in QAD dependencies. We have analyzed this in terms of a cue-based parser that uses syntactic category to identify a licensor in memory, creating partial feature matches and illusory licensing only with quantifiers that can participate in +QAD dependencies. However, further work is necessary to further delineate the scope of *de*-NP illusions in French.

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DATA-AVAILABILITY STATEMENT

All original data discussed in this article (stimuli, results, script) are available on the corresponding Open Science Framework repository: https://osf.io/sgw48/?view_only=1ff62b0d0ed04467b68ba8f773052013.

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