Predicting Definiteness:
The Impact of Definiteness Information on Comprehender Expectations

Zoe Schlueter
University of Maryland
Ling 895
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1 Introduction

Definiteness plays an important role in signaling the status of a discourse referent. In English, one of the ways in which definiteness can be encoded is on the article of a noun phrase. Which article is appropriate in a certain discourse context is a matter of the status of the discourse referent the noun phrase refers to. The referents of NPs with the definite article “the” are usually old, already mentioned in prior discourse, whereas those of NPs with the indefinite article “a” are usually new.

In principle, comprehenders might use these facts to predict what kind of noun will follow either article. The current project asks whether they are able to make use of this information at all, and if so, how fast they can incorporate definiteness information encoded on the article into predictions about the upcoming noun in online processing. The question of whether and how quickly comprehenders use definiteness information bears on several important issues in the field of sentence processing. Firstly, it is not clear whether information that is used by comprehenders offline is
always available online. While some models incorporate all contextual information into expectations immediately (e.g. Levy, 2008), recent work suggests that some predictions take time. Secondly, our understanding of discourse processing is still very limited, as this is an area of study that has been gaining interest only recently. There is a small number of studies that has examined how discourse processing interacts with predictive mechanisms in language comprehension. For example, van Berkum et al. (2005) found evidence that comprehenders anticipate specific nouns in relatively unconstraining sentences based on the content of a preceding context sentence. Furthermore, Nieuwland and van Berkum (2006) demonstrated that discourse context can modulate the response to verb-object animacy violations. Although this work shows that predictions are made across discourse, there has been hardly any work focusing on how predictive mechanisms utilise discourse-related information encoded on single words.

Here we report four experiments investigating how quickly definiteness can inform predictions of upcoming input. We find that definiteness information on the article affects the prediction of the following noun offline. However, it is not incorporated fast enough by predictive mechanisms to do so in online processing, as evidenced by the absence of an N400 effect on the noun. We do see an N400 effect on the article, with the indefinite article eliciting a greater negative deflection than the definite article. This suggests that prediction may be happening already at the article, which is supported by results from an offline cloze task. It should be pointed out that the prediction happening at the article is potentially a different kind of prediction than that at the noun. While the prediction of the upcoming noun we see offline is based on the definiteness information specifically encoded on the article, the prediction at the article is not based on a particular word or feature, but rather on comprehenders’ general expectations about how a discourse is likely to unfold. Our results suggest
that comprehenders are not able to rapidly use definiteness to inform expectations, but they may be able to use the general discourse context to predict definiteness.

1.1 Definiteness and Discourse Status

There is a difference between definites and indefinites regarding the contexts in which they can be used felicitously. While there is consensus that definites are constrained by requirements on the context of use that do not apply to indefinites, there is disagreement about what exactly these requirements are. Broadly speaking, in order to use a singular definite the N, it must be possible for the hearer to identify a unique N as the speaker’s intended referent. This is not the case for the use of a singular indefinite a N. As Strawson puts it,

We use ‘the’ either when a previous reference has been made, and when ‘the’ signalises that the same reference is being made; or when, in the absence of a previous indefinite reference, the context (including the hearer’s assumed knowledge) is expected to enable the hearer to tell what reference is being made. We use ‘a’ either when these conditions are not fulfilled, or when, although a definite reference could be made, we wish to keep dark the identity of the individual to whom, or to which, we are referring. (Strawson, 1950, p. 342)

However, although there is agreement that definites are associated with certain requirements, there is a lot of disagreement about the details. If a definite needs a uniquely identifiable referent, the question arises what it means to be “unique” or “identifiable”. Moreover, there is a debate about the status of this requirement. While it has been claimed that it is part of what is said in using a definite, it has also been argued that it is a condition on when a sentence containing a definite description
has a classical truth-value. In this section, we will briefly review some of the major responses to these questions.

The well-known dispute between Russell and Strawson mainly concerned the status of the requirement. Russell (1905) proposed that descriptions of the form article plus noun are not referring expressions. Their semantic function is not to contribute an individual to the proposition expressed by the sentence in which they occur. Instead, they contribute a restricted existential quantifier, and sentences containing a definite or indefinite description express existential propositions. This is illustrated in (1-b) and (2-b). (1-a) and (2-a) are based on how Russell’s ideas have usually been translated into predicate logic.

(1) The cat slept.
   a. \( \exists x (\text{cat}(x) \land \forall y (\text{cat}(y) \rightarrow y = x) \land \text{slept}(x)) \)
   b. There is only one thing that is a cat, and that thing slept.

(2) A cat slept.
   a. \( \exists x (\text{cat}(x) \land \text{slept}(x)) \)
   b. There exists something that is both a cat and slept.

According to Russell’s proposal, the difference between definite and indefinite descriptions is that sentences containing a definite description express a proposition that contains a uniqueness condition. In the example in (1), the sentence contains the definite noun phrase the cat and thus expresses an existential proposition with a uniqueness condition, meaning that there is exactly one entity that both cat and slept apply to. This is not the case for the sentence in (2), since it contains the indefinite noun phrase a cat. Although Russell did not make this claim very clearly, it has since become standard to assume as part of the “Russellian view” that the proposition
expressed by a sentence with a description is asserted. This makes the uniqueness requirement part of what is asserted in using a sentence with a definite description.

This view was challenged by Strawson (1950), who argued that definite descriptions are, at least sometimes, referring expressions, and their semantic function is to contribute an individual to the proposition expressed in using a sentence. According to Strawson, the existence and uniqueness requirements of definite descriptions are preconditions on the possibility of reference. He argues that a definite description can only be used by a speaker to refer to an object when “the context [...] is expected to enable the hearer to tell what reference is being made” (Strawson, 1950, p. 342). It follows that when a speaker uses a definite description that fails to refer, they fail to assert any proposition with the sentence containing it. For example, the sentence The rose is red. cannot be used to attribute redness to a particular rose unless the context provides a referent for the rose. For this reason the preconditions on successful reference contribute to what a speaker presupposes in using a definite. If they want to communicate a proposition, the speaker will only use the N when they presuppose that the context provides a single relevant N.

Another topic of disagreement has been the exact content of the requirement associated with definites. Much of this dispute centers on cases where uniqueness seems to be violated. In these cases there seems to be more than one N in the context and the content of the definite description used by the speaker does not seem sufficient to pick out a unique referent. Nevertheless, the speaker successfully refers to just one of the N. These are called “incomplete descriptions”. For example, when the sentence in (3) is uttered in a context in which there are multiple rabbits, the descriptive content of the definite description the rabbit is not sufficient to identify a unique rabbit.
Abbott (2003) points out that a popular way of maintaining the uniqueness analysis is to assume that the uniqueness has to hold only in a certain domain of evaluation. However, this raises the issue of how exactly that domain is determined. To illustrate, imagine that the sentence in (4) is uttered in a situation in which there is a number of jurors and a number of contestants, and one member of each group is Russian. In order for the uniqueness requirement of the definites to be fulfilled, the relevant domain of evaluation has to shift during the sentence. For the Russian in subject position to have a unique referent, the domain of evaluation has to include only the members of the jury, but for the Russian in object position it must be the group of contestants.

(4) The Russian voted for the Russian. (Neale 2004)

Roberts (2003) proposes that definites have an informational uniqueness requirement rather than an absolute uniqueness requirement. She argues that the uniqueness of definites is presupposed (following Strawson), but that it is a presupposition of informational uniqueness. This means that "sufficient information has been given to uniquely indicate the intended antecedent, a discourse referent, among all those in the common ground of the participants" (Roberts, 2003, p. 307). In the rabbit example, this would mean that although there are multiple rabbits at the moment of utterance, what matters is not that the domain contains a single N, but that the hearer has enough information to know which referent the speaker means to refer to. It should be noted that this is very similar to Strawson’s proposal, as can be seen from the quote above. This would account for the fact that uttering (3) in a situation in which there are multiple rabbits but only one is in a hat seems fine, whereas it would be
infelicitous in a situation where multiple rabbits are in a hat (at least as long as none of them is clearly more salient than the others and could be uniquely identified that way). An important aspect of this account is that the referent of a definite description is a discourse referent and only has to be uniquely identifiable in the common ground of the discourse participants. It is important to note that discourse referents can be in the common ground without having been explicitly mentioned, which brings us to the familiarity presupposition of definites.

Sentences usually occur as part of a discourse rather than in isolation. A major feature of discourse is that it is possible to refer back to things that have been previously mentioned. Karttunen (1976) introduced the concept of discourse referents, which are referent representations stored in the participants’ mental model of a discourse. Generally, use of a definite noun phrase presupposes that its discourse referent is already present in the model. Use of an indefinite, however, does not. Thus, use of an indefinite will commonly introduce a new discourse referent, one not already in the model. As Karttunen showed, however, the context in which the indefinite occurs will decide whether its discourse referent will remain in the model. For instance, a discourse referent introduced by an indefinite within the scope of a modal may not persist outside its scope. Nevertheless, the definiteness of a noun phrase is crucial in signaling the status of its referent representation in the discourse.

Heim (1982) proposed a non-quantificational treatment of definite and indefinite noun phrases, according to which they introduce only a free variable, much like pronouns, and a descriptive predicate. To explain the difference between definite and indefinite noun phrases, Heim argues that they have different felicitousness conditions. While definites have a familiarity presupposition, indefinites must be novel. Following Karttunen (1976), this means that indefinites introduce a new discourse referent into the discourse model, while definite NPs are anaphoric in nature and refer back to an
already existing discourse referent. It is an important point that the antecedent of a definite is not a particular linguistic expression, but a discourse referent, because it explains why it is not always necessary for the antecedent to have been explicitly mentioned in the discourse. Instead, it is sufficient if there is a contextually salient referent in the common ground. Roberts (2003) refers to this as weak familiarity, meaning that the referent’s existence has to be entailed by the context, compared to strong familiarity, for which the antecedent must have been previously mentioned. It is possible for people to update their common ground to include entities that are inferable in the context, making the felicitous use of definites without a linguistic antecedent possible through accommodation.

It should be noted that the familiarity account of definites also runs into trouble with examples such as (3). As mentioned above, this sentence can be felicitously uttered in a situation in which there are multiple rabbits, but only one is in a hat. It is not the case that the rabbit in the hat is any more familiar than the other rabbits, so it is not clear how familiarity can explain this fact. Instead, it seems that it is identifiability that matters. In this situation, it is not the definite description by itself which achieves this, but its combination with the predicate that makes the referent identifiable to the hearer.

For the present study, the most important point is that there is a difference in the familiarity assumption for definite and indefinite descriptions. Definite NPs must have antecedents, even if they are not explicitly linguistic. Moreover, it is important to remember that the felicitousness condition of indefinites does not have the same status as the familiarity requirement of definites. Whether familiarity is a presupposition or part of the assertion made by uttering a sentence containing a definite description is a question that will not be addressed by our study.
1.2 Previous Studies

The aim of the present study is to investigate whether the definiteness information encoded on the definite/indefinite article is used as a cue by comprehenders in real-time language processing in order to anticipate the following noun. To our knowledge, only a small number of ERP studies have looked at how nouns are processed after the definite versus indefinite article, and none of them have done so specifically in terms of prediction. We will review the evidence for the predictive mechanisms that underlie sentence processing in the next section. Previous studies that have systematically varied the definiteness of an article (Anderson & Holcomb, 2005; Schumacher, 2009; Kirsten et al., 2014) have had conflicting findings in regard to the ERPs elicited by the following noun and the ERPs elicited by the definite and indefinite articles themselves.

Previous research has shown that in a context where a noun has already been mentioned, a repeated mention of the noun preceded by the definite article results in faster reaction times in a lexical decision task (Irwin et al., 1982) and shorter sentence reading times (Murphy, 1984) than when preceded by the indefinite article. Although these results suggest that the definite article facilitates processing of the following noun under these circumstances, there is reason to be cautious about drawing this conclusion considering the measures used in these two studies. In the study by Irwin et al., participants were presented with the entire context sentence and the definite/indefinite article preceding the target noun, but they did not see the target until they pressed a button. Once the screen changed to the target word, they immediately had to make a lexical decision. It could be argued that results from this task design might not accurately reflect the processing of nouns after the definite versus the indefinite article in normal language processing. Although the study by
Murphy (1984) required participants to read short paragraphs and thus used a task that might encourage language processing that is more natural, this measure might still not provide us with the information we need. In this study, reading time was measured for the entire sentence containing the noun phrase of interest, rather than specifically at the region of interest. Therefore, it is uninformative about how exactly the temporal dynamics of noun processing are impacted by the definite versus the indefinite article.

A way of avoiding these methodological concerns is to conduct studies using methods with high temporal resolution, such as ERP. ERP has the advantage that it can provide information about the timecourse of linguistic processing at the millisecond level. The first study to investigate the real-time processing of nouns after definite compared to indefinite articles using ERPs was a study into the effects of noun repetition, synonymy, and coreference by Anderson and Holcomb (2005). In one of their experiments, they presented sentences starting with either the definite or indefinite article followed by the critical noun. These sentences were preceded by a context sentence containing either the same critical noun or a synonym, as illustrated in (5) and (6). Coreference was manipulated by using the definite or indefinite article to indicate whether the following noun had an anaphoric relation to a previously mentioned entity, or if it introduced a new referent. Co-referential nouns (following the definite article) elicited a more negative going waveform over anterior electrodes in the 300-600ms time window. However, this main effect of definiteness only appeared when ERPs were time-locked to the noun rather than to the article. With a pre-article baseline, there was only an interaction between definiteness and scalp distribution, with the effect of definiteness being significant at anterior electrodes. They also observed an increased anterior negativity at the article in the indefinite condition between 300-600ms.
Anderson and Holcomb’s (2005) results demonstrate an important methodological point for ERP studies of definiteness processing. In ERP studies it is conventional to time-lock to the word of interest and baseline to the immediately preceding time-window. However, although the word of interest here is the noun, the definite and indefinite condition do not actually differ at the noun, but at the preceding article. This makes time-locking to the noun problematic, as the difference between conditions at the preceding word can cause baseline issues. As mentioned above, Anderson and Holcomb only observed a main effect of definiteness in the 300-600ms interval when ERPs were time-locked to noun onset. Since they did not find this main effect when they used a pre-article baseline, it is most likely due to the baseline difference caused by the response to the article. Therefore, in the rest of this paper I will focus on ERP results that are time-locked to article onset, unless otherwise noted.

In order to ensure that the findings from their experiment were not driven by a basic preference for definiteness rather than by the relation to context, Anderson and Holcomb conducted a control experiment to assess how nouns are processed following the definite compared to the indefinite article in the absence of any context. They used the same target sentences as in (6), but they were presented without the context sentence. In the absence of context, there would be no reason to anticipate any particular noun after a definite article. The results were slightly different from
those of the experiment in which they included context sentences. Just as in the other experiment, they found that, when time-locked to the noun, there was a main effect of definiteness at the noun between 300-600ms, with those preceded by the definite article eliciting a more negative going waveform over anterior electrodes. However, this effect disappeared when using a pre-article baseline. Unlike in the experiment with context sentences, there was not only no main effect of definiteness, but also no interactions involving definiteness as a factor at the noun. The indefinite article elicited a more negative-going waveform than the definite article over midline anterior electrodes in the 300-600ms interval, which is consistent with the findings from their other experiment. Anderson and Holcomb point out that this effect cannot be due to coreference per se, since there is no context provided for these sentences in the control experiment and the articles were in sentence-initial position. Instead, there is a general preference for definite noun phrases in subject position, which could account for this difference. In spite of the potential baseline issues when time-locking to the noun, Anderson and Holcomb argue that the results from this control experiment indicate that the effect they found on the noun in the 300-600ms time window in the experiment including context sentences is an instance of a left anterior negativity. They interpret this to be an index of the greater working memory demand for processing referential assignment when encountering a coreferential noun that has to be linked to its antecedent.

A study by Schumacher (2009) not only varied the definiteness of the article, but also used three different kinds of context sentences. Depending on the context, the critical noun phrase in the target sentence was either given, inferred or new, as illustrated in (7) and (8). She found that there was no effect of definiteness on the noun in the 300-500ms interval, which is inconsistent with the interaction of definiteness and scalp distribution Anderson and Holcomb observed in this time window, which showed
a significant effect of definiteness at anterior electrodes. However, while Anderson and Holcomb failed to find a main effect of definiteness on the noun, Schumacher’s results showed an effect on the noun in the 550-700ms time window, in which previously introduced nouns following a definite article did not elicit a late positivity compared to nouns following an indefinite article.

(7) Context sentence
   a. *Given*
      
      Peter besuchte neulich einen Redner in München.
      
      Peter has recently visited a speaker in Munich.
   
   b. *Inferred*
      
      Peter besuchte neulich einen Vortrag in München.
      
      Peter has recently visited a lecture in Munich.
   
   c. *New*
      
      Peter traf neulich Hannah in München.
      
      Peter has recently met Hannah in Munich.

(8) Target sentence
   a. *Definite*
      
      Er erzählte, dass der Redner sehr nett war.
      
      He said that the speaker had been very nice.
   
   b. *Indefinite*
      
      Er erzählte, dass ein Redner sehr nett war.
      
      He said that a speaker had been very nice.

These findings do not support Anderson and Holcomb’s claim that processing a
coreferential noun following a definite article requires more working memory resources than processing a non-coreferential noun following an indefinite article. Instead, Schumacher argues that her results show that the processing of a noun following the indefinite article places additional cognitive demands on the comprehender, as indicated by the late positivity. According to Schumacher, the reason for this is that the indefinite article signals that current discourse representation structures have to be updated by adding a new discourse referent. Contrary to Anderson and Holcomb’s conclusions, this suggests that processing a noun is more difficult when it follows an indefinite article rather than when it follows a definite article. However, it should be noted that the ERP component Anderson and Holcomb interpret to index increased working memory demands associated with processing coreferential nouns occurs in a different time window than the component taken by Schumacher to show that processing a non-coreferential noun is more effortful.

Another interesting difference between the findings by Schumacher and Anderson and Holcomb is that Schumacher’s results show that the definite article elicited a more negative going waveform between 400-700ms, especially over the left hemisphere. This is the reverse of the pattern observed by Anderson and Holcomb, who found an increased negativity on the indefinite article. If the increased negativity is a sign of greater processing demands, Schumacher’s results indicate that preparing for reference resolution to an antecedent upon encountering the definite article is more costly than the processing occurring at the indefinite article. In contrast, Anderson and Holcomb’s findings would indicate that cognitive demands are higher at the indefinite article when comprehenders have to prepare for establishing a new discourse referent. This suggests a timecourse of processing that is different from Schumacher’s claim that the processing cost associated with this form of discourse updating occurs late at the noun.
While Schumacher found that definiteness did not have a significant effect on the noun in the N400 time window, context did. Nouns that were 'new' based on the context sentence elicited a stronger N400 response than 'inferred' or 'given' ones. It could be argued that the reduction in N400 amplitude for the 'given' and 'inferred' nouns is a result of comprehender expectations that are not generated based on the 'new' context sentences. However, Schumacher assumes a view of the N400 according to which it is an index of plausibility rather than prediction. Specifically, she interprets the N400 in relation to referential processing as reflecting the degree of difficulty of referent identification. Schumacher justifies this by conducting an offline sentence completion task showing that there is no main effect of context in the completions, which she takes as evidence that an expectation-based explanation of the ERP patterns is not warranted. However, as only an extremely small number of items was included in the sentence fragment completion task, this conclusion does not seem fully warranted.

Another concern regarding this study is that participants were presented with all six versions of each item set. This means that they saw the same sentences multiple times during the course of the experiment, which is less than ideal. It has been shown that comprehenders can adapt their predictions based on the input over the course of an experiment (Hanulikova, 2012). Considering that only 100 of the 340 stimuli participants saw were filler items, it is possible that they stopped using the definiteness on the article as a cue to the following noun, since this prediction would have been violated in a large percentage of trials.

In contrast to the studies by Anderson and Holcomb (2005) and Schumacher (2009), Kirsten et al. (2014) did not find any difference between nouns following a definite compared to an indefinite article in either the N400 or P600 time window. However, they were primarily concerned with the way in which presupposition triggers
such as the definite and indefinite articles are processed and did therefore not focus on
the following noun. In their experiment, participants were presented with a context
sentence that either introduced a single entity or a group of entities, as illustrated
in (9). They then saw a test sentence that contained a repetition of the same noun
(or a synonym) preceded by either the definite or indefinite article, as can be seen in
(10). Depending on the context sentence, the presupposition of the article in the test
sentence is either fulfilled or violated. Kirsten et al. argue that the definite article
triggers a uniqueness presupposition, meaning that a ‘definite’ test sentence can only
be used felicitously after a ‘unique’ context sentence. Conversely, they consider the
indefinite article to be an “anti-uniqueness” presupposition trigger, which can only
be felicitously used after a ‘non-unique’ context sentence.

(9) Context sentence
a. Unique
Antje war gestern im Zoo in Düsseldorf und besuchte einen Eisbären im
Bärengehege.
Antje visited the Duesseldorf zoo yesterday and saw a polar bear in the
bear enclosure.

b. Non-unique
Antje war gestern im Zoo in Düsseldorf und besuchte einige Eisbären im
Bärengehege.
Antje visited the Duesseldorf zoo yesterday and saw some polar bears in
the bear enclosure.

(10) Test sentence
a. Definite

16
Antje beobachtete, dass der Eisbär sehr aggressiv war.
Antje noticed that the polar bear was very aggressive.

b. *Indefinite*

Antje beobachtete, dass ein Eisbär sehr aggressiv war.
Antje noticed that a polar bear was very aggressive.

When only considering the English translation of the materials, it is not clear why a ‘definite’ test sentence becomes infelicitous at the definite article after a ‘non-unique’ context sentence. In English, this only happens at the following noun “bear”, at which point the noun phrase is unambiguously singular. Up to that point, it is possible that the full noun phrase is the plural form “the polar bears”, which would be fine after a ‘non-unique’ context sentence, since it could pick out the unique group of polar bears as its referent. However, in German number is explicitly encoded on the definite article. There are three forms of the definite article: “der” (masculine), “die” (feminine), and “das” (neuter). Whereas the form of the definite article differs for singular nouns depending on their syntactic gender, the plural form of the definite article is “die”, regardless of gender. Therefore, upon being presented with the masculine or neuter form of the definite article, comprehenders can conclude that the noun phrase’s number can only be singular. It should be noted that the same is not true for “die”, which could precede either the singular form of a feminine noun or the plural form of a noun of any gender. As far as we can tell, Kirsten et al. did not only include masculine and neuter nouns for which number is disambiguated at the definite article.

The interpretation of the results from Kirsten et al.’s study is complicated by the fact that it uses a 2x2x2 design, in which not only definiteness but also the type of noun (repetition versus synonym) and the context (matching versus mismatching)
are included as factors. Kirsten et al. found an effect of definiteness on the article in the 350-450ms time window, with the definite article eliciting an enhanced negativity in comparison to the indefinite article. This is consistent with the findings from Schumacher (2009), but the reverse pattern from that observed by Anderson and Holcomb (2005). However, this includes data from both matching and mismatching trials. Kirsten et al. explain this effect in line with Schumacher’s interpretation, arguing it demonstrates that the definite article triggers the preparation of a search for a unique referent and thus requires a higher amount of working memory capacity to process. Although they mention that the negativity could be an N400 caused by expectancy violation, they disregard this possibility because they see no reason for the definite article to be less predicted than the indefinite article in their materials.

Additionally, they found an effect of matching at the article in both the N400 and P600 time window. For test sentences that were preceded by a context sentence which did not fulfill the article’s uniqueness/anti-uniqueness presupposition, the results show an increased negativity at the article between 350-450ms and an increased positivity between 500-700ms. This pattern emerged for both the definite and indefinite article, leading Kirsten et al. to suggest that processing differences between the two articles occur during a later stage of processing. Kirsten et al. claim that the effect in the N400 time window is indeed an N400 reflecting the semantic mismatch, while the late positivity is an index of attempts to reevaluate the sentence. Interestingly, there was no main effect of definiteness or of matching at the noun in either the N400 or P600 time window. Nevertheless, the fact that they did not observe any difference on the noun depending on the definiteness information of the article does not preclude the possibility that this information can be used as a cue to the upcoming noun.

There are some concerns about the design of this study. The study uses an unusually small number of participants (N=15) and suffers from the same issue of
stimulus repetition as the study by Schumacher. 80 sets of experimental items in four
conditions each plus 40 sets of filler items following the same pattern were presented
to all participants. This means that participants saw all four test sentence pairs of
every experimental item set (plus fillers), so a total of 480 sentence pairs. Kirsten et
al. mention that the ERP recording session lasted for approximately 4 hours, which
is unusually long. This might be problematic, since longer recording sessions can lead
to a decrease in the quality of the data due to participant fatigue.

Reviewing the small number of studies in the previous literature, it remains un-
clear what effect the definiteness of an article has on the processing of the following
noun. There is conflicting evidence not just regarding the ERPs at the noun, but
the studies also found different patterns evoked by the definite and indefinite articles
themselves. As mentioned above, none of the studies presenting data on the ERPs
evoked by nouns after a definite versus indefinite article were interested in whether
definiteness information on the article had an impact on the prediction of the upcom-
ing noun. Consequently, the studies by Anderson and Holcomb (2005) and Kirsten
et al. (2014) did not establish the cloze probability of the critical nouns in their ma-
terials. Although Schumacher (2009) conducted an offline completion task, this only
included six items in which the noun was given in the context sentence, in spite of the
fact that the ERP study used 40 item sets. In order to assess whether definiteness
information can be used as a cue in online processing, it is important to establish that
it is actually informative in offline measures. Another issue with the previous studies
is that all three of them had complicated designs in which definiteness was only one
of the factors. As a result, the analyses involved multiple factors and interaction
effects, often making them difficult to interpret regarding the effect of definiteness on
the noun.

If we want to establish whether definiteness information can be rapidly incorpo-
rated into predictions about the upcoming noun, a study focusing on definiteness with a simpler design is warranted. Therefore, we conducted a series of experiments using materials in which only the definiteness of the article preceding the critical noun is systematically varied, while context sentences and target nouns were kept constant across conditions. As a first step we conducted a sentence completion task to establish the cloze probability of the target nouns following the definite versus indefinite article (experiment 1).

1.3 Predictive Mechanisms in Language Comprehension

The aim of our study is to investigate whether definiteness information encoded on the article is available to inform predictions of the upcoming noun. If it turns out that this information is in principle available to comprehenders, we also want to establish whether it can be rapidly incorporated into expectations of the following noun in online processing. Therefore, in this section we provide a brief overview of the research on predictive mechanisms in language comprehension, and the recent suggestion that prediction may not always be fast.

Comprehenders are presented with linguistic input at a rapid rate and yet they are able to effortlessly and successfully derive the intended interpretations. Recent research has shown that the mechanisms underlying language comprehension are not driven exclusively by bottom-up processes. Instead, there is overwhelming evidence that top-down mechanisms that make use of the existing information to predict upcoming input also play a large role. However, it is not clear how quickly different kinds of information are available to generate predictions. The predictability of a word in a given context can be assessed with an offline task that measures the frequency with which it is used to complete a sentence fragment. Although this can provide us with
information about the cues that comprehenders utilise in an untimed task, it does not answer the question of whether they are able to make use of the same information in real-time processing. Since language unfolds so rapidly in time, predictive processes must be fast to be useful, i.e. a prediction must have been computed before the actual input is received. It is quite possible that certain kinds of information are either not encoded or incorporated fast enough to inform expectations immediately. While it is in principle possible that predictive mechanisms may use all contextually available information (e.g. Levy, 2008), recent work suggests that some information cannot be integrated immediately (Chow et al., 2014).

Much of the research on predictive mechanisms in real-time processing has been conducted using event-related potentials, due to the high temporal resolution of this method. In these studies, the N400, a negative-going ERP component that begins to emerge around 250ms and peaks at approximately 400ms post stimulus onset (Kutas & Hillyard, 1980), is used as an index of prediction. The initial view of the N400 was that it is a response to semantic incongruity, since semantically incongruous words elicit a stronger N400 than their congruent counter-parts (Kutas & Hillyard, 1980). However, subsequent research has demonstrated that expectations modulate the amplitude of the N400, with words that are highly predicted in a context eliciting a reduced N400 compared to unexpected words in the same context (Kutas & Hillyard, 1984; Wlotko & Federmeier, 2013; Lau et al., 2015). This is thought to be a reflection of the fact that when the upcoming input is consistent with the previously computed prediction this results in facilitated access of lexical information, and hence easier processing of the word (Lau et al., 2009).

The expectations comprehenders generate arise in part from semantic memory based on the unfolding sentential context (Federmeier & Kutas, 1999). However, the N400 effect is not driven by activation that spreads passively in semantic memory, but
by predictions of upcoming input that are generated ahead of time (Lau et al. 2013). More support for this view of the N400 comes from a study by Wicha et al. (2004), who used the Spanish gender system to show that native-speaker comprehenders were predicting nouns in highly constraining contexts. They measured the ERP response at the article preceding the noun and found that articles that did not match the gender of the most likely upcoming noun elicited an increase in N400 amplitude. Since it was always possible to continue the sentences with a noun of a different gender without creating semantic incongruity, this response indicates that the processor is not only sensitive to the probability of words when it encounters them in the input. In order to see this effect on the article, comprehenders must have actively predicted the upcoming noun, including its gender. A similar study in English comes from DeLong et al. (2005). This experiment also measured the ERP response at the article of highly predictable nouns to confirm that comprehenders anticipate upcoming input. They used the two forms of the indefinite article in English ("a"/"an"), which are determined by the phonological form of the noun they precede. In highly constraining contexts in which the noun with the highest cloze probability required the indefinite article "an", the indefinite article "a" evoked an increased N400 response. Once again, we see an effect of the subsequent noun on the article, although the comprehender has not yet encountered the noun in the input. In this case, the results suggest that the prediction of the noun must include its phonological form.

In spite of mounting evidence for the importance of context-based prediction in online language processing, there are studies that suggest that not all populations equally make use of contextual information to generate predictions. It has been found that older adults do not compute predictions to the same extent as younger adults (Federmeier et al., 2002). Moreover, second language learners also do not seem to use top-down predictive processes as much as native speakers and instead
rely heavily on bottom-up input (Martin et al., 2013). It has been suggested that this is linked to comprehension difficulties these populations experience, especially in noisy environments in which the bottom-up input is degraded.

A lot of research has emphasised how fast the processor actively generates predictions. However, recent work suggests that some predictions take time. Chow et al. (2014) investigated how quickly predictions are generated in real-time and whether this depends on the information source based on which they are computed. They looked at verb prediction in a verb-final construction in Mandarin Chinese, where the verb prediction is generated based on the verb’s arguments. Their findings show that changing the lexical identity of one of the arguments did have an immediate effect on the prediction of the verb. In contrast, changing the argument role information did not result in an N400 effect at the verb. For example, when "police officer" was the patient and "thief" was the agent, there was no N400 effect at the verb "arrested" compared to the canonical condition, in which "police officer" was the agent and "thief" was the patient. The effect re-emerged when comprehenders were given more processing time by introducing extra adverbial material between the arguments and the verb. Based on these findings, it appears that lexical identity is an information source that is immediately available and can rapidly be incorporated into predictions, whereas predictions based on argument role need time to be computed. These are two very different kinds of information that are available in the sentential context. The fact that the timecourse of prediction differs between them raises the question of when different sources of information become available to predictive mechanisms. Furthermore, it also raises the question of what underlying processes are responsible for these differences in timing.
2 The present study

The aim of the present study was to investigate whether the definiteness information encoded on the article is used as a cue by comprehenders in real-time language processing to inform their expectations of the following noun. The small number of ERP studies that have systematically varied the definiteness of the article to look at how the processing of a noun differs depending on whether it occurs after the definite or indefinite article, have not done so in terms of the predictive mechanisms that underlie sentence processing. These previous studies (Anderson & Holcomb, 2005; Schumacher, 2009; Kirsten et al., 2014) have had conflicting findings not only in regard to the ERPs elicited by the nouns, but also about the ERPs in response to the definite versus indefinite article. Consequently, we conducted a number of empirical studies to establish whether definiteness is in principle available to inform expectations of the upcoming noun when there is no time constraint, and whether it can be rapidly incorporated into predictions in real-time comprehension. In addition, we conducted another offline experiment to assess the possibility that comprehenders may be predicting definiteness already at the article.

2.1 Experiment 1: Offline Completions

The goal of experiment 1 was to examine whether the definiteness of the article affects the choice of the upcoming noun in offline completions, since cloze probability is closely related to predictability (Wlotko & Federmeier, 2013). If people are able to extract the definiteness information on the article and incorporate it into their choice of the subsequent noun, we would expect the target noun (a noun that we already introduced in the context sentence) to have a higher cloze probability in the definite condition. This means that we would see a higher number of completions with the
target noun after the definite article compared to after the indefinite article. However, if definiteness has no influence on the choice of the following noun, there should be no difference between the two conditions in how frequently people used the target noun to complete the sentences.

2.1.1 Methods and Design

Participants

Data from 124 individuals was analysed for this experiment. All participants were recruited via Amazon Mechanical Turk and had passed a test designed to verify that American English was their native language. This test assessed knowledge of a number of complex grammatical structures and participants had to score at least 8 out of 10 points to be eligible for the study. Participants gave informed consent and received $4 for completing the experiment. Data from two additional participants was excluded, one did not pass the native speaker test and the other repeated the given sentence fragments as part of their answers.

Materials

The materials for this experiment were 30 item sets consisting of a context sentence introducing a discourse referent using a noun N, and a continuation sentence where a second token of N follows either the definite or the indefinite article, see (11) and (12). The subject of the first sentence was always a proper name and was also used as the subject of the continuation sentence, where it occurred in pronominal form. In 17 of the items the critical noun phrase appeared in object position, in 12 it was the subject of a subordinate clause, and in one item it was part of an adjunct.

(11) Mary tried on a dress in the new store. She bought the dress because it fit
(12) Mary tried on a dress in the new store. She bought a dress because it fit her really well.

For this cloze experiment, the items were then cut off after the critical article in the continuation sentence, see example (13) and (14). There were six conditions in this experiment, but only two of these will be reported here.

(13) Mary tried on a dress in the new store. She bought the _____________

(14) Mary tried on a dress in the new store. She bought a _____________

In addition to the 30 experimental items, there were 70 filler items. 36 of these consisted of a single sentence fragment that was highly constraining towards a specific noun. The other 34 fillers consisted of a context sentence and a continuation sentence fragment. The subject of the context sentence was always a full plural definite description, and the subject of the continuation sentence was always “they”. This was similar to the construction of the experimental items and served to ensure that there was no immediately obvious difference between the fillers and the experimental items. Furthermore, the fillers were chosen so that 26 of them contained either the definite or indefinite article as the last word before the sentence was cut off. This introduced variation into the kind of word participants encountered in this position, while not leading to a categorical and easy to observe difference between fillers and experimental items.

Procedure

Participants were recruited via Amazon Mechanical Turk and completed the experiment on their own computers, using the online experiment platform IBEX (Drum-
mond, 2010). Materials were distributed across six lists using a Latin Square design. Each participant saw all 70 fillers and all 30 experimental items, but each one only in one condition. Consequently, each participant saw five items per condition. Presentation of the items was automatically randomised by IBEX for each participant. Participants were presented with the beginning of a sentence and were instructed to complete the rest of the sentence through text entry. They were informed that the completion could be just one word or a lot longer, depending on how they thought the sentence should finish. Before starting the experiment, participants had to complete two practice items. The first was an incomplete sentence prompting a short (possibly one-word) completion, and the other one consisted of a context sentence followed by a sentence fragment favouring a longer completion. On average, the study took participants about 30 minutes to complete.

2.1.2 Results

Since the goal of this experiment was to determine whether people use the definiteness information encoded on an article to predict the following noun given unlimited time, we extracted the first three words of the completions for analysis. Although the noun immediately follows the article in our materials, it is possible that participants included intervening material such as adjectives, which is why we decided not to limit our analysis to the first word.

The extracted words were visually inspected for misspellings and manually corrected when necessary. Punctuation immediately following a word was also removed. Once these corrections had been made, we computed the number of cases in which any one of the extracted words matched the target noun. The results can be seen in table 1.

The first word of the completions was the target noun in 304 out of 620 cases (49%)
Table 1: Percentage of target noun following the article.

<table>
<thead>
<tr>
<th></th>
<th>Definite</th>
<th>Indefinite</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st word</td>
<td>49.03</td>
<td>9.19</td>
</tr>
<tr>
<td>2nd word</td>
<td>2.58</td>
<td>3.87</td>
</tr>
<tr>
<td>3rd word</td>
<td>0.32</td>
<td>0.65</td>
</tr>
<tr>
<td>total</td>
<td>51.93</td>
<td>13.71</td>
</tr>
</tbody>
</table>

in the definite condition, compared to in only 57 out of 620 cases (9.2%) in the indefinite condition. Completions in both conditions were almost exclusively felicitous. When not choosing the target noun, participants usually continued the fragment with a noun semantically related to the target or the sentential context. A chi-square test of independence was performed to examine the relation between definiteness and frequency of target noun completions. The relation between definiteness and frequency of target noun completions was significant ($\chi^2 (1, N = 620) = 163.77, p < .001$). Participants were significantly more likely to complete the definite condition with the target noun than the indefinite condition.

2.1.3 Discussion

The results of Experiment 1 show that participants are able to use the definiteness of the article to inform their choice of the upcoming noun in an offline sentence completion task, and specifically that a definite determiner context leads to a much higher proportion of completions that repeat a noun previously mentioned in the context. However, the fact that comprehenders can extract and use this information when given unlimited time does not necessarily mean that they are able to utilise it in real-time language comprehension. This question is addressed in the following two experiments using time-sensitive online measures.
2.2 Experiment 2: Self-Paced Reading

Experiment 1 demonstrated that people are able to use the definiteness information of the article to predict the following noun when they have unlimited time. Since it seems that this information is in principle available, the question arises how quickly definiteness can have an effect in online processing. We address this question in Experiment 2 with a self-paced reading task. If the definiteness of the article is rapidly incorporated into predictions about the upcoming noun, we expect to see a slow-down on the critical noun after the indefinite article compared to the reading time on the noun in the definite condition. The reason for this is that definite “the” is likely anaphoric, so comprehenders might predict the previously introduced noun to follow it. In contrast, there are no grounds for this prediction after indefinite “a”, since it does not signal anaphora. Instead, comprehenders might predict that a previously mentioned noun will not occur, since “a” rather than “another” was used.

Alternatively, it is possible that a self-paced reading slow-down could occur due to differences in integration difficulty between the two conditions, even if people were not actively predicting the upcoming noun. In that case, when people are presented with the indefinite article followed by the target noun, difficulties may arise when they integrate them because the noun has already been mentioned. The self-paced reading measure is not specific in this regard and a slow-down could reflect either of these possibilities.

If the definiteness of the article is not available to inform predictions of the upcoming noun in online processing (and it does not have an impact on integration difficulty), we should see no difference in reading times between the two conditions.
2.2.1 Methods and Design

Participants
36 members of the University of Maryland community participated in this experiment. They gave informed consent and received either class credit or financial compensation for their participation. All participants were native-speakers of American English and had normal, or corrected to normal, vision.

Materials
The materials for this experiment were adapted from Experiment 1 and followed the same structure. The stimuli consisted of 36 item sets, each containing a context sentence and a continuation sentence. The context sentence introduced a discourse referent using a noun N, and the continuation sentence contained the critical region consisting of a second token of N preceded either by the definite or indefinite article, depending on the condition. Following the design of Experiment 1, the referent of the subject was the same in the context sentence and the continuation sentence. The subject of the first sentence was always a proper name and the subject of the second sentence the matching pronoun. The critical noun phrase of definite/indefinite article plus N in the continuation sentence was in object position in 20 of the items, in embedded subject position in 15 items, and in adjunct position in 1 item. An example of an experimental item set is presented in (15).

(15) Melinda baked a cake for the office party.

  a. Definite condition: She brought the cake into the break-room and received many compliments.
  b. Indefinite condition: She brought a cake into the break-room and received many compliments.
Although there were a total of six conditions in this experiment, only two will be reported here. The experimental items were distributed across six lists using a Latin Square design and 6 participants were assigned to each list. Participants saw all 36 items, but each item only in one of the conditions. Consequently, each participant saw six items per condition.

Fillers consisted of 24 item sets in four conditions. Each item consisted of a passive sentence with or without a by-phrase followed by a reason clause either in the same sentence or in a second sentence. Participants saw all 24 filler items, but only in one condition each. There were 96 additional fillers, half of which consisted of only one sentence and the other half of two sentences.

Procedure
Participants were seated in front of a computer screen in a dimly lit room. The items were presented on the screen in a self-paced reading task with a moving-window display (Just et al., 1982), using the software Linger (Rohde, 2003). For each trial, the whole item appeared on the screen with the words masked by dashes. Participants saw one word at a time and had to press a button to move on to the next word. When they moved on to the next word, the previous word was remasked. Reading times for each word were recorded. In order to ensure that participants were paying attention to the sentences, they had to answer a yes/no comprehension question after every item by keyboard entry, pressing the ‘f’-key for “yes” and the ‘j’-key for “no”. The experiment took about 30 minutes to complete.

2.2.2 Results
The overall accuracy for the comprehension questions in both the definite and indefinite condition reported here was 94.4%. This indicates that participants were paying
### Table 2: Linear mixed-effects model results for third word after the critical noun in the self-paced reading experiment.

<table>
<thead>
<tr>
<th>Contrast</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>5.69765</td>
<td>0.04278</td>
<td>133.2</td>
</tr>
<tr>
<td>Definiteness</td>
<td>0.04905</td>
<td>0.02578</td>
<td>1.9</td>
</tr>
</tbody>
</table>

attention to the items they were being presented with. No subject scored below the threshold of 75% accuracy across experimental conditions, so data from all 36 subjects was included in the analysis.

We identified the regions of interest as the article, the noun and the post-noun region, up to three words after the noun. In addition to the region of interest, we also analysed RTs at the article and the two words preceding it to ensure that there was no difference between conditions before the critical noun.

Reaction times (RTs) that exceeded a threshold of 2000ms were removed. This resulted in an exclusion of 0.08% of the trials for two words before the article, 0.23% of the trials for three words after the noun, and 0.15% of the trials for four words after the noun. RTs were then log-transformed to correct for positively skewed distributions. RTs were analysed using mixed-effects linear regression with definiteness as the fixed effect (definite vs. indefinite) and subjects and items as random intercepts. No significant effects were observed in any of the regions of interest. However, the effect of definiteness trends towards significance at the third post-noun region, as shown in table 2.

We also analysed RTs at the regions of interest using traditional one-way repeated measures by-subjects ANOVAs. The results confirmed that there was no significant difference in RT between the two conditions on the regions preceding the noun. Furthermore, there was also no significant difference between conditions at the noun or
on the following two regions. However, there was a main effect of definiteness at the third post-noun region ($F(1,35) = 5.23; p = 0.01$). As can be seen in the reading times graph in 1, participants took significantly longer at post3 in the indefinite condition.

2.2.3 Discussion

Although the indefinite condition did show a slow-down relative to the definite condition, the slowdown appeared on the third word after the critical noun rather than on the noun itself or its immediate spill-over region. The observed pattern suggests that article definiteness does have an effect in online processing, but that it is a late effect.
Although the results show that people are sensitive to the difference between the two conditions in online comprehension, they do not demonstrate that the definiteness of the article was immediately incorporated into predictions of the upcoming noun. If that were the case, we would have expected the slow-down observed in the indefinite condition to occur earlier than on the third word after the critical noun. Moreover, the self-paced reading results cannot disambiguate between a slow-down due to a disconfirmed prediction or due to integration difficulty. It is possible that the slow-down in the indefinite condition occurs as a result of difficulty when participants integrate the critical noun with the indefinite article, since the noun has been previously mentioned.

Alternatively, a possible explanation for the observed late effect is that the slow-down is neither a reflection of a prediction being violated nor of integration difficulty at the critical noun, but rather that in our materials integration difficulties arise further downstream in the indefinite condition. While people may have no trouble integrating the critical noun and the indefinite article, once they reach the predicate the sentences in our materials generally become infelicitous in the indefinite condition.

However, it is still possible that people are incorporating the definiteness information of the article into their expectations of the following noun in online processing. Self-paced reading may just not be sufficiently sensitive to pick up any earlier effects than the one we observed here. To address this issue, we followed these results up with an ERP experiment, since that measure has the advantage that it is highly time-sensitive. Furthermore, there is a concern that the large amount of material participants had to click their way through in each item before reaching the critical region might have contributed to the messiness of the data. In future work, it should be explored whether presenting the context sentence as a whole and using a moving-window display only for the continuation sentence could improve the quality of the
2.3 Experiment 3: ERP

The results from the self-paced reading experiment indicate that participants notice the pragmatic inappropriateness of the indefinite condition in online comprehension. However, it is unclear whether this is due to prediction, integration difficulty at the critical noun, or integration difficulty further downstream. Consequently, we conducted an ERP experiment to investigate the temporal dimension of this effect. The advantage of using ERP rather than self-paced reading is that we can distinguish whether an effect is due to processing at the critical noun or whether it arises only in combination with subsequent material. Furthermore, the N400 specifically reflects expectation, while self-paced reading is a less specific measure.

The aim of this experiment was to examine how quickly the definiteness information on the article is incorporated into predictions about the upcoming noun. If definiteness information is immediately encoded and available to predictive mechanisms, we expect to see an effect on the noun. In the definite condition, the article is compatible with anaphora and participants should expect a noun that is compatible with a previously mentioned discourse referent. In contrast, the indefinite article does not signal anaphora, but rather that the noun phrase does not refer to a previously established discourse referent. In fact, participants might predict that a previously mentioned noun will not occur following the indefinite article, since indefinites introduce new discourse referents and “a” rather than “another” was used. If predictions are updated according to this information, we expect the amplitude of the N400 on the noun to be higher in the indefinite condition compared to the definite condition. However, if predictive processing mechanisms cannot incorporate the definiteness in-
formation on the article before the following noun is presented, we should see no difference in N400 amplitude on the noun between conditions.

2.3.1 Methods and Design

Participants
The participants in this study were members of the University of Maryland community, who received monetary compensation or class credit for their participation. All participants gave informed written consent according to the established guidelines of the Institutional Review Board of the University of Maryland. All participants were native speakers of American English, who had only had minimal exposure to another language before age 5. They were all right handed as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971). In total, 48 participants took part in the study. However, 16 participants were excluded due to excessive artifacts in the recordings, defined as a rejection rate above 39%. In 12 of these cases, the high rejection rate that led to the exclusion of the participant’s data was a result of equipment failure. The other 4 participants were excluded due to excessive blinking. Of the 32 participants whose datasets were included in the study, 18 were female and 14 were male, with a mean age of 21.4 years (range: 18-30).

Materials
Sixty experimental items were created based on the items used in the self-paced reading task. Each item consisted of two sentences, a context sentence in which a noun N is introduced, and a continuation sentence in which N follows either the definite or indefinite article. Apart from the article in the critical noun phrase, the items were identical in the two conditions. In the second sentence, the critical noun phrase consisting of article plus N was in object position in 34 of the items, in subject...
position of a subordinate clause in 24 of the items, and in two items it was in adjunct position.

Since the question of interest is whether definiteness can influence the prediction of an upcoming noun, the critical noun phrase in the second sentence of each item appeared either with a definite article (“the necklace”) or an indefinite article (“a necklace”), as can be seen in (16) and (17).

(16) Ann wore a necklace to her friend’s birthday party. She told everyone that
the necklace was an heirloom from her grandmother.

(17) Ann wore a necklace to her friend’s birthday party. She told everyone that a
necklace was an heirloom from her grandmother.

Items were distributed across four lists such that every participant saw all 60 experimental items, but only in one condition. For each list, the same 90 filler items were added and the order of items was randomised between lists.

The 90 filler items were equally divided between three different types. One type consisted of one sentence containing a pair of entities that have a typical, non-reversible relationship. For example, the relationship between fish and penguins is that penguins eat fish, but fish do not eat penguins. 16 of these sentences occurred with the entities in the appropriate argument roles, as in (18), but in 14 of them the argument roles were reversed, as in (19). Since the typical relationship between the arguments is non-reversible, this renders the sentences implausible.

(18) plausible: The aquarium visitor wondered which fish the penguins had eaten
during the performance.

(19) implausible: The aquarium visitor wondered which penguins the fish had
eaten during the performance.
The second type of filler item also consisted of one sentence, all of which were constructed to be highly constraining towards a certain target word. 10 of these 30 fillers contained that expected target word and were plausible, while the other 20 contained an unpredicted word instead. We introduced filler items that contained anomalies such as semantic incongruity and implausibility, so that the experimental items in the indefinite condition would not be noticeable as the only odd sentences in the experiment. For the third type of filler, the items contained two sentences, just like the experimental items. The first sentence set up a context that the second sentence builds on. All of these filler items were plausible to ensure that there were more items without than with any semantic or pragmatic anomalies.

**Procedure**

Participants were asked to read 150 items and had to answer simple yes/no comprehension questions for fifty of them, 20 of those experimental. During the experiment, participants were seated in a dimly lit room in front of a computer monitor. Stimuli were presented visually on the computer monitor in white 24-point case Arial font on a black background. Items were presented at the centre of the screen, one word at a time. Each word was shown for 300 ms, followed by a 200 ms blank screen. For the items followed by a comprehension question, the last word was immediately followed by the question being displayed in full in the centre of the screen. It remained on the screen until the participant responded by button press. The experiment was self-paced and participants were able to take as long between items as they needed. In total, the experiment took about 35-40 minutes to complete.

**Electrophysiological Recording**

We recorded continuous EEG across twenty-nine tin electrodes (O1, O2, P7, P3, Pz,
P4, P8, TP7, Cp3, CPz, CP4, TP8, T7, C3, Cz, C4, T8, FT7, FC3, FCz, FC4, FT8, F7, F3, Fz, F4, F8, FP1, FP2). Scalp electrodes were held in place by an elastic cap (Electro-Cap International, Inc., Eaton, OH) in a 10-20 configuration. Bipolar electrodes were placed above and below the left eye and at the outer canthus of the right and left eyes to monitor horizontal and vertical eye movements. Additional electrodes were attached over the left and right mastoids. Scalp electrodes were referenced online to the left mastoid and re-referenced offline to the average of left and right mastoids. Impedances were maintained at less than 5 kΩ for all scalp electrode sites, less than 2 kΩ for mastoid sites, and less than 5 kΩ for ocular electrodes. The EEG signal was amplified by a NeuroScan SynAmps® Model 5083 (NeuroScan, Inc., Charlotte, NC) with a bandpass of 0.05-100 Hz and was continuously sampled at 500 Hz by an analog-to-digital converter.

Analysis
Event-related potentials were computed from trials free of ocular and muscular artifact using preprocessing routines from the EEGLAB (Delorme & Makeig, 2004) and ERPLAB (erpinfo.org/erplab) toolboxes. This was done separately for each subject and condition for the 2000ms after the onset of the target article. 16 participants with fewer than 60% surviving trials were excluded from further analysis and are not included in the dataset presented here. Across the 32 participants whose datasets are included in the analysis, approximately 17.2% of trials were rejected because of artifact. A 100-ms pre-stimulus baseline was subtracted from all waveforms before statistical analysis, and a 20-Hz low-pass filter was applied to the data offline. Grand-average ERPs across participants were computed for both conditions.

Although we were primarily interested in whether there was an N400 effect at the noun, it was not possible to use ERPs time-locked to the noun, since the difference
in the preceding article between the conditions led to baseline issues. Consequently, all ERPs were computed time-locked to the article. Since all trials were time-locked to the article and there was a SOA of 500ms, the N400 time window for the noun is 800-1000ms after article onset.

Analyses were computed on a number of timeframes using R (R Development Core Team, 2010), chosen based on the literature and visual inspection of the data: 300-500ms for the N400 response at the noun, 250-650ms for the N400 response at the article, and 750-1300ms after article onset. We conducted simple one-way ANOVAs with condition as a factor, collapsing across all 29 electrodes to look for widespread effects. Additionally, we performed a 2x2x2 ANOVA on 20 electrodes divided into quadrants (left anterior: FP1, F7, FT7, F3, FC3; left posterior: TP7, P7, CP3, P3, O1; right anterior: FP2, F4, FC4, F8, FT8; right posterior: TP8, P8, CP4, P4, O2) with condition, quadrant, and anterior-posterior as factors. We will only report effects of topography that included definiteness as a factor.

2.3.2 Results

The grand average ERPs (N=32) time-locked to the article in both conditions are shown in figure 2. Visual inspection shows no hint of a reduced N400 response for the noun following the definite article relative to the indefinite article. Instead, the indefinite condition elicits a more positive going waveform at midline anterior sites between approximately 250-1100ms after noun onset (750-1600ms after article onset). In addition, we observe what appears to be an N400 effect at the article itself, such that at midline posterior sites, the indefinite condition elicited an increased negativity between approximately 250 and 650ms after article onset. We conducted statistical analyses for these time intervals in addition to the canonical N400 time window for both the noun and the article.
The goal of the experiment was to determine whether article definiteness has an impact on the prediction of the following noun; if we see an N400 effect between conditions at the noun, this would indicate that article definiteness has been incorporated into the prediction. However, we saw the opposite pattern of what this would have predicted, in that the indefinite condition was more positive than the definite condition. Overall repeated measures ANOVAs showed a significant effect of definiteness. This effect can also be seen in a repeated measures quadrant ANOVA, which also showed a main effect of condition. There were no significant interactions. As can be seen in the scalp map in figure 2, the effect has a midline anterior distribution, while the N400 has a posterior distribution. This suggests that what we are seeing in this time window is not an N400 effect.

**Noun: Sustained positivity (250-1100ms)**
Figure 3: Grand-average ERPs at frontal midline electrode FZ and the topographic distribution of ERP effects in the 250-1100ms interval after noun onset.

In the 250-1100ms interval after noun onset (750-1600ms relative to article onset), overall repeated measures ANOVAs revealed a significant effect of definiteness ($p < .05$). Quadrant repeated measures ANOVA also showed a significant effect of condition, but no significant interaction effects. As can be seen in figure 3, in this time window the indefinite condition elicited a more positive response than the definite condition.

**Article: N400 response**

In the 300-500ms interval after article onset, overall and quadrant repeated measures ANOVA found no significant effect of definiteness. However, visual inspection of the waveform shows that the waveform for the indefinite condition is more negative going between approximately 250-650ms, as can be seen in figure 4, so we also conducted an analysis on this interval.

In the 250-650ms interval, overall repeated measures ANOVAs showed no main effect between conditions. However, quadrant repeated measures ANOVAs revealed a
2.3.3 Discussion

The absence of an N400 effect at the noun in this experiment indicates that definiteness information on the article is not immediately incorporated into predictions of the upcoming noun. This is in spite of the fact that it has an effect on the noun’s cloze probability offline, as demonstrated in experiment 1. There are two possible reasons for this, if we assume that definiteness information is in principle available for online prediction. First of all, it is possible that the definiteness information on the article has not been encoded by the time the noun is presented and is thus not accessible. Secondly, it is also possible that the definiteness information is encoded immediately upon encountering the article, but the integration of this information by predictive mechanisms might require more processing time than was available to participants in this experiment.
We did find a significant difference between conditions in the 300-500ms time window, but this was due to a sustained anterior positivity. The waveform elicited by the indefinite condition was more positive going than that of the definite condition in this time window, which is the opposite direction of the N400 effect that we were looking for. Visual inspection of the waveforms revealed that this anterior positivity was very sustained and lasted from 750-1600ms after article onset. It is not clear from this experiment whether this effect is a late effect evoked by the article, or an early effect elicited by the noun. We will discuss this point further in the General Discussion.

An additional unexpected finding pertains to the separate question of whether definiteness itself is predicted. We observed an N400 effect on the article, with the indefinite article eliciting a stronger N400 response than the definite article. Although the increased negativity in the indefinite condition at the article is slightly more sustained than a traditional N400 effect, it has a classical N400 distribution across central-parietal sites. This suggests that comprehenders might be generating predictions about the definiteness status of an upcoming noun phrase. This finding also has potential implications for determining whether it is the encoding of definiteness information or the integration of this information into predictions that is delayed. The fact that we see an N400 effect at the article suggests that the delay is due to incorporation of definiteness information into predictions about the following noun, rather than due to a delay in encoding. If comprehenders were not encoding definiteness immediately, we would not expect to see an N400 effect between the two conditions at the article.
2.4 Experiment 4: Offline Completions

Although there was no N400 effect on the noun in the ERP experiment, the N400 effect we observed on the article suggests that comprehenders might be predicting the definiteness of the article. We decided to conduct an offline sentence completion task to establish the cloze probability of the definite and indefinite article in target position in our materials.

2.4.1 Methods and Design

Participants

42 people participated in this sentence completion experiment. Following the methods of Experiment 1, participants were recruited via Amazon Mechanical Turk and had to pass a native speaker test in order to be eligible for participation. All participants provided informed consent and were paid $6 for completing the experiment.

Materials

The materials in this experiment were identical to the materials used for the ERP experiment. The same 60 experimental items were modified for an offline sentence completion task by cutting the continuation sentence off before the target article, as illustrated in (20). Since the items were modified in a way that included removing the article before the target noun, there was only one condition instead of the two conditions in the ERP experiment. Consequently, all participants were run on the same list.

(20) Ann wore a necklace to her friend’s birthday party.  
She told everyone that ________________
The 90 fillers were also the same as those used in the ERP experiment, modified for a sentence completion task. It should be noted that the filler items that were implausible or semantically incongruous in the ERP experiment were not implausible/semantically incongruous in this experiment. The reason for this is that the sentences were truncated before the point at which they became anomalous. Therefore, it was possible for participants to complete them in a plausible way.

Procedure

The experiment was administered via the online experiment platform IBEX (Drummond, 2010). Since there was only one condition, all participants saw all 60 experimental items and all 90 fillers. Items were automatically randomised between participants. Participants were instructed to complete sentence fragments by text entry. The instructions specified that appropriate completions would vary in length and that they were encouraged to complete the sentences in whatever way they thought was best. The two practice items participants had to complete before the start of the experiment were designed to prompt completions of two different lengths.

2.4.2 Results

The aim of this sentence completion task was to establish the cloze probabilities of the definite and indefinite articles, as well as definites in general, in the positions in which the critical article occurred in our materials. Consequently, the first word of all completions was extracted for analysis. We visually inspected the extracted words and removed punctuation immediately following them, as well as contractions.

Next, we counted the number of words that matched the definite article ("the"), the indefinite article ("a"/"an") or one of the following pronouns: "he", "she", "it", "they", "him", "her", "them", "his", "its", "their". The results are provided in table
Table 3: Completions in percent.

<table>
<thead>
<tr>
<th>Subject Object Adjunct Total</th>
<th>(N=1008)</th>
<th>(N=1428)</th>
<th>(N=84)</th>
<th>(N=2520)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indefinite Article</td>
<td>0.6</td>
<td>2.8</td>
<td>8.33</td>
<td>2.1</td>
</tr>
<tr>
<td>Definite Article</td>
<td>13.79</td>
<td>32.07</td>
<td>53.57</td>
<td>25.48</td>
</tr>
<tr>
<td>Pronoun</td>
<td>77.08</td>
<td>46.29</td>
<td>25</td>
<td>57.9</td>
</tr>
<tr>
<td>Definite Total</td>
<td>90.87</td>
<td>78.36</td>
<td>78.57</td>
<td>83.37</td>
</tr>
</tbody>
</table>

3, which includes not only the distribution across all experimental items, but also divided according to the position the critical noun phrase had in our materials.

We can see that the overall cloze probability of the indefinite article in our materials was only 2.1%, compared to 25.48% for the definite article. It should be noted that participants showed a preference for using pronouns (57.9%) as the first word of their sentence completions, which brings the total cloze probability for definites up to 83.37%. Although percentages vary depending on whether the target article plus noun were in subject, object, or adjunct position, the cloze probability of the indefinite article is consistently a lot lower than that of the definite article. Whether participants preferred to continue the sentence fragments with the definite article or pronouns differed between positions in the sentence. However, there is an overwhelming preference for definites (operationalised as definite article plus pronouns), regardless of position.

2.4.3 Discussion

The results of this sentence completion experiment show that participants had a strong preference for definites in the target positions in our materials. The cloze probability of the definite article is considerably higher than that of the indefinite article, which is consistent with the hypothesis that the definite article is more predicted than the indefinite article. If this prediction was fast enough to have an impact in
online processing, that would account for the N400 effect we observed on the article.

The question arises what exactly led to this preference for a definite continuation. It is possible that definites are always more preferred than indefinites, regardless of context, or that the contexts in our materials specifically led to this preference. Given that the materials were designed to make the target noun an expected continuation after the definite article, it is likely that they were biased towards the prediction of a definite in those positions.

Examining the data according to the syntactic position the target NP occurred in shows that the preference for a definite continuation, either in the form of a pronoun or a definite NP, was higher in subject position than in object position. This finding is not surprising, since it is well known that there is a preference for definites in subject position. Conversely, the cloze probability of the indefinite article in subject position is vanishingly small. There is a further difference between continuations in subject versus object position, namely the proportion of the cloze probability of the definite article compared to that of pronouns. While participants were more likely to complete the fragment with a pronoun in either position, this tendency is a lot stronger in subject position. Again, this is consistent with the fact that subjects tend to be highly accessible entities and those are compatible with pronouns as their referring form. Nevertheless, although there are some differences in cloze probabilities between subject and object position, the fact remains that in both positions the cloze probability of the definite article is a lot higher than that of the indefinite article, which is what is crucial for the N400 effect.

It should be emphasised that pronouns were overall a lot more preferred than the definite article. This raises the possibility that the N400 effect was not a result of comprehenders predicting the definite article as a lexical item. Instead, they might be predicting definiteness per se, which is a prediction that can be satisfied by either
the definite article or pronouns. We talk about this in more detail in the general discussion.

3 General Discussion

In the present study, we investigated whether comprehenders can utilise the definiteness information on the article to inform predictions about the upcoming noun, and if so, whether this information can be rapidly incorporated into predictions in online processing. We found in an offline completion task that in the absence of time pressure comprehenders were able to use definiteness to inform predictions about the upcoming noun. However, data from a self-paced reading experiment and from an ERP experiment demonstrated no evidence that this information is immediately available to predictive mechanisms in online comprehension. On the other hand, we found evidence suggesting that prediction was already happening at the article. Below we discuss each of these findings in more detail.

3.1 Comprehenders use Definiteness Information offline

The first step in the present study was to determine if the definiteness information of an article can in principle be used by comprehenders to inform predictions about the following noun when there is no time constraint. To answer that question, we conducted an offline sentence completion task to establish the cloze probabilities of the target nouns following the definite versus indefinite article. We found that in our materials the target nouns had a cloze probability of 49% after the definite article, compared to a cloze probability of 9.2% following the indefinite article. This statistically significant difference between the two conditions demonstrates that participants in this experiment used the definiteness information on the article to inform their
choice of the following noun when given unlimited time.

3.2 Late Effect of Definiteness in SPR

Having established the cloze probability of the target nouns in the two conditions, we investigated whether comprehenders are also able to rapidly integrate definiteness information in online processing. We first conducted a self-paced reading experiment, which did not show a difference between conditions until the third word after the critical noun, at which point there was a slowdown in the indefinite condition. This effect is later than an effect of definiteness would be expected if participants immediately updated their expectations of the upcoming noun when presented with the article. It is not clear whether the slowdown is a late result of a prediction being violated, or, more likely, due to integration difficulties downstream in the indefinite condition.

Nevertheless, this does not rule out that definiteness information is immediately incorporated into expectations. Self-paced reading may not be a sensitive enough online measure to detect processing differences on the critical noun in the two conditions. In fact, the results of the ERP experiment we subsequently carried out show that the critical noun itself is processed differently in the two conditions; meaning participants were sensitive to the definiteness of the article in online processing. However, the effect we found on the critical noun was not in the expected direction and may not reflect the rapid integration of definiteness information into predictive processes.

3.3 No Evidence of Definiteness Effects on Noun Prediction

In the ERP experiment, we observed no difference in N400 amplitude on the noun depending on the definiteness of the preceding article. This was in spite of the fact that the definite and indefinite article resulted in very different predictions about the
following noun offline. The lack of an N400 effect suggests that comprehenders are not able to rapidly incorporate the definiteness of an article into expectations about the following noun in online processing. Since cloze probability has been closely linked to N400 amplitude (Wlotko & Federmeier, 2013) and there is a robust difference in cloze probability of the target nouns in the two conditions, the question arises why we see no modulation of the N400 in this experiment. There are two potential reasons for this: First, it is possible that definiteness information is not computed immediately upon presentation of the article and is thus not available to predictive mechanisms before presentation of the noun. The second potential reason is that, although definiteness is immediately encoded, integrating it into predictions takes more processing time than was available to participants in this experiment, in which there was a stimulus onset asynchrony of 500ms.

One argument against the possibility that the lack of N400 effect is due to comprehenders not immediately computing an article’s definiteness, is that the definite and indefinite article evoked different ERPs. This suggests that the failure to use definiteness information in predicting the upcoming noun is not due to a failure to rapidly encode it. Of course, the differences between the ERPs elicited by the definite compared to the indefinite article could be attributed to low-level differences between them such as length or frequency. However, some evidence that the difference we see on the article is not simply a reflection of the definite and indefinite article being different words comes from Kirsten et al. (2014). In their study, they observed mismatching effects of definiteness immediately upon presentation of the article. These mismatching effects arose for both the definite and indefinite article when they occurred in a context in which they were infelicitous, so their meaning (including definiteness) must have been computed at that point. This strongly suggests that the definiteness information on the article is encoded without delay. Therefore,
we believe the absence of an N400 effect of definiteness at the noun instead indicates that integrating definiteness information into predictions takes time. This stands in contrast to the results from multiple studies that have found that the N400 effect on words that are pragmatically anomalous in their local context is eliminated if they are situated in previously established fictional contexts (Nieuwland & Van Berkum, 2006; Filik & Leuthold, 2008). This indicates an immediate impact of discourse information on the processing of linguistic input. However, the kind of discourse information that is relevant in these cases is of a more global, situational kind, rather than a particular feature encoded on one lexical item.

Our results are consistent with findings by Chow et al. (2014), who found that some predictions take time. In their experiments, they used the BA-construction in Mandarin Chinese which has SOV word order to examine the impact of argument role-reversal on the N400 amplitude at the verb. They used sentences with strongly constraining argument role information, such as “cop” as the agent and “thief” as the patient, which is highly predictive of the verb “arrest”, as in (21). They found that the N400 amplitude at the verb was not immediately affected by the role-reversal of its arguments, so there was no difference at “arrest” between the canonical condition in (21) and the role-reversed condition in (22). This was in spite of the fact that the verb’s cloze probability in an offline measure was drastically affected.

(21) Canonical: cop BA thief arrest – “the cop arrested the thief”

(22) Role-reversed: thief BA cop arrest – “the thief arrested the cop”

They further showed that the N400 effect at the verb re-emerged if participants were given sufficient processing time to incorporate argument-role information into expectations. They achieved this by including adverbial phrases between the arguments.
and the verb. Based on this, Chow et al. propose that the timecourse with which different sources of information become available to inform predictions varies. They suggest that computations involving structural role are more complicated, causing their impact on predictions to be slow.

The results of our study support the previous findings that offline cloze probability does not always correspond to a modulation of the N400 amplitude in online comprehension. Furthermore, they are also consistent with Chow et al.’s suggestion that not all information is immediately available to inform predictive processes. Nevertheless, since we found that definiteness information on the article informs predictions about the upcoming noun offline, we suggest that it can in principle also be informative during online processing. Based on the findings by Chow et al., we predict that we would find an N400 effect on the noun if comprehenders were given additional time to process the definiteness information on the article and incorporate it into their expectations of the upcoming noun.

One important consideration that should be mentioned is whether we think that comprehenders may already be predicting what we will call the target discourse referent or the target noun prior to getting to the article. By target discourse referent, we mean the referent representation established in the context sentence that is the antecedent of the target noun phrase in the definite condition. For example, in (23) the target discourse referent would be the necklace introduced in the first sentence. If we assume that they are not doing so, then the definite article would be a cue that the current noun phrase is going to be anaphoric to an existing discourse referent and in the offline completion task their prediction of the following noun would be based on that information. In contrast, if they were already predicting the target discourse referent prior to the article, the indefinite article would be a cue that instead a new discourse referent is going to be introduced and that their current prediction is wrong.
To rephrase this, the question is whether the definiteness information on the article is used to generate expectations or to inhibit existing expectations.

(23) Ann wore a necklace to her friend’s birthday party. She told everyone that the necklace was an heirloom from her grandmother.

As we saw in experiment 1, the rate of completions with the target noun was a lot higher after the definite article than after the indefinite article. However, in experiment 4 in which the items were truncated before the article, the rate of completions that appear to refer to the target discourse referent is 58.57%, although it should be noted that in many cases we cannot be definitively sure which referent the participant intended, so this is only an estimate. This is very similar to the frequency of the target noun following the definite article in experiment 1. This pattern suggests that the indefinite article decreased prediction of the target noun in experiment 1, rather than the definite article increasing prediction of the target noun. Consequently, when we ask whether definiteness information on the article can be incorporated into predictions about the upcoming noun in online processing, at least with our materials, it seems that we are asking whether comprehenders can use it as a cue to inhibit an existing prediction that was not generated solely based on definiteness information. We could speculate that the reason that definiteness does not rapidly impact predictions in our experiment is that inhibition takes time. If that is the case, the timecourse might be different when the definite article is used as a cue for generating a prediction, since this would not involve inhibition. However, our study was not designed to test this idea and it should be addressed in future work.
3.4 Sustained frontal positivity

Although we found no N400 effect on the noun, our study revealed a sustained frontal difference between conditions at the noun. As we had no a priori hypothesis regarding this effect, it is unclear whether it should be interpreted as an increased positivity in the indefinite condition or an increased negativity in the definite condition. Furthermore, the waveforms for the two conditions start to diverge 250ms after noun onset, meaning that it could either be an early effect of the noun, or a late effect of the article. This effect is very sustained and continues until 1100ms after noun onset. Whatever this effect turns out to be, it is not a P600. It is not limited to the P600 timewindow and it also does not have the P600’s parietal distribution. For these reasons, analysis of this component can only be speculative at this point.

In our materials, the critical noun is the same in both conditions, so any processing difference we see on the noun is caused by how its processing is affected by the difference in the preceding article. If the definite article indicates that the following noun is assumed to refer to a previously introduced discourse referent, it is possible that the noun triggers retrieval processes trying to link it to the matching discourse referent. Therefore, one possibility is that these retrieval processes are indexed by an increased negativity in the definite condition. This would be somewhat consistent with the proposal by Anderson and Holcomb (2005) that processing referential assignment requires greater working memory capacity, as they claim they observed on coreferential nouns following the definite article. However, although the effect they found also had an anterior distribution, it was not nearly as sustained and appeared to be a left anterior negativity, unlike the one in our study.

In contrast to the definite article, the indefinite article has no anaphoric connotation, so comprehenders may treat the following noun differently. They would not try
to retrieve an already established discourse referent, but rather integrate a new one. It is possible that encountering a previously mentioned noun leads comprehenders to try to match it with the discourse referent the noun was previously used to refer to. In that case, there would be a conflict with the information on the indefinite article, which might lead to an increased positivity in this condition. Schumacher (2009) did find a late positivity on the noun in the indefinite condition, which she argues indicates the additional cognitive cost imposed on comprehenders by having to update current discourse representation structures with a new discourse referent. However, this does not seem to be the same effect. The late positivity in Schumacher’s study occurs in the P600 timewindow and has a parietal distribution, unlike the sustained frontal positivity we found.

It should be mentioned that the effect bears a resemblance to late positivities previously observed in low cloze contexts (DeLong et al., 2011, Federmeier et al., 2007). Federmeier et al. (2007) found a frontal positivity between 500-900ms in response to nouns that violated strong sentential constraints, but were nonetheless plausible. A similar late frontal positivity was found by DeLong et al. (2011) in response to low cloze relative to high cloze nouns. The positivity was very sustained (500-1200ms), like the one in our study. However, the positivity we see in our experiment has an earlier onset (250ms) than those reported by other authors, if we assume that it is evoked by the noun following an indefinite article rather than by the indefinite article itself. Nevertheless, DeLong et al. (2011) suggest that the latency of this late positivity can be more variable than what we see for other components, so the possibility that they index the same process should not be ruled out without further investigation. Federmeier et al. argue that the late positivity indexes the processing cost associated with encountering an unexpected word in a highly constraining context, an interpretation that DeLong et al. seem to agree with. However, in both of those studies, the late
positivity occurred following a clear N400 effect, which is not the case in our study. The lack of an N400 effect makes it difficult to argue for an interpretation of the late positivity that reflects prediction disconfirmation.

3.5 Definiteness Effects at the Article: Predicting Definiteness?

Although we failed to find any evidence that comprehenders rapidly use the definiteness information of the article to inform predictions about the upcoming noun, we did find an N400 difference between the two conditions on the article. This finding does not directly pertain to the question of whether noun expectancy is impacted by definiteness, but it suggests that comprehenders might be making predictions about the upcoming noun phrase earlier than we had anticipated.

Experiment 3 showed that in our materials the definite article elicited a reduced N400 compared to the indefinite article. This is consistent with the results from the offline sentence completion task in experiment 4, which showed a higher cloze probability for the definite article (25.5%) compared to the indefinite article (2.1%) in our materials. Schumacher (2009) also found that the definite and indefinite article elicited different responses in the N400 time window, although in her experiment the response to the definite article was more negative-going. She uses the results of an offline completion task to argue that the effect she found on the article was not due to predictive processing. The reason she gives for this claim is that both the definite and indefinite article were unexpected, since most subjects completed the fragments with a pronoun. Schumacher does not report the respective cloze probabilities of the definite and the indefinite article. The offline completion task we conducted to establish the cloze probability of the definite versus the indefinite article in our materials also
showed that the most preferred completion was pronominal (57.9%) rather than either of the articles. However, there was still a difference in cloze probability between the definite and indefinite article, indicating that they were not predicted to the same extent. This might be enough to modulate N400 amplitude.

If prediction is already happening at the article, what exactly are comprehenders predicting? There are a number of possible answers to this question. First of all, it is possible that based on contextual cues and general preferences for information packaging, comprehenders are anticipating a particular discourse referent. Previous work on prediction has often focused on predictions for particular lexical items. For example, DeLong et al. (2005) found an N400 effect on the article matching the phonological form of less predicted nouns. In this case article selection was clearly driven by the phonological form of the following noun, so comprehenders must have preactivated a particular noun, including its phonological representation. It is possible, although far from conclusive, that in our study comprehenders were predicting a specific discourse referent, thus making a specific prediction on the level of discourse representations. Much like DeLong’s case, in which the form of the noun being predicted impacted the compatibility of the preceding article, in our study predicting an established discourse referent would result in an indefinite noun phrase being unexpected since it cannot be used to refer back to an already existing discourse referent. As discussed above, in the sentence fragment completion task in experiment 4, in which items were truncated before the critical article, 58.6% of completions seemed to refer back to the target discourse referent, although participants often used pronouns or synonyms rather than the target noun in our materials. This pattern would certainly be consistent with the hypothesis that in the target position in our materials comprehenders anticipated a particular discourse referent.

Alternatively, comprehenders may be expecting a particular lexical item. As the
offline completion task revealed, in our materials pronouns were by far the most frequent continuation, with a cloze probability of 57.9%. Nevertheless, predicting a pronoun may still facilitate processing of the definite article. Federmeier and Kutas (1999) showed that an unexpected word from the same semantic category as the most likely continuation elicited a reduced N400 compared to an unexpected word from a different semantic category. To illustrate, in (24) the expected continuation was ”palms”. Although ”pines” and ”tulips” were both equally unexpected in this position, ”pines” elicited a reduced N400 compared to ”tulips”.

(24) They wanted to make the hotel look more like a tropical resort. So along the driveway, they planted rows of palms/pines/tulips.

They argue that this is the result of spreading activation from a specific semantic feature of the highly expected word to the unexpected word with the same semantic feature. Maybe a similar hypothesis could be made in our case: if comprehenders are predicting a particular pronoun, that activated pronoun’s definiteness property might lead to spreading activation to the definite determiner. Alternatively, comprehenders may not be anticipating a particular pronoun/lexical item or even discourse referent, but rather have a more general expectation that something definite will come up next, preactivating a “definiteness feature” (in the non-technical sense). This expectation of something definite may then be fulfilled by either the definite article or a pronoun. The results of our study cannot distinguish between these possibilities and we leave it to future research to investigate further.

It should be mentioned that there are potential alternative explanations for the ERP difference we found on the indefinite relative to the definite article, which do not assume prediction to have had already happened at the article. Kirsten et al. (2014) argue that the anaphoric nature of the definite article means that it requires more
working memory capacity to process, which is how they explain the more negative response to it compared to the indefinite article. The idea is that the definite article signals that a previous discourse referent must be retrieved from memory. However, our results show an increased negativity for the indefinite article rather than for the definite article, so the question arises why the definite article is not more costly to process in our materials. The greater negativity evoked by the indefinite article is to a certain extent consistent with the findings from Anderson and Holcomb (2005), since they also observed a greater negativity in response to the indefinite article compared to the definite article. Since all their critical articles occurred sentence initially, this might have been a reflection of the general preference for definites over indefinites in subject position (Grosz et al., 1995). However, this negativity has an anterior distribution, unlike the classic N400 distribution found in our study. Anderson and Holcomb speculate that the greater negativity elicited by the indefinite article might be a reflection of processes anticipating the introduction of a new entity. Although this is in principle compatible with our results, it does not account for the fact that the effect in our study occurs in the N400 time window and follows the classical N400 distribution, facts which strongly suggest that it is in fact an N400 effect indexing predictive processes.

4 Conclusion

In this study, we investigated whether comprehenders use the definiteness information encoded on the article to inform their predictions of the upcoming noun, and if so, whether this information can be rapidly incorporated into predictions in online processing. We found that in an offline sentence completion task comprehenders used the definiteness encoded on the article, which establishes that this information is in
principle available to inform predictions of the upcoming noun. However, we found no evidence that the definiteness on the article is immediately incorporated into predictions in online processing. Instead, the results from our ERP experiment and a follow-up offline sentence completion task suggest that in our materials the definite article is more expected than the indefinite article. However, it is unclear what exactly comprehenders are predicting at the article. Future work should address the question whether they are predicting definiteness per se, a noun phrase referring to a particular discourse referent, or a specific lexical item.

Our results are consistent with the findings from Chow et al. (2014), who argue that some predictions take time. We suggest that the difference in the timecourse of the prediction at the noun and the prediction at the article is due to the fact that they are generated based on two different kinds of contextual information.
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