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Predicting Definite and Indefinite Referents During Discourse Comprehension: Evidence from Event-Related Potentials

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Abstract

Linguistic predictions may be generated from and evaluated against a representation of events and referents described in the discourse. Compatible with this idea, recent work shows that predictions about novel noun phrases include their definiteness. In the current follow-up study, we ask whether people engage similar prediction-related processes for definite and indefinite referents. This question is relevant for linguistic theories that imply a processing difference between definite and indefinite noun phrases, typically because definiteness is thought to require a uniquely identifiable referent in the discourse. We addressed this question in an event-related potential (ERP) study ($N = 48$) with preregistration of data acquisition, preprocessing, and Bayesian analysis. Participants read Dutch mini-stories with a definite or indefinite novel noun phrase (e.g., “het/een huis,” the/a house), wherein (in)definiteness of the article was either expected or unexpected and the noun was always strongly expected. Unexpected articles elicited enhanced N400s, but unexpectedly indefinite articles also elicited a positive ERP effect at frontal channels compared to expectedly indefinite articles. We tentatively link this effect to an antiuniqueness violation, which may force people to introduce a new referent over and above the already anticipated one. Interestingly, expectedly definite nouns elicited larger N400s than unexpectedly definite nouns (replicating a previous surprising finding) and indefinite nouns. Although the exact nature of these noun effects remains unknown, expectedly definite nouns may have triggered the strongest semantic activation because they alone refer to specific and concrete referents. In sum,

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results from both the articles and nouns clearly demonstrate that definiteness marking has a rapid effect on processing, counter to recent claims regarding definiteness processing.

Keywords: Definiteness; Presupposition; Uniqueness; N400; Prediction

1. Introduction

People are known to predict upcoming information during language comprehension. Research using various paradigms demonstrates that predictions often involve upcoming referents. For example, in the visual-world eye-tracking paradigm, listeners fixate their eyes on depicted referents that the speaker has not yet mentioned but is likely to mention next (e.g., Altmann & Kamide, 1999). In the prenominal event-related potential (ERP) paradigm, articles that mismatch the gender of a likely upcoming but not yet seen noun elicit an enhanced negativity compared to matching articles (e.g., in Dutch, the article “de” when people predict “het boek”, *the book*; Fleur, Flecken, Rommers & Nieuwland, 2020). This suggests that people can predict a specific noun by preactivating its meaning and possibly its gender, and then use the available gender-marking on a prenominal article or adjective to inform and subsequently change their noun prediction. Recent ERP research also suggests that noun predictions may include definiteness (Fleur et al., 2020; Kirsten et al., 2014; Schlueter, Namyst & Lau, 2018). Prenominal articles that are unexpectedly definite (“de” when people predict “een boek”, a book) elicit an enhanced negativity compared to expectedly definite articles (e.g., Fleur et al., 2020). Such effects are compatible with the idea that predictions are generated from and evaluated against the broader situation model (e.g., Otten & Van Berkum, 2009), which is a meaning-based representation of the events and referents described in the discourse, including its information structure (e.g., Zwaan & Radvansky, 1998).

The current study addresses an important question that has remained: Do people engage similar prediction-related processes for definite and indefinite referents? This question traces back to linguistically motivated theoretical discussions on the use and meaning of definite and indefinite noun phrases (Abbott, 2004, 2006; Fraurud, 1990; Heim, 1982; Lyons, 1999; Reuland & ter Meulen, 1987; Schwarz, 2009, 2019a,b; Von Heusinger, 2002), in particular on the requirement for definite noun phrases to be uniquely identifiable within the discourse. We, therefore, compared ERP responses to definite and indefinite referents whose definiteness is either predictable or unpredictable from the discourse context. Before we describe the details of our study, we introduce its theoretical background and discuss relevant behavioural and ERP research.

1.1. Theoretical approaches to definites and indefinites

There are two main theoretical frameworks that distinguish between the semantics of definite and indefinite articles – uniqueness and familiarity. In the uniqueness framework (Abbott, 2006), definite articles assert the existence of a specific and unique referent that fits the noun phrase description, whereas indefinite articles only imply the existence of such an entity. In the familiarity framework, the distinction relates to whether the addressee is acquainted with

the referent or not. Definite reference can be used when the addressee is acquainted with the referent, otherwise indefinite reference is used (Abbott, 1999, 2006; Heim, 1982).

An example of the uniqueness framework is depicted below (Examples 1 and 2), whereby the bracketed paraphrase details the discourse assumption that is made.

- (1) *I have a paintbrush. [There is at least one paintbrush that I have.]*
- (2) *I have the paintbrush. [There is one and only one paintbrush that I have.]*

The assumption made by the familiarity framework is borne out slightly differently. Heim (1982) argues that the use of a definite article is only valid once that entity has been established within the discourse context. As such, the two instances of “movie” in Example 3 refer to the same entity, but the flexible use of the indefinite and definite articles (in the first and second sentences, respectively) highlights a difference in its position within the discourse.

- (3) *Mary saw a movie last week. The movie was not very interesting.* (taken from Abbott, 2006).

In both frameworks, definite and indefinite articles signal distinct discourse processes. Definite articles require access back to a suitable anaphoric referent, while indefinite articles necessitate the addition of an entirely new referent (Fraurud, 1990; Garrod & Sanford, 1982; Prince, 1981). A number of mechanisms can be used to ensure full cohesion of the discourse model, such as presuppositions, bridging inferences, and accommodation. These processes establish inferences about a referent and its discourse status, allowing comprehenders to overcome missing details in order to maintain a coherent discourse representation (Burkhardt, 2006; Clifton, 2013; Frazier, 2006; Singh, Fedorenko, Mahowald & Gibson, 2016).

Bridging inferences, supported by situational and world knowledge, are required when information that is necessary for a correct interpretation of the discourse is not explicitly stated in the utterance (Burkhardt, 2006; Clark, 1975; Singer, 1994). In order to establish this type of coherence, an anchor, such as a familiar entity, must already be present in the discourse model. Bridged determiner phrases hold a special position in the discourse model, having aspects of both discourse-old (i.e., entities introduced with a definite article) and discourse-new (i.e., entities introduced with an indefinite article) determiner phrases (Burkhardt, 2006).

Another framework for maintaining cohesion incorporates presuppositions, which mark what a speaker believes is or should be in the background of a conversation (Abbott, 2000; Karttunen, 1973; Stalnaker, 1973). If an utterance incorporates an entity that has not been explicitly stated before, presupposition is required to amend the context such that the presupposed assumption is satisfied. For example, introducing an entity with a definite article for the first time, such as in “*The bride looked beautiful on her wedding day,*” requires an inference about the existence of the bride to be made (Singh et al., 2016). This theory predicts that there should be a degree of inappropriateness when accommodating an implausible presupposition. For instance, if a proper antecedent has not been previously established, processing an entity introduced with a definite article should incur processing costs. A recent proposal maintains that a speaker is required to use felicitous sentences with the strongest presupposition

possible, dubbed the Maximize Presupposition principle (Heim, 1992; Schneider, Schonard, Franke, Jäger & Janczyk, 2019). This principle predicts that entities introduced with an indefinite article will induce higher processing costs as a two-step verification procedure is required. First, the uniqueness presupposition is verified, and then subsequently negated. The authors refer to this process as an antipresupposition (Percus, 2006), and suggest that this extra step leads to higher processing costs, compared to entities introduced with a definite article. They also support the idea that presuppositions and antipresuppositions differ and must be treated as distinct pragmatic phenomena with systematic differences in their processing signatures.

Behavioural investigations into the comprehension of definite and indefinite articles may be able to shed light on the induced processing costs, and in turn, extend our understanding of their role within a discourse model.

1.2. Behavioural research on definiteness processing

One dominant question in previous research has been whether indefinite noun phrases are more cognitively costly compared to definite noun phrases, or vice versa. It has been suggested that definite noun phrases are more costly because they require readers to search in memory for the intended referent, whereas indefinite noun phrases do not (e.g., Irwin, Bock & Stanovich, 1982; see also Clark & Haviland, 1974). Alternatively, indefinite noun phrases may be more costly because they introduce new referents and, therefore, lead to a more complex discourse representation, whereas definite noun phrases refer to already existing referents (e.g., Murphy, 1984). Consistent with the latter hypothesis, Murphy (1984) reported slower reading times for indefinite noun phrases compared to definite noun phrases in mini-stories, such as “*Though driving 55, Steve was passed by a truck. Later, George was passed by a/the truck too.*”

However, the relative processing costs associated with definite and indefinite noun phrases may crucially depend on the discourse context, in particular, as to whether a unique identifiable referent has already been introduced or is easily inferable from or entailed by the context (e.g., Clifton, 2013; Evans, 2006; Frazier, 2006; Garrod & Sanford, 1982; Singh et al., 2016). For example, a book typically has one title and multiple pages. This makes it relatively felicitous to refer to “the title” whether or not a title was previously mentioned, but makes it infelicitous to refer to “a title” given that this appears to imply a different title than that of the book or that the book in question may have multiple titles. Conversely, if no page was previously mentioned, it may be felicitous to refer to “a page” but referring to “the page” would be ambiguous and, therefore, incur a processing cost. Likewise, discourse context may render a referent either unique or nonunique (e.g., a stove in a kitchen or in a kitchen appliance store), thereby affording different definiteness expectations. Using eye-tracking during reading, Clifton (2013) demonstrated that people read noun phrases more slowly when their definiteness is infelicitous given the situational context (“a stove” when situated in a kitchen or “the stove” when situated in an appliance store) than when it is felicitous, although this pattern was not stable over multiple experiments.

A recent study by Schneider et al. (2019) investigated definiteness processing using a mouse-tracking paradigm. They presented felicitous and infelicitous definite and indefinite

descriptions paired with a visual display wherein a character received one of three objects that was either unique or nonunique (e.g., a pear when the display contained either a pear and two bananas or two pears and one banana). They observed increased processing costs for infelicitous descriptions, similar to those reported by Clifton (2013). Crucially, they also observed overall increased processing costs associated with indefinite descriptions. They concluded that participants may have had difficulty with indefinite descriptions because they initially anticipated a definite description.

In these previous studies, processing times were computed for article–noun combinations, which means that it is unclear whether the observed effects occurred already for the articles themselves. However, some studies have examined processing consequences of definite and indefinite articles ahead of the subsequent noun. For example, unpublished work by Ahern and Stevens (2014) suggests that effects of situational context may already impact processing of the articles. In a visual-world eye-tracking experiment (see also Sedivy, Tanenhaus, Chambers & Carlson, 1999), they found that participants fixate more on objects with a maximally unique (i.e., the most salient) shape upon hearing definite articles. They concluded that definite articles caused participants to predict the most unique shape as the upcoming referent. A related result was observed in a recent mouse-tracking study with spoken language by Schneider, Bade, Franke and Janczyk (2020). Their participants had to select one of two potential referents presented on screen according to an auditorily presented stimulus sentence. The data revealed that participants used definite and indefinite articles to rapidly disambiguate sentence meaning, but only when they are exclusively faced with felicitous uses of articles. Regarding a processing difference between definite and indefinite articles, Schneider et al. (2020) concluded that their results were inconclusive.

In sum, only a few behavioural studies have examined the processing costs associated with definite and indefinite articles alone, rather than the costs associated with definite and indefinite noun phrases. Nevertheless, the available studies suggest that people rapidly use article definiteness to constrain their interpretation of an unfolding sentence, and may even use definiteness to predict which referent will be mentioned next.

1.3. ERP research on definiteness processing

Several ERP studies have investigated how people process definite and indefinite noun phrases and the role of context therein. ERPs can be particularly useful because they allow researchers to examine responses to articles separately from responses to nouns, and because they allow inferences regarding qualitative processing differences, for example, on whether unexpectedly definite articles elicit distinct neural responses from unexpectedly indefinite articles.

In two ERP studies on English discourse comprehension, Anderson and Holcomb (2005) compared responses to definite and indefinite noun phrases at the beginning of a sentence (e.g., “The/A taxi”). In Experiment 1, the sentences were presented in isolation, whereas in Experiment 2, the sentences were preceded by a sentence introducing that noun or a synonymous noun (e.g., a first sentence introducing “a taxi/cab,” followed by a second sentence starting with the target expression “The/A taxi”). In both experiments, indefinite

articles elicited an enhanced anterior negativity compared to definite articles, but the authors refrained from strong conclusions about this finding, also due to lexical differences between the two articles (i.e., length and frequency). In Experiment 2, given nouns elicited smaller N400s than synonymous nouns regardless of definiteness, but definite nouns elicited a left anterior negativity compared to indefinite nouns, which the authors took to index coreference processing. Interestingly, sentence-final words elicited an extended, N400-like negativity in sentences beginning with indefinite noun phrases compared to definite noun phrases, which they took as evidence of continued integration difficulty after a new referent had been introduced. A similar lack of a definiteness effect on noun-elicited N400s was reported by Calloway and Perfetti (2020). Here, nouns repeated across a sentence boundary elicited smaller N400s, regardless of whether it was preceded by a definite or an indefinite article. This pattern suggested that initial semantic processing was dominated by lexico-semantic factors and not by discourse-level integration (see also Perfetti & Helder, 2021).

In an ERP study on German discourse comprehension, Schumacher (2009) compared responses to definite and indefinite articles preceding nouns that were either given, inferable from the context or novel (example item translated into English: “*Peter has recently visited a speaker/a lecturer/Hanna in Munich. He said that the/a speaker was very nice*”). Unlike Anderson and Holcomb (2005), Schumacher observed an enhanced left-anterior negativity for definite articles compared to indefinite articles. She suggested that this effect reflects the working memory processing costs associated with identifying a unique referent in the discourse. Moreover, novel nouns elicited larger N400s than inferable nouns, which in turn elicited larger N400s than repeated nouns (see also Burkhardt, 2006). This pattern occurred regardless of definiteness and was considered to reflect the “low-level” lexical–semantic relationships between the nouns and context. In the post-N400 time window, however, nouns that required a new referent (all nouns except definite given nouns) elicited an enhanced positivity compared to definite given nouns. Schumacher took this positive ERP effect to reflect the updating of the discourse representation with a novel referent (see also Burkhardt, 2006). Based on these results, Schumacher concluded that definiteness has a relatively late effect during referent resolution (see also Hirotsu & Schumacher, 2011), after the initial processing of lexical–semantic relationships.

A study by Kirsten et al. (2014) investigated processing of contextually felicitous or infelicitous definite and indefinite articles. They used German sentence pairs consisting of a first sentence that introduced either one or more antecedents of the same type (English translation: “*Antje visited the Dusseldorf zoo yesterday and saw a polar bear/some polar bears in the bear enclosure*”, which introduces either one or more polar bears) followed by a second sentence containing a definite or indefinite noun phrase of the same type (“*Antje noticed that a/the polar bear was very aggressive*”). Regardless of whether article definiteness was felicitous given the context, definite articles elicited larger N400s than indefinite articles. The authors suggested that this effect is related to the left-anterior negativity reported by Schumacher (2009), indexing working memory processes involved in identifying an antecedent. Importantly, contextually infelicitous definite and indefinite articles both elicited enhanced N400s and subsequent positivities compared to felicitous articles. Kirsten et al. interpreted these patterns as detection of a semantic mismatch and subsequent top-down monitoring

processes, respectively. No results were reported for the nouns. Based on the observed similarity in the ERP responses to infelicitous definiteness, they concluded that processing differences between definite and indefinite articles, as assumed in several linguistic theories, probably take place later in the cognitive processing chain.

An ERP study by Brocher and Von Heusinger (2018) compared responses to German definite and indefinite noun phrases with a noun that was easily inferable (or predictable) from the context or unrelated to the context (e.g., a discourse context introducing either a gym or an art gallery, followed by “*Phillip stared at a/the trainer next to the window*”). They observed a left-anterior negativity for definite articles compared to indefinite articles but a reverse pattern at left-posterior channels. They concluded that the former effect reflects the attempt to identify a referent from the context, whereas the latter effect reflects anticipation of a new discourse referent. As in previous studies (e.g., Burkhardt, 2006), unrelated nouns elicited larger N400s than inferable nouns. Similar to the noun-effects reported by Schumacher (2009), noun-elicited ERPs were not affected by definiteness.

In sum, these previous studies do not yield a consistent pattern of results, neither for articles nor for nouns. Enhanced processing costs are sometimes reported for definite articles, sometimes for indefinite articles, or for both. Moreover, while most studies find definiteness effects on articles, there is a surprising lack of accompanying effects for subsequent nouns. We suspected that these inconsistencies reflect differences in the used discourse contexts, in particular in whether the context suggested a definite or indefinite noun phrase as the most likely continuation, in other words, whether definiteness was predictable. In the studies discussed so far, no norming was reported on what participants considered the most likely continuation, as typically done with a cloze completion task (Taylor, 1953). We consider such norms important, because processing costs incurred by definite and indefinite noun phrases can depend on their predictability (e.g., Fleur et al., 2020). In the next section, we further discuss the potential role of definiteness predictability.

1.4. *Definiteness and predictability*

People can predict upcoming referents, where such predictions are likely based on a situation model, which is a mental representation of the referents and events as described in the discourse context that is grounded in world knowledge (e.g., Zwaan & Radvansky, 1998). Predictive processing is thought to facilitate language comprehension, and has been widely debated with regards to the extent and ubiquity of predictions (e.g., Huettig, 2015; Kuperberg & Jaeger, 2016; van Petten & Luka, 2012). Some researchers have proposed that prediction is a probabilistic process that is engendered by the linguistic environment (i.e., highly constraining contexts), rather than a necessarily automatic process (Kuperberg & Jaeger, 2016). Investigations into determining the nature of predictive processing have led to particular empirical paradigms, such as a focus on prenominal information, in order to demonstrate the influence of context prior to noun onset (true preactivation), compared with facilitation due to easier integration (Federmeier, 2007).

Demonstrating prediction, participants in visual world eye-tracking paradigms use information from verbs and adjectives to anticipate which depicted noun is going to be mentioned

(e.g., Altmann & Kamide, 1999). ERP research using prenominal manipulations has demonstrated yet stronger evidence for predictions, namely the prediction of novel noun phrases. Articles (or adjectives) that mismatch the gender of an unseen but likely upcoming noun elicit an enhanced negativity compared to matching articles (e.g., Fleur et al., 2020; Otten & Van Berkum, 2008; Wicha, Bates, Moreno & Kutas, 2003, 2004; but see also Nieuwland, Arkhipova & Rodríguez-Gómez, 2020). Given that linguistic predictions are about an upcoming referent, predictions may also include whether the referent is definite or indefinite. Indeed, several previous studies have already alluded to a role of predictability in the processing of definiteness (Brocher & Von Heusinger, 2018; Kirsten et al., 2014), but did not themselves quantify the predictability of definite or indefinite noun phrases.

An unpublished ERP study by Schlueter, Namyst, and Lau (2018) investigated the role of definiteness predictability more directly, using cloze norming for article–noun combinations. Participants read two types of discourse context, one that rendered a previously mentioned definite noun phrase predictable in the second sentence (e.g., “*Emily dropped a book on the way to class. A friendly janitor picked up the/a book ...*”), and another that rendered a novel, indefinite noun phrase predictable (e.g., “*Sara looked in her bag for something to sign the forms. She found a/the pen ...*”). Unpredictable (in)definite articles elicited larger N400s than predictable articles, and the authors, therefore, concluded that participants generated predictions about the discourse status of upcoming referents. Schlueter et al. did not observe differences in the predictability effect for definite and indefinite articles. However, their experiment was not designed to detect such a difference, as 80% of the predictable articles were definite.

Most relevant to the current study, Fleur et al. (2020) also investigated the ERP effect of definiteness predictability along with that of a prenominal gender-mismatch. Their main objective was to establish whether the prenominal gender-mismatch effect on Dutch articles (e.g., Kochari & Flecken, 2019; Otten & Van Berkum, 2009) reflects the prediction of only the noun or the article–noun combination. They capitalised on the Dutch gender marking system, which marks gender on the definite articles “de/het” but not on the indefinite article “een.” Like Schlueter et al. (2018), they created contexts that either suggested a definite noun phrase as the most likely continuation (e.g., “*Het is zondagochtend. De gehele gelovige familie gaat zoals altijd naar*”, English translation: “It is Sunday morning. The whole religious family goes, as always, to”) or an indefinite noun phrase containing the same noun (e.g., “*Mijn moeder is erg gelovig. Op vakantie gaan we altijd direct op zoek naar*”, English translation: “My mother is really religious. When on vacation, we always look directly for”). Each context was followed by a definite noun phrase containing the predictable noun or containing an unpredictable noun of a different gender (e.g., “de kerk”, the church, or “het gebedshuis”, the place of worship). Depending on whether the most predictable noun phrase was definite or indefinite, the presented noun phrase was either expectedly definite or unexpectedly definite, and either matching or mismatching the gender of the predictable noun. Fleur et al.’s rationale was that if articles themselves are predicted (e.g., Wicha et al., 2003), then the gender-mismatch should have little effect for unexpectedly definite articles because readers expected an indefinite article without gender marking. If gender-mismatch has an effect also for unexpectedly definite articles, this would demonstrate that readers use the article gender during predictive processing even when the form of the article itself is not predicted.

In two experiments, Fleur et al. found distinct gender-mismatch effects for expectedly and unexpectedly definite articles. Although both effects were negativities (more negative voltage for unexpected than expected gender), the former effect was strongest at occipital channels in the 300–400 ms time window, while the latter was strongest at parietal channels in the 500–700 ms time window. They, therefore, concluded that prediction of a specific article form, which is determined in Dutch by both definiteness and gender, is sufficient but not necessary to elicit a prenominal prediction effect. Most relevant for the current study, Fleur et al. also found a negative ERP effect of unexpected definiteness that resembled a standard N400 effect in terms of timing and scalp distribution, consistent with the results reported by Schlueter et al. (2018). Moreover, they found that this effect of definiteness was stronger, at least at the N400 region-of-interest (ROI), than that of gender. Fleur et al. suggested a potential explanation, wherein unexpected definiteness may have had greater repercussions for semantic processing than unexpected gender. Unexpected definiteness violates the presupposition of a uniquely identifiable referent (Karttunen, 1974; Krahmer, 1998; Levinson, 1983; Von Stechow, 2004) and could lead to a change in how the meaning of the sentence is represented (by accommodation of a unique referent into the discourse representation, e.g., one specific church; see Beaver, 1999; Von Stechow, 2008). In contrast, unexpected gender may signal a smaller change in upcoming meaning, for example, instead of “church,” participants could revise their prediction to a less specific conceptual representation or a plausible, lexically specific alternative. Indeed, Fleur et al. reported additional norming and ERP evidence that participants altered their prediction upon encountering an article with unexpected gender.

The previous studies thus show enhanced N400s for articles whose definiteness is unexpected given the context. This result is compatible with the idea that readers predict whether the most likely following referent is unique (definite) or not (indefinite), and may predict an entire definite or indefinite noun phrase. Articles that match the prediction are facilitated during semantic processing compared to articles that do not. However, it is not clear whether the processing consequences of definiteness predictions are similar for definite and indefinite articles. The results from Schlueter et al. were inconclusive on this issue, whereas Fleur et al. only compared responses to definite articles. We, therefore, addressed this issue in the current ERP study, by adapting the materials and design from Fleur et al. to investigate the prediction of definite and indefinite noun phrases.

1.5. The current study

Our participants read two-sentence mini-stories, with a critical noun phrase embedded in each second sentence (Table 1). The story contexts up to the critical noun phrases were created to suggest either a definite or indefinite noun phrase as the most likely continuation (e.g., “het/een huis”, the/a house), as established using an offline cloze test (see Methods). We manipulated whether each context continued with the most likely expected noun phrase or with an unexpectedly definite or indefinite noun phrase (“het huis” when the expected noun phrase was “een huis”, or “een huis” when the expected noun phrase was “het huis”, respectively). Our design was, therefore, similar to the one used in Schlueter et al. (2018), but our design was fully balanced (i.e., equal numbers of definite/indefinite noun phrases), we used

Table 1

Dutch example item and approximate English translation in each of the conditions

Context		Critical phrase		
		Expected definite	Unexpected indefinite	Ending
Suggesting definite	<i>De koop was rond. De makelaar gaf de kopers de sleutels van de purchase was done. The broker gave the buyers the keys to</i>	<i>het huis the house</i>	<i>een huis a house</i>	<i>in het centrum. in the center.</i>
Suggesting indefinite	<i>Esmee en Paul willen gaan samenwonen. Met de makelaar gaan ze op zoek naar Esmee and Paul want to move in together. With the broker they look for</i>	Expected indefinite <i>een huis a house</i>	Unexpected definite <i>het huis the house</i>	<i>in het centrum. in the center.</i>

Note Each context strongly suggested either a specific definite (top) or indefinite (bottom) noun phrase. The critical noun phrase always contained the contextually predictable noun, preceded by an expected or unexpected definite or indefinite article. Of note, participants in the ERP experiment read the first context sentence as a whole and the entire second sentence one word at a time.

a stronger predictability manipulation (cloze values for articles and nouns of at least 75%), and all of our critical noun phrases were novel (i.e., not mentioned in the context sentence). Unlike Schlueter et al., we also analysed ERPs elicited by the nouns, which were identical across conditions.

Our four dependent variables (anterior 300–500 ms; anterior 500–700 ms; posterior 300–500 ms; and posterior 500–700 ms) followed the preregistration of Fleur et al. (2020), and were defined by a combination of two spatial and two temporal ROIs. We averaged activity from a selection of central-parietal (N400) or frontal channels, and we averaged activity within the 300–500 ms time window, our main N400 time window, or the subsequent 500–700 ms time window, where we could test post-N400 effects associated with definiteness processing (e.g., Schumacher, 2009).

Based on previous reports (Fleur et al., 2020; Kirsten et al., 2014; Schlueter et al., 2018), we predicted that unexpected definite articles would elicit enhanced N400 amplitudes compared to expected definite articles, reflecting enhanced semantic processing when articles suggest a unique¹ referent, while the context up to that point did not (i.e., uniqueness failure). We also predicted an equivalent effect for unexpected indefinite articles compared to expected indefinite articles (e.g., Kirsten et al., 2014), reflecting enhanced semantic processing when articles suggest a nonunique or novel referent, while the context strongly suggested a unique referent (i.e., antiuniqueness failure; Kirsten et al., 2014, see also Bade & Schwarz, 2019; Schneider et al., 2019). Of crucial importance was whether we would observe an interaction between definiteness and expectedness. We compared the N400 effect elicited by unexpected

definite articles to the N400 effect elicited by unexpected indefinite articles, each involving a comparison to the expected (in)definite control condition. This allowed us to establish which situation has a bigger impact on semantic processing, uniqueness failure, or antiuniqueness failure. The study by Kirsten et al. (2014) did not find evidence for such an interaction, but involved reference to previously mentioned referents, whereas in our study, the expected referents have not been mentioned in the context. As introducing new referents is the default use of indefinite articles, we considered it more likely that unexpected indefinite articles elicit a weaker N400 effect compared to unexpected definite articles than vice versa. Another potential scenario is that uniqueness failure and antiuniqueness failure elicit qualitatively different effects (cf. Kirsten et al., 2014).

We did not have a strong prediction regarding an overall difference between definite and indefinite articles. Previous studies have reported inconsistent results (e.g., Anderson & Holcomb, 2005; Brocher & Von Heusinger, 2018; Schumacher, 2009), but none of these studies manipulated definiteness predictability, which makes their design difficult to compare to our own because we used materials wherein definite and indefinite articles were equally expected or unexpected. If anything, we predicted that there would not be an overall effect associated with article definiteness.

For the noun-elicited ERPs, we predicted that unexpected definite nouns would elicit smaller N400s than expected definite nouns. Of note, this pattern may seem counterintuitive because unexpected words typically elicit larger N400s than expected words, but it would be consistent with the results of Fleur et al. (2020). Here, too, the question is whether a similar pattern would be obtained for indefinite nouns, or whether a smaller effect would be obtained for indefinite nouns given that they might be easier to introduce compared to novel definite nouns.

2. Methods

2.1. Preregistration

We preregistered the methodological and analytical procedures on the Open Science Framework (https://osf.io/b8fuz/?view_only=278b4c6f61ca49249d459243cd667edf). We label analyses that were not preregistered as exploratory.

2.2. Participants

Participants were native Dutch speakers, right-handed, and had normal or corrected-to-normal vision with no history of language impairments. They were recruited from the Max Planck Institute for Psycholinguistics participant pool and paid €18 for participation. Written consent was obtained in accordance with ethics approval by the Ethics Committee for Behavioral Research of the Social Sciences Faculty at Radboud University Nijmegen in compliance with the Declaration of Helsinki. We tested a total of 51 participants, but excluded data of three participants from the analysis based on preregistered criteria about the number of remaining trials after artifact rejection (less than 25 trials in any of the conditions, or less

than 30 trials on average across conditions) and comprehension question accuracy (less than 80% correct). The ERP analysis was conducted on the preregistered sample size of 48 participants (females: 37; average age: 24.5; age range: 19–45). This sample size was not based on an a priori power calculation, but it was identical to the sample size of Experiment 1 in Fleur et al. (2020), which yielded a strong effect of unexpected definiteness in the same four ROIs as used here.

2.3. Materials

Our materials, procedure, and analyses were adapted from Fleur et al. (2020). Fleur et al. describe the construction of 160 items consisting of two different mini-story contexts, strongly suggesting a specific definite noun phrase (e.g., “het huis”, the house) or a specific indefinite noun phrase (e.g., “een huis”, a house) as the most likely continuation, as established in cloze completion norms whereby participants were asked to fill in sentence endings that had been truncated before the entire noun phrase (article and noun combined). Combining these contexts with the most likely continuation yielded our expected definite condition and expected indefinite condition (average cloze = 94%, $SD = 7$, range = 75–100). Combining these contexts with a noun phrase that consisted of the same noun (“house”) preceded by an unexpectedly indefinite or definite article yielded the unexpected indefinite condition and the unexpected definite condition, respectively (average cloze = 1%, $SD = 3$, range = 0–15).

To ensure that manipulating the definiteness of the article did not alter the predictability of the noun, we conducted an additional cloze test, whereby participants were asked to produce sentence endings that were truncated after the expected or unexpected article, but before the target noun. Cloze values of the target nouns were very high, regardless of whether the preceding article was definite/indefinite and expected/unexpected (average cloze for expected definites, 93%, $SD = 12$, range = 20–100; expected indefinites, 90%, $SD = 16$, range = 0–100; unexpected definites, 87%, $SD = 17$, range = 10–100; unexpected indefinite, 88%, $SD = 17$, range = 20–100), although they were slightly higher for the expected conditions.

In the ERP experiment, the nouns were never sentence-final and were always followed by either two or three additional words. For approximately half of the items, these sentence endings were identical for the two contexts. For the other items, the sentence endings differed between contexts such that they were a plausible continuation following the expected noun.

In addition to these experimental items, we included 80 filler items. Half of these were taken from the Fleur et al. (2020) filler stories, which all contained a highly predictable (i.e., high cloze) indefinite noun phrase. The other half was generated from items that had not made it into the Fleur et al. (2020) experimental items, and all contained a highly predictable definite article (Article: $mean = 91%$, $SD = 10$, range = 60–100%; Noun: $mean = 70%$, $SD = 33$, range = 0–100%). Each filler story consisted of only one version. For example, “*Iris had gister te veel gedronken. Ze werd vanochtend wakker met een kater van de drank.*” (Translation: Yesterday, Iris had drunk too much. She woke up this morning with a hangover from the booze). The purpose of these filler stories was to reduce the number of stories with unexpected or implausible endings, while balancing the set of materials as a whole in terms of expected definiteness.

We created four stimulus lists by pseudo-randomising the order of items. Each list contained 40 trials of each condition, 80 filler items, and 60 comprehension questions; across the lists, each item was seen per condition equally as often. No single condition was shown for more than three successive trials and comprehension questions were not shown for more than two successive trials. We presented practice sentences and questions prior to the experiment to ensure that the participant became familiar with the procedure (five sentences and two comprehension questions). Participants were equally divided over the four lists.

We utilised the 60 comprehension questions that were presented in Fleur et al. (2020) and added 20 more to our material set to be matched with our high-cloze definite fillers. In total, 80 comprehension questions were presented to our participants (50% yes and 50% no) as a way to ensure that they were paying attention. A translated example question is “Did the car have a full tank?”, which required a “no” response following the text “The car’s fuel gauge indicated a low level. Quickly they went looking for a gas station close by.” The average percentage of accuracy was: 97%.

2.4. Procedure

Participants were instructed to read and sign the consent form, which was followed by a set of brief instructions. After the electroencephalogram (EEG) setup, participants were seated within a soundproof booth and instructed to carefully read the sentences presented onscreen and answer the accompanying comprehension questions. Sentences were presented in black letters on a white screen (Times New Roman, size 34). Each trial began with a fixation cross in the center of the screen. Participants controlled how long the fixation cross stayed onscreen and were instructed to use that time to get comfortable in an effort to minimise movement and/or blinking during sentence presentation. Through a keypress, the first sentence was presented in full in the center of the screen; once the participant had read this, another keypress was required to present the second sentence word-by-word. Each word was presented for 300 ms with a 300 ms interval between words. The sentence-final word was followed by either another fixation cross, indicating the start of a new trial, or a comprehension question. The 240 items (160 targets and 80 fillers) were presented in six blocks, of 40 trials each. Between these blocks, we encouraged participants to take small breaks. In total, the experiment lasted for approximately 75 minutes.

2.5. EEG recording and preprocessing

The EEG signal was continuously recorded from 27 active scalp electrodes mounted in an elastic cap (ActiCap), and placed in a 10–20 convention. The signal was referenced online to the left mastoid. Eye movements were measured both horizontally and vertically; we placed two electrooculography (EOG) electrodes on the outer canthi of the left and right eyes, and placed two other EOGs above and below the left eye. The signal was amplified using a BrainAmps DC amplifier and recorded with BrainVision Record (Brain Products, Munich) at a sampling rate of 500 Hz and band-pass filtered at 0.016–150 Hz with a time constant of 10 s. The data were preprocessed using BrainVision Analyzer.

Based on visual inspection, we interpolated bad channels using spline interpolation (a total of 13 channels in the entire dataset, with at most two channels for each subject). We band-pass filtered the continuous data at 0.1–100 Hz (24 dB/octave roll-off) plus 50 Hz notch-filter (the notch filter was not preregistered but added to remove line noise), and then rereferenced to the average of the mastoids. We epoched the time windows from –500 to 1000 ms relative to the onset of the target article and noun. We visually inspected the epochs to remove bad trials (e.g., due to large movement-related artifacts, muscle activity, or amplifier blocking). After this, we performed an independent component analysis (ICA)-based correction to remove blinks, eye movements, and steady muscle activity. Next, we performed a 30 Hz low-pass filter (24 dB) and a baseline correction to 200 ms before each critical word. Finally, segments with values that exceeded $\pm 75 \mu\text{V}$ at any channel were automatically removed. In total, 4.7% of trials were removed (range across conditions, from 4.4% to 5.3% removed).

2.6. Statistical analyses

We used the same spatiotemporal ROI approach as Fleur et al. (2020). Our main dependent measure (N400 amplitude) was the average voltage across six posterior channels (Cz, CP1, CP2, P3, Pz, and P4) in the 300–500 ms window after word onset for each trial. To evaluate effects at anterior channels, we also computed average voltage across six anterior channels (F3, Fz, F4, FCz, FC1, and FC2). Additionally, for both ROIs, we computed average voltage in the 500–700 ms (post-N400) time window. For the articles, we performed analyses at both time windows in both ROIs, resulting in four analyses. For the nouns, we only performed analyses on posterior channels in the 300–500 ms time window and on anterior channels in the 500–700 ms time window.

We performed Bayesian mixed-effects models using the “brms” package (Bürkner, 2017) in R (R Core Team, 2018), which fits models in the Stan programming language (Stan Development Team, 2018). The Bayesian models estimate posterior distributions using Markov chain Monte Carlo sampling, which draws random samples from the posterior that were not available. A key benefit is that these models can include prior information about possible parameter values. The current models included the deviation-coded fixed effects of expectancy, definiteness, and their interaction. We used fully maximal models with by-subject and by-item random slopes for expectancy and definiteness and their interaction (Barr et al., 2013). We included normally distributed, weakly informative priors for the intercept ($mean = 0$, $SD = 2$) and for the effects of expectancy, definiteness, and all interactions ($mean = 0$, $SD = 1$). These were chosen to reflect our initial beliefs about how each of our manipulations may have an effect on predictive processing, which have not exhibited strong influences in previous literature. As such, we erred on the side of caution and chose weakly informative priors in order to maximise the chances of objective inference from the results of our statistical models. The models were fit using four chains, with 10,000 iterations each (2000 warm-up).

From the Bayesian mixed-effects models, we calculated Bayes factors using the Savage–Dickey method (e.g., Wagenmakers, Lodewyckx, Kuriyal & Grasman, 2010). With this method, we calculated Bayes factors for each fixed effect as the ratio between the posterior and prior distribution density at an effect size of $0 \mu\text{V}$, thereby quantifying the obtained

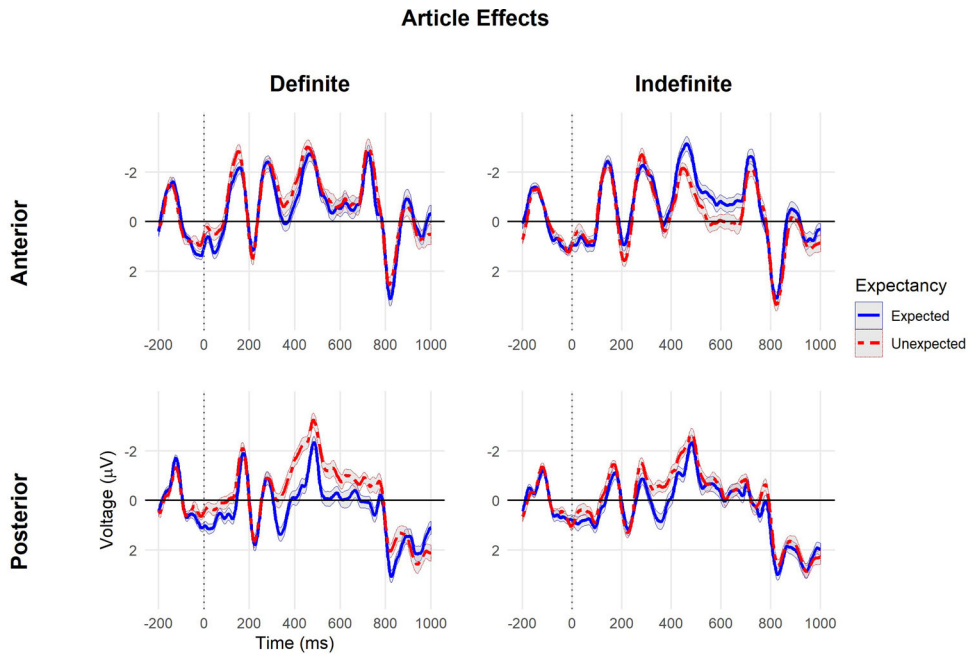


Fig 1. Article effects. The graphs show the grand-average ERPs elicited by expected (solid blue lines) and unexpected (dotted red lines) articles at the anterior and posterior ROIs (top and bottom graphs, respectively), when they were either definite or indefinite (left and right graphs, respectively). The gray-shaded areas correspond to the within-subject standard error of the condition mean (Cousineau, 2005; Morey, 2008; calculated with the “Rmisc” package in R). In this and all subsequent ERP figures, negative is plotted upward. Note that noun onset occurred 600 ms after article onset.

evidence for the null hypothesis (H_0) such that there is a zero effect. This approach has the main benefit of quantifying support for/against the null-hypothesis, which is not possible with the traditional, significance-testing approach. We interpret Bayes factor evidence strength following the convention of Jeffreys (1939), see also Lee and Wagenmakers (2013). For consistency, each reported Bayes factor (BF_{null}) was calculated as the posterior density at zero divided by the prior density at zero, such that values greater than one correspond to an increase in evidential strength for the null hypothesis (e.g., $BF_{\text{null}} = 3$ means that belief in the null hypothesis has increased three-fold), whereas values smaller than one correspond to increased evidential strength against the null hypothesis (e.g., $BF_{\text{null}} = 1/3$ means that belief in the null hypothesis has decreased three-fold).

3. Results

3.1. Preregistered article analyses

In line with our predictions, we observed modulations of N400 activity across both time windows and ROIs (Fig. 1; see also Figs. A1 and A2 in the online Appendix, for ERPs at

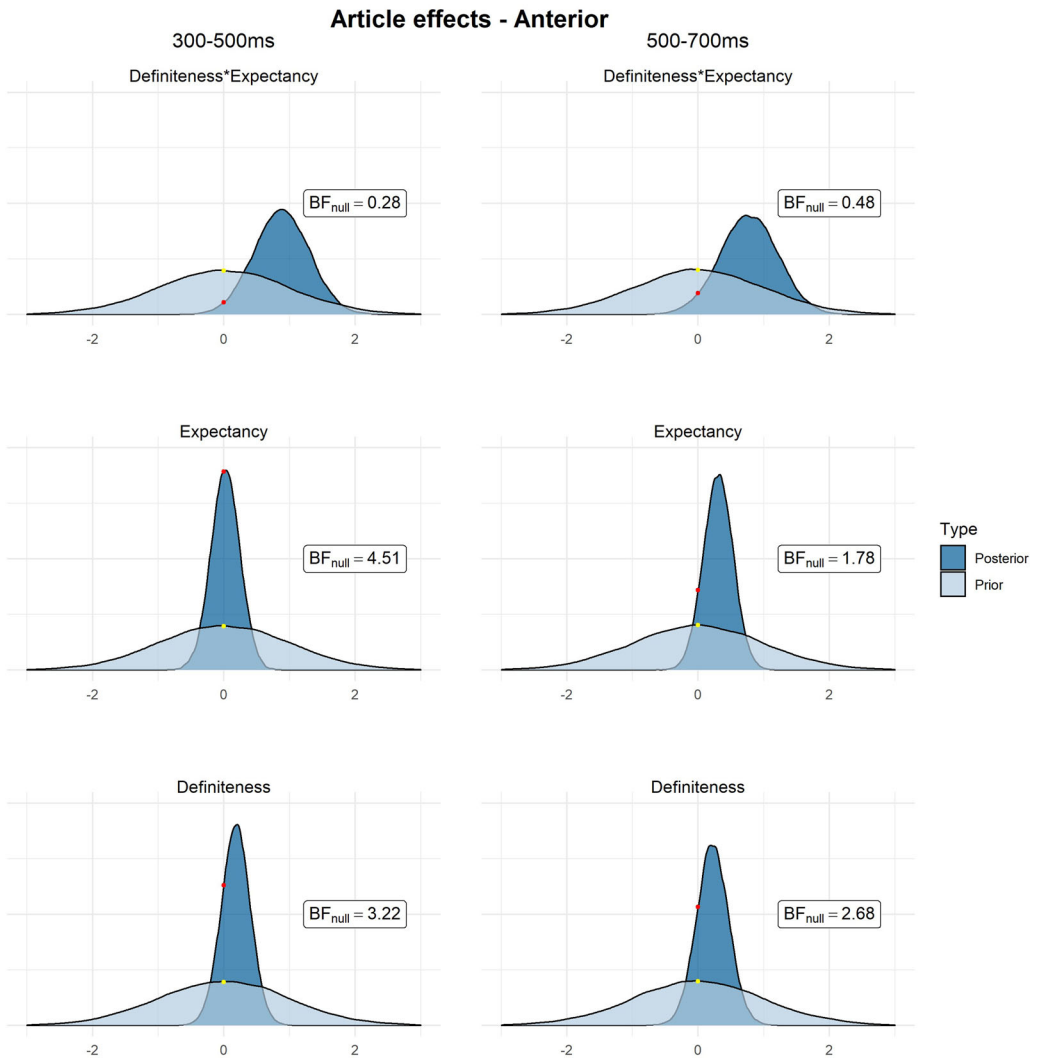


Fig 2. Article effects at the anterior ROI. Prior and posterior density distributions and Bayesian hypothesis tests are shown for the effect of definiteness (indefinite minus definite), expectancy (unexpected minus expected), and the interaction term corresponding to the expectancy effect for indefinites minus that for definites. Graphs depict the prior (light blue) and posterior (dark blue) density, with prior and posterior density at zero marked by a yellow and red dot, respectively. The ratio of the density values at zero (posterior/prior density), the Bayes factor, is labeled on the graph, here showing the Bayes factor evidence in support of the null hypothesis (BF_{null}), with higher values corresponding to the increased belief in the null-hypothesis given our data.

all channels). Unexpected articles elicit larger (more negative) N400s than expected articles, most prominently at the posterior ROI. In the 500–700 ms time window, unexpected indefinite articles elicited an enhanced positive voltage compared to expected indefinite articles at the anterior ROIs. Results of the Bayesian mixed-effects models are shown in Figs. 2 and 3, which

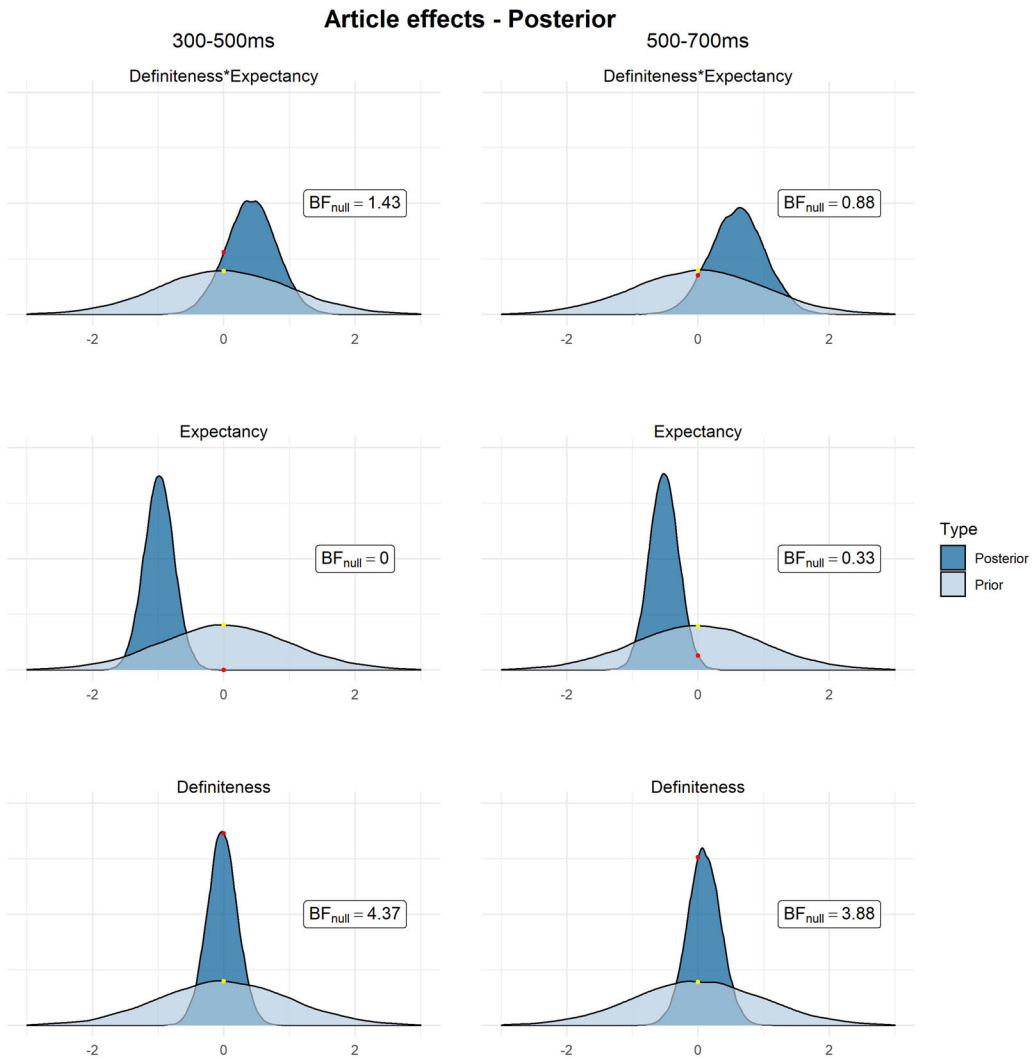


Fig 3. Article effects at the posterior ROI.

plot prior and posterior probability densities and Bayes factors for the anterior and posterior ROIs, respectively. BF_{null} values correspond to the prior/posterior density ratio at an effect size of zero. Table 2 lists the corresponding details of the parameter estimates, and Fig. 4 shows the estimated condition means for expected and unexpected articles.

Results for the anterior ROI yielded moderate evidence for an interaction between expectancy and definiteness in the 300–500 ms time window, with a $BF_{null} = 0.28$. This value means that at an effect size of zero, the posterior density is 0.28 times smaller than the prior density. In other words, the new data have decreased belief in an interaction effect of zero, or increased belief that the effect is not zero, by about $1/0.28 = 3.6$ times. This BF result

Table 2

Article results from the preregistered Bayesian mixed-effect model analyses

Factor	ROI	Time window (ms)					
		300–500			500–700		
		μ	σ	CrI	μ	σ	CrI
Definiteness*Expectancy	Anterior	0.88	0.42	[0.05 1.70]	0.77	0.44	[-0.10 1.64]
	Posterior	0.42	0.38	[-0.34 1.16]	0.60	0.42	[-0.22 1.42]
Expectancy	Anterior	0.02	0.22	[-0.42 0.46]	0.30	0.23	[-0.14 0.75]
	Posterior	-0.99	0.23	[-1.44 -0.54]	-0.52	0.23	[-0.96 -0.08]
Definiteness	Anterior	0.18	0.22	[-0.26 0.62]	0.22	0.25	[-0.27 0.71]
	Posterior	-0.02	0.23	[-0.48 0.43]	0.09	0.25	[-0.41 0.59]

Note Estimated mean (μ) for the main effects of definiteness (indefinite minus definite) and expectancy (unexpected minus expected) and their interaction, along with the standard deviation (σ) and associated 95% credible interval (CrI), for each spatial and temporal region-of-interest (ROI).

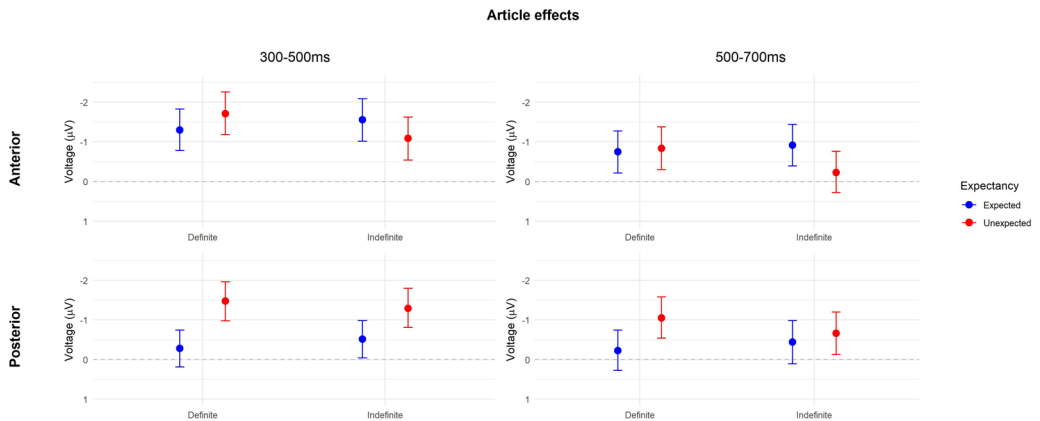


Fig 4. Article effects. Estimated marginal means and 95% uncertainty interval for each condition at the anterior and posterior ROIs (top and bottom graphs, respectively), in the 300–500 ms and 500–700 ms time windows (left and right graphs, respectively).

is associated with an expectancy effect (unexpected minus expected) that was negative for definite articles ($M = -0.42$, CrI: [-1.03 0.17]) and positive for indefinite articles ($M = 0.46$, CrI: [-0.13 1.07]). This interaction was also visible but weaker in the subsequent 500–700 ms time window, as well as in the posterior ROI, yielding anecdotal evidence for the interaction pattern.

Results for the posterior ROI yielded extreme evidence for an expectancy effect in the 300–500 ms time window (because the posterior samples did not include zero, we can state that $BF_{null} = 0$). This pattern is consistent with enhanced N400 activity for unexpected articles compared to expected articles (e.g., Fleur et al., 2020), whether definite ($M = -1.20$, CrI: [-1.75 -0.60]) or indefinite ($M = -0.78$, CrI: [-1.37 -0.17]), although the effect was numerically stronger for definites than indefinites. This pattern carried over into the 500–700 ms time

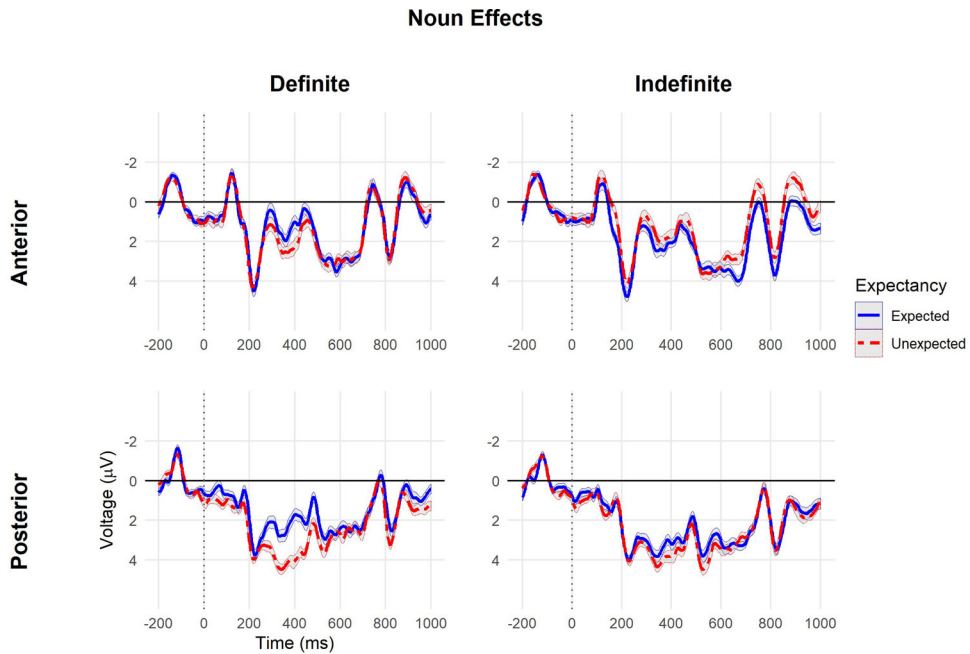


Fig 5. Noun effects. The graphs show the grand-average ERPs elicited by nouns following expected (solid blue lines) and unexpected (dotted red lines) articles at the anterior and posterior ROIs (top and bottom graphs, respectively), plotted for definite or indefinite noun phrases separately (left and right graphs, respectively).

window, yielding moderate evidence for the effect of expectancy; here too, the expectancy effect was evident for definite articles ($M = -0.82$, CrI: $[-1.41 -0.23]$) but not for indefinite articles ($M = -0.22$, CrI: $[-0.84 0.39]$).

The results did not reveal evidence for a main effect of definiteness, with three out of four ROIs yielding moderate evidence for the null hypothesis and parameter estimates very close to zero.

3.2. Preregistered noun analyses

As shown in Fig. 5, we observed modulations of N400 activity in the 300–500 ms time window, most prominently in the posterior ROI (see also Figs. A3 and A4 in the online Appendix, for ERPs at all channels). Nouns following unexpected definite articles elicited smaller (more positive) N400s than following expected definite articles ($M = 1.47$, CrI: $[0.80 2.11]$), consistent with the pattern reported by Fleur et al. (2020). This expectancy effect was also visible for nouns following indefinite articles at the posterior ROI ($M = 0.56$, CrI: $[-0.11 1.18]$), but in a reduced form. When resolving the interaction pattern by expectedness at this ROI, indefinite expected nouns elicited smaller N400s than definite expected nouns ($M = 0.87$, CrI: $[0.20 1.57]$), whereas the definiteness effect for unexpected nouns is close to zero ($M = -0.04$, CrI: $[-0.75 0.65]$).

Results of the Bayesian mixed-effects model analyses are shown in Fig. 6, which plots probability densities and Bayes factors for the posterior ROI in the 300–500 ms time

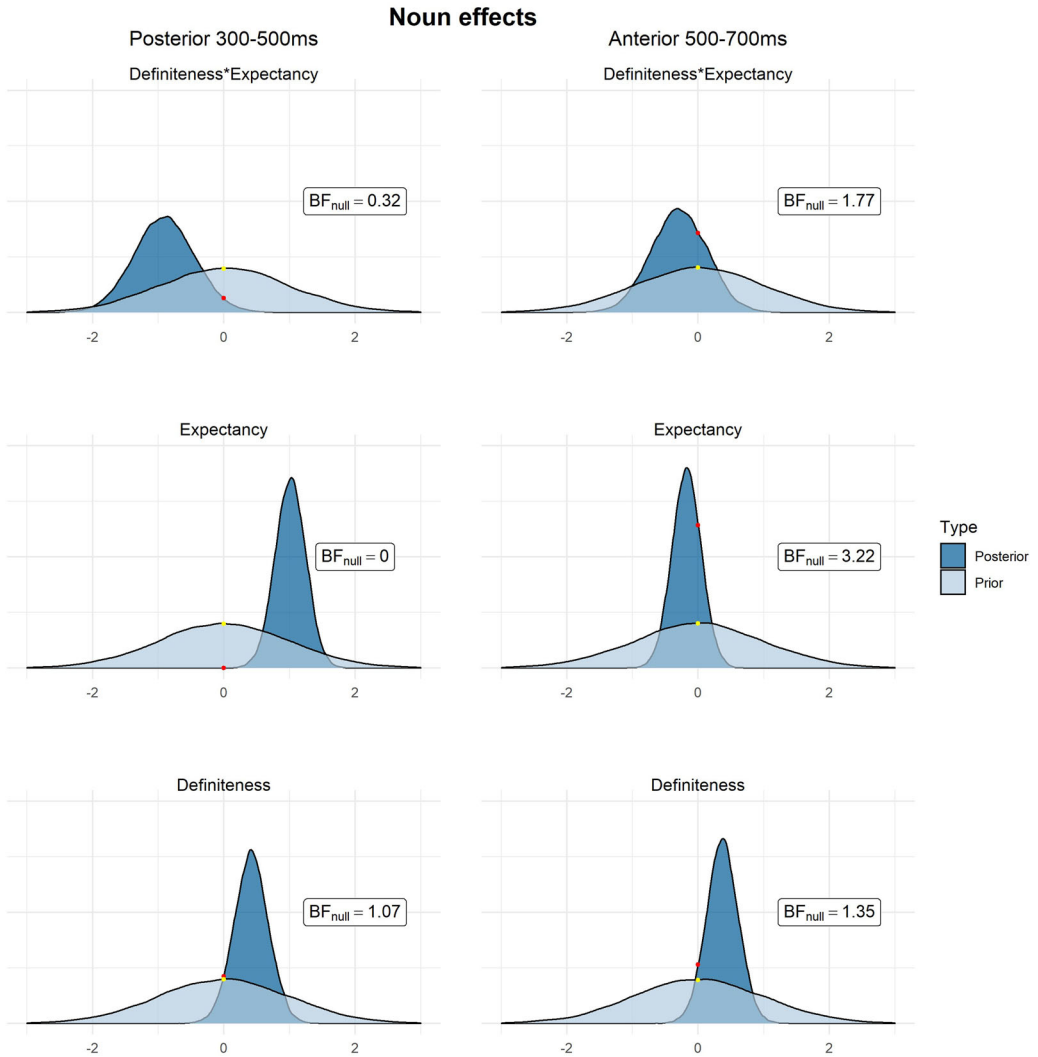


Fig 6. Noun effects. Prior and posterior densities and Bayesian hypothesis tests for the posterior ROI in the 300–500 ms time window and the anterior ROI in the 500–700 ms time window.

window and for the anterior ROI in the 500–700 ms time window. Table 3 lists the corresponding details of the parameter estimates, and Fig. 7 shows the estimated condition means and estimated means of the expectancy effect (unexpected minus expected).

These analyses yielded extreme evidence for the effect of expectancy at the posterior ROI in 300–500 ms time window ($BF_{null} = 0$, so the posterior samples did not contain zero), but also moderate evidence for an interaction effect, corresponding to the much larger expectancy effect for nouns following definite articles than those following indefinite articles. As visible in Figs. 5 and 7, this interaction pattern was mostly driven by the more

Table 3

Noun results from the Bayesian mixed-effects model analyses, obtained only for the posterior ROI at 300–500 ms and anterior ROI at 500–700 ms

Factor	ROI					
	Posterior, 300–500 ms			Anterior, 500–700 ms		
	μ	σ	CrI	μ	σ	CrI
Definiteness*Expectancy	-0.91	0.47	[-1.82 0.00]	-0.29	0.43	[-1.13 0.55]
Expectancy	1.01	0.23	[0.55 1.47]	-0.18	0.22	[-0.62 0.26]
Definiteness	0.41	0.27	[-0.11 0.93]	0.37	0.25	[-0.12 0.85]

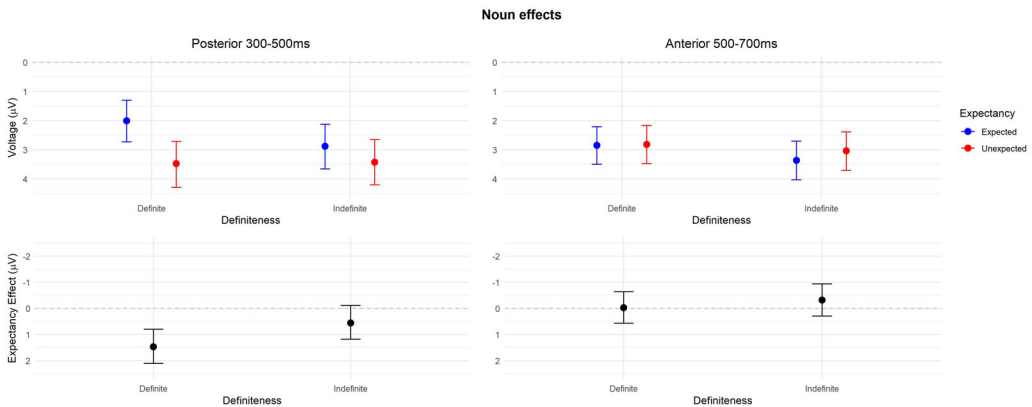


Fig 7. Noun effects. Estimated marginal means and 95% uncertainty interval for each condition (top graphs), and estimated means and 95% uncertainty intervals for the expectancy effect (unexpected minus expected).

negative (less positive) voltage for the expected definite noun compared to the other three conditions.

No clear effects emerged at the anterior ROI in the 500–700 ms time window, although we note that unexpected indefinite articles at least visibly did elicit an enhanced negativity compared to expected indefinite articles from roughly 600 ms after noun onset onward.

3.3. Sentence final effects

We performed exploratory analyses of ERPs elicited by sentence-final words. We briefly summarise the results here and present full details in the online Appendix. Sentence-final words elicited more positive ERPs following unexpected noun phrases than expected noun phrases. This pattern could be interpreted as a modulation of the N400 but given the equally strong effect in the 500–700 ms time window, the pattern could instead reflect an enhanced positive response. Further, we note that inspection of ERPs at all channels is suggestive of an expectancy by definiteness interaction pattern at occipital-parietal channels but further research is needed to address this issue. Although we refrain from strong conclusions based on these patterns, unexpected (in)definiteness incurs processing consequences that remain visible at the end of a sentence.

4. Discussion

We investigated the predictive processes that can be associated with definite and indefinite referents. People are known to sometimes predict upcoming referents during language, which has been demonstrated using ERP responses to prenominal articles. By adapting a previously used paradigm using Dutch stimuli (Fleur et al., 2020), we compared the processing consequences of unexpectedly definite or indefinite articles preceding an expected noun. Definite articles that mismatch an expected indefinite noun phrase (e.g., “the” when participants expect “a house”) are said to incur a uniqueness violation, because they require comprehenders to retrieve a unique referent that is unavailable from the context. Indefinite articles that mismatch an expected definite noun phrase (e.g., “a” when participants expect “the house”) are said to incur an antiuniqueness violation, because they suggest a new referent distinct from the one already strongly implied by the context. Processing differences between these two violations have not yet been observed in previous research (e.g., Clifton, 2013; Kirsten et al., 2014), and reports of general processing differences between definite and indefinite articles have thus far been inconsistent (e.g., Schneider et al., 2019; Schumacher, 2009). However, the inconsistency in previous results may be due to predictability differences between the definite and indefinite noun phrases, both within and across previous studies.

To address this issue, our study compared ERP responses to definite and indefinite articles that were similarly expected or unexpected given the discourse context. Using preregistered Bayesian analyses, our study revealed a novel interaction pattern at the anterior ROI in the 300–500 ms time window, with a qualitatively different expectancy effect for definite and indefinite articles. Expected articles elicited less negative voltage than unexpected articles when definite, but more negative voltage when indefinite. In addition, unexpectedly definite or indefinite articles elicited enhanced N400 activity, consistent with previous results (Fleur et al., 2020; Kirsten et al., 2014; Schlueter et al., 2018). Unlike some previous studies (e.g., Kirsten et al., 2014), we did not observe a general ERP difference between definite and indefinite articles. In particular, we did not observe clear ERP differences between expected definite and indefinite articles. Interestingly, the nouns also yielded a novel interaction pattern: While expected definite nouns elicited enhanced N400s compared to unexpected definite nouns, replicating a surprising finding from Fleur et al. (2020), the equivalent effect was smaller (and not evident) for indefinite nouns. Finally, exploratory analyses suggested that the enhanced processing costs for unexpected articles lingered as far downstream as the discourse-final word. ERP responses to discourse-final words were also more positive overall following definite compared to indefinite noun phrases. In the following sections, we relate these findings to key claims from the extant literature on definiteness processing.

4.1. Prenominal article effects

We observed diminished N400 responses at the posterior ROI to expectedly definite or indefinite articles. This pattern is consistent with participants anticipating a likely upcoming referent that was definite or indefinite, in other words, with the prediction of definite or indefinite noun phrases (Fleur et al., 2020; Kirsten et al., 2014; Schlueter et al., 2018). This conclusion is compatible with the view of definiteness, or specificity, as a semantic

feature of noun phrases (e.g., Abbott, 2004, 2006; Lyons, 1999; Von Heusinger, 2002). As N400 amplitudes reflect the activation of semantic information (Kutas & Federmeier, 2011), our result can be taken to suggest that definiteness is preactivated along with other semantic information associated with the noun. Although the article effects by themselves could, in principle, be explained in terms of integration difficulty (e.g., difficulty integrating a definite article that is implausible or incongruent given the context, without having predicted any noun meaning), such an explanation is not very satisfying and not very plausible in light of other demonstrations that participants indeed appear to predict a specific article–noun combination in highly constraining contexts (e.g., Fleur et al., 2020).

Article-elicited N400 responses did not yield convincing evidence for an interaction between definiteness and expectancy, but yielded moderate evidence against an effect of definiteness. This suggests that participants may have anticipated definite and indefinite referents more or less equally strongly. This finding is of theoretical interest, because it suggests that when predictability is matched between definite and indefinite referents, the N400 response is mostly modulated by expectedness rather than article definiteness. In other words, when the discourse context already strongly implies the existence of a unique referent, use of the definite article does not seem to incur a processing cost compared to the more common use of an indefinite article to introduce a nonunique referent.

Compared to the posterior N400 ROI, the anterior ROI more clearly suggested a processing difference between definite and indefinite articles. Expectancy elicited opposite voltage effects for definite and indefinite articles. Judging from Fig. 1, the observed interaction is due to the more negative effect of expectancy for definite articles, which appears to be an anterior extension of the posterior N400 modulation, but a more positive effect for indefinite articles. The latter effect does not appear to be related to the posterior N400 modulation, but instead it seems to be the earlier part of a positive ERP effect that continues up to 700 ms after article onset.

We acknowledge that these results suggest weak differences between definite and indefinite articles. The obtained interaction of definiteness and expectancy in this earlier, anterior ROI comes from two opposite voltage effects that are both more prominent at a different ROI. However, the ROIs where these effects are most prominent (the earlier, posterior ROI for the N400 and the later, anterior ROI for the positive effect) themselves did not yield convincing evidence for an interaction. Our study was likely underpowered to detect such interaction effects, because our sample size was not specifically tailored to detect smaller effects, as demonstrated in, for example, Fleur et al. (2020). The weakness of the observed effects is unfortunate, because it means we cannot make a fully convincing case for an interaction effect involving either the N400 or the later anterior positivity. In addition, we note that Bayes factor evidence also depended on the preregistered prior.²

That said, we can nevertheless speculate that there is a qualitative processing difference between definite and indefinite articles. Both article types can elicit an N400 effect of expectancy, but while this effect extends into the post-N400 time window for definite articles (see also Fleur et al., 2020), it is followed by an anterior, positive effect for indefinite articles. This positive effect could be related to the anticipation of a new referent over and above the already predicted referent (Kirsten et al., 2014; Schneider et al., 2019).

According to a recent “semantic updating” account of the N400, prenominal N400 effects reflect the article-induced change in a probabilistic semantic representation with respect to the subsequent noun (Rabovsky, 2020; Rabovsky, Hansen & McClelland, 2018). It remains to be seen how the semantic updating account would explain the current and other recent article-elicited ERP effects (see also Fleur et al., 2020). Articles in the current study, whether definite or indefinite and expected or unexpected, did not seem to incur a big change in what subsequent noun was considered most likely (as established in cloze norms).

4.2. Noun effects

For definite nouns, we found the same pattern as Fleur et al. (2020): Expectedly definite nouns elicited enhanced N400 amplitudes compared to unexpectedly definite nouns. Fleur et al. speculated that unexpectedly definite articles could have boosted the semantic preactivation of the predictable noun. An alternative explanation was that this effect was due to contamination from article-elicited ERPs rather than a new effect elicited by the nouns, for example, if unexpected articles elicited a relatively late-onset positive-going ERP effect.

Based on two novel findings from the current study, we no longer consider these explanations plausible or sufficient. First, indefinite nouns did not clearly elicit this “reversed N400 expectancy effect”, or perhaps only in a strongly reduced manner. Second, the different effects for definite and indefinite noun phrases did not come from unexpected nouns but from expected nouns (Figs. 5 and 7), as expected definite nouns elicited an enhanced N400 compared to expected indefinite nouns. This suggests that the reversed N400 expectancy effect was not elicited by unexpected articles, but is a genuine effect elicited by the nouns themselves. This raises the question as to why expected definite nouns elicited larger N400s than the other three conditions. If we take the N400 patterns to reflect semantic preactivation, we are left to conclude that expected definite articles are less effective in boosting preactivation than unexpected articles, which seems implausible. An alternative explanation can be considered in terms of specificity and its equivalent of the concreteness effect. Concrete nouns elicit more negative N400s than abstract nouns (e.g., Holcomb, Kounios, Anderson & West, 1999; Kounios & Holcomb, 1994), which is thought to reflect the greater amount of semantic activation. We speculate that expected definite nouns trigger more semantic activation than indefinite nouns because they are more specific and, therefore, more concrete. For example, in our example story about the house purchase, after “*The purchase was done. The broker gave the buyers the keys to*”, the expected definite “the house” could trigger activation of semantic features of a specific kind of house and/or possibly of semantic information regarding the event (the purchase), whereas the indefinite “a house” may not because it refers to a nonspecific house about which nothing is known. Expected definite nouns may also be more specific and, therefore, concrete than unexpected definite nouns, despite similar definiteness. For example, after “*Esmee and Paul want to move in together. With the broker they look for*”, the continuation “the house” could still constitute a nonspecific/abstract house (e.g., the house of their dreams), and as such not activate as much semantic information as when the noun phrase refers to one specific/concrete house already implied by the context. In other

words, the noun results may thus reflect the combined referential implications of definiteness and the discourse context.

As pointed out by a reviewer, noun-elicited N400s need not only reflect semantic activation of noun meaning but could reflect a more general change in the semantic representation of the entire context (e.g., Rabovsky et al., 2018). It is possible that expected definite nouns incur the greatest change in the semantic representation because they refer to specific and concrete entities that were strongly implied by the context, while nonspecific entities incur a weaker change in the event representation.

While any interpretation of the noun results is tentative, the results do suggest that definiteness processing does not occur late, or beyond the N400 time window, as has been claimed by Schumacher (2009). According to the discourse-updating hypothesis (Burkhardt, 2006; Schumacher, 2009), the creation of new discourse referents and associated updating or modifying of prior discourse representations exerts processing demands in a relatively late time window, reflected in a late positivity. However, nouns in the current study had clear effects on the N400, which is not consistent with the discourse-updating hypothesis.

5. Conclusion

The current study demonstrates evidence for prediction of definite and indefinite referents during discourse comprehension. Definite and indefinite articles matching the contextually expected definiteness at that point elicit a reduced N400 response compared to unexpected definiteness. In addition, our results demonstrate a processing distinction between unexpectedly definite and unexpectedly indefinite articles, which relate to the uniqueness and antiuniqueness violations. Although unexpectedly definite articles only elicited N400 activity, unexpectedly indefinite articles elicited a positive ERP effect at frontal channels compared to expectedly indefinite articles. We tentatively link this effect to an antiuniqueness violation, which may force people to introduce a new referent over and above the anticipated one. Interestingly, expectedly definite nouns elicited larger N400s than unexpectedly definite nouns (replicating a previous surprising finding by Fleur et al., 2020) and indefinite nouns. The exact nature of these noun effects remains unknown, but we speculate that expectedly definite nouns trigger the strongest semantic activation because these nouns alone refer to specific and concrete referents. Counter to recent claims regarding definiteness processing, our results both at the articles and nouns clearly demonstrate that definiteness marking has a rapid effect on processing.

Notes

1. The predictions here and elsewhere are formulated in terms of uniqueness (Abbott, 2006). Alternatively, predictions can be framed in terms of familiarity (Heim, 1982), if one assumes that the definite-suggesting context implies an already familiar referent, while the indefinite-suggesting context does not. However, because both contexts, to

some extent, imply familiarity with the same noun meaning, the uniqueness framework seems to make the clearest distinction between expected and unexpected conditions.

2. Bayes factors are known to strongly depend on the preregistered prior, more so than the effect estimates. Had we preregistered a different prior, the resulting Bayes factor may not have supported the alternative hypothesis. To demonstrate this issue, we performed a prior sensitivity analysis for the interaction effects that yielded moderate evidence against the null hypothesis (results are reported in Fig. A11 in the online Appendix).

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Fig. A1. Grand-average ERPs at all EEG channels elicited by definite articles, plotted.

Fig. A2. Grand-average ERPs at all EEG channels elicited by indefinite articles, plotted separately for expected articles (blue) and unexpected articles (red).

Fig. A3. Grand-average ERPs at all EEG channels elicited by nouns following definite articles, plotted separately for expected articles (blue) and unexpected articles (red).

Fig. A4. Grand-average ERPs at all EEG channels elicited by nouns following indefinite articles, plotted separately for expected articles (blue) and unexpected articles (red).

Fig. A5. Scalp topography of the unexpected definiteness and indefiniteness effects for articles in the two pre-registered time windows.

Fig. A6. Scalp topography of the unexpected definiteness and indefiniteness effects for nouns in the two pre-registered time windows.

Fig. A7. Scalp topography of the unexpected definiteness and indefiniteness effects for sentence-final words.

Fig. A8. Grand-average ERPs at all EEG channels elicited by sentence-final words following definite noun phrases, plotted separately for expected articles (blue) and unexpected articles (red).

Fig. A9. Grand-average ERPs at all EEG channels elicited by sentence-final words following indefinite noun phrases, plotted separately for expected articles (blue) and unexpected articles (red).

Fig. A10. Effects elicited by sentence-final words.

Table A1. Results from exploratory analyses on ERPs elicited by sentence-final words.

Fig. A11. Sensitivity analyses for the interaction between definiteness and expectancy, in the ROIs that yielded moderate evidence against the null hypothesis.