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The Electrophysiological Correlates of Text Integration and Direct vs. Indirect Articles: A Centralized and Lateralized Examination

Deanna C. Hall
Wilfrid Laurier University

The Electrophysiological Correlates of Text Integration and Direct vs. Indirect Articles: A Centralized and Lateralized Examination

by Deanna C. Hall

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Abstract

As we read, we develop mental models of the discourse content called situation models. Situation models are integral to how we keep track of information, and to do so in an ongoing event incoming information needs to be integrated into the model or discarded. The type of information being presented, and its relation to prior data, impacts how that new information is processed. The current research examined discourse passages containing concepts that were either previously mentioned (match), mentioned with a general term (general category), unmentioned in lieu of another concept (mismatch), or completely unmentioned previously (indeterminate), and examined how these four target/antecedent relation types were integrated. Before this research these four types of relations had never been directly compared in one experiment and as such, the current work aimed to establish a baseline for the mental processing of these relations during online reading tasks.

In Chapter 2 the four aforementioned types of relations were examined in two ways: through event-related potential (ERP) technology and sentence completion surveys. The ERP analysis was performed to observe what happens within the brain during reading as it happens. The sentence completions were implemented to provide insight into *how* readers incorporated these discourse concepts into their situation models. In this chapter the target stimuli were always preceded by the definite article *The*, which adds a certain level of contextual constraint by presupposing that the referent already exists within the situation model. The N400 amplitudes showed that the mismatch and the indeterminate relations were the least congruent with the provided discourse. The extended N400 results indicated that the indeterminate relations showed the highest cost of integration into the situation model, compared to the match, mismatch, and general category relations.

Chapter 3 applied the exact same methodologies as Chapter 2, but instead had the target stimuli preceded by the indefinite article *A*/*An*. The goal of these experiments was to determine what, if any, differences became apparent when an indefinite article was used to indicate the target stimuli, rather than a definite article. Indefinite articles are not as contextually constraining as definite articles and therefore may allow for more open interpretation of the four target/antecedent relation types. It was found that when presented with an indefinite article, targets in the indeterminate condition had the least semantic congruency with developing situation models, less so even than the mismatching information, as shown by the N400 amplitudes. The sentence completions results indicated that the indefinite article led to slightly more variability in how concepts were integrated into the situation model than the definite article. General category targets were much less likely to be considered coreferential with the relevant antecedent when an indefinite article was used. This finding aligns with the overall increase in semantic availability (less negative N400) following indefinite article use, particularly with the general category relations.

In Chapter 4 the same ERP methodology and stimuli as seen in Chapter 2 were again used, however the visual hemifield technique (VHF) was applied to allow for comparison of processing between the left (LH) and right hemispheres (RH). It was found that the indeterminate relations were more difficult semantically to integrate into the situation models than the mismatching relations, but only in the LH and not the RH, where they did not differ. There was no difference found in the integration cost between the indeterminate, mismatching, or general category concepts. These findings support the idea that both hemispheres are required for the processing of such nuances and therefore to optimal discourse processing as a whole.

Overall, this dissertation provides novel neurocognitive data on how people integrate discourse concepts into situation models during language processing, both across and between the cerebral hemispheres. The sentence completion results provided insight into what exactly the examined ERP components express in the process of situation model development. By examining the definite and indefinite articles, this dissertation emphasized the importance of grammatical nuances on the ease of mental processing, as well as how it may influence what information is integrated or not in the situation model.

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Chapter 1: General Introduction

Situation Models

During reading we build a mental representation of the information in the text called a situation model (van Dijk & Kintsch, 1983). It is an integrated mental representation of a described situation and incorporates information both stated explicitly in the text and from inferences (Zwaan & Radvansky, 1998). It has been shown that readers have more difficulty updating their situation models when new information is inconsistent with the current model being constructed (Singer, 2009; Zwaan & Madden, 2004). This suggests that readers keep track of situations as they evolve and update their situation models, and that encountering text ideas that are consistent with previous information does not initiate extensive memory searches for similar concepts, in comparison to inconsistent text ideas.

The basic unit of the situation model is an event representation (Zwaan, 2016). Event representations formed during language comprehension are updated on at least six dimensions: time, space, entity, causation, intentionality/motivation, and number (Dwivedi, Goertz, & Selvanayagam, 2018; Zwaan, 2008). As the described events unfold, the comprehender must continuously update their mental representation: Characters move to new locations, objects are left behind, events are no longer operative, lost objects are found again. Successful comprehension is impossible without some form of updating.

This dissertation aims to build on previous work by investigating the electrophysiological (i.e., EEG) response in the brain that is generated when text ideas become less consistent with the situation models that readers construct. Much of the prior research investigating situation model updating has primarily examined discourse passages in which several sentences are dispersed throughout corresponding text ideas. As a result, discourse concepts can become less

available in situation models because of decay from working memory, and not just from manipulations made to the text itself. In the present research, all passages were only two sentences in length in order to control for decay of information from working memory.

Four coreferential relations are examined in the current research: when text ideas (target) are completely consistent/match with previous text idea (antecedent), when they are inconsistent/mismatch, when the original text ideas are general and underspecified, and when no previous text idea is provided that could be consistent or inconsistent (see Table 1, Sentence One (Antecedent) column). These four relations have never been compared together within a single experiment before. As such, one of the main goals of this dissertation was to compare and contrast these conditions together to allow for a direct examination of accessibility and integration of discourse concepts into situation models. To investigate this, participants were presented with pairs of sentences. The EEG response of participants to the key target word in the second sentence was measured, based on its match, mismatch, general category, or non-presence (indeterminate) with the text ideas in sentence one.

The current research also contrasts the impact of two different types of articles that modify the critical targets concepts - the indefinite article "*a/an*" and the definite article "*the*". Definite articles are used when there is already a particular concept that the reader is familiar with (Singer, 1976), and indefinite articles are often used to add new tokens to situation models (Kidd & Bavin, 2007; Murphy, 1984). Thus, it can be expected that preceding the target concepts with a definite article versus an indefinite article can influence the ability to integrate the concepts into a developing situation model, particularly when paired with the four relations examined within this research. For example, a mismatching relation (such as *bus* and *truck* in Table 1 below) could be interpreted quite differently if presented with the different articles.

Using “the truck” implies a specific truck already exists within the narrative, and therefore a mental search for such a truck may occur, as the only antecedent to potentially relate this truck to is the bus mentioned in sentence one. However, if “a truck” is seen after the antecedent of “bus”, then there is the potential opportunity for the reader to infer that a truck is being added into the existing situation model. As such, examining both definite and indefinite articles is important for establishing how readers resolve the four coreferential relations of interest.

Table 1. *An example of a discourse passage for each of the four relation conditions: match, mismatch, general category, and indeterminate within each chapter of the dissertation*.

Condition/ Relation	**Sentence One (Antecedent)**	**Sentence Two Definite Article (Target) Chapters 2 & 4**	**Sentence Two Indefinite Article (Target) Chapter 3**	**Sentence Two Completion Definite (Target) Chapter 2**	**Sentence Two Completion Indefinite (Target) Chapter 3**
Match	Dan drove past a truck that had been in a minor accident.	The truck was blocking traffic at the worst time of day.	A truck was blocking traffic at the worst time of day.	The truck _____.	A truck _____.
Mismatch	Dan drove past a bus that had been in a minor accident.	The truck was blocking traffic at the worst time of day.	A truck was blocking traffic at the worst time of day.	The truck _____.	A truck _____.
General Category	Dan drove past a vehicle that had been in a minor accident.	The truck was blocking traffic at the worst time of day.	A truck was blocking traffic at the worst time of day.	The truck _____.	A truck _____.
Indeterminate	Dan drove past a minor accident.	The truck was blocking traffic at the worst time of day.	A truck was blocking traffic at the worst time of day.	The truck _____.	A truck _____.

This dissertation will also further investigate these four relations and how they are processed and integrated into the situation models within each cerebral hemisphere. In Chapter 4, a visual half field technique (VHF, see Banich, 2002 for review) is employed to gain insight into the importance of each hemisphere during situation model updating. The hemispheres have been shown to both work separately and together during different aspects of language processing (e.g., dos Santos, Nespoulous, Celsis, & Viallard, 1991; Johns, Tooley, & Traxler, 2008). Due to the four examined relations not being studied together previously, there is also no research that has examined these relations together within the different hemispheres.

Event-Related Potentials

Throughout this dissertation event-related potentials (ERPs) will be examined. These electroencephalographic (EEG) measurements are a widely used neural measure of cognition and are measured in temporal relation to a critical "event", such as a specific word. The EEG recording is time-locked to this critical event. The resulting ERP waves are a reflection of the activity related only to the time-locked event, as spontaneous EEG fluctuations (that are unrelated to the target event) are averaged out (Beres, 2017). As ERPs are recorded by electrodes across the scalp, it allows for a certain amount of examination of the localization of the brain activity, although not as much as functional magnetic resonance imagery (fMRI). ERP methodology has high temporal resolution. Consequently, it has an advantage over behavioural measures (such as response time), and even compares favorably with other neural measures like fMRI. The high temporal resolution allows the evaluation of a text manipulation to happen “on-line”, or during the actual sentence, rather than only at the end of a sentence or after a decision is made (e.g., lexical decision).

Several ERPs are of interest in the present research. The P2, a positive component that is elicited between 200-300 ms following target onset, varies as a function of very strong semantic expectancies (Federmeier, Mai, & Kutas, 2005; Ferretti, Singer, & Patterson, 2008) and word repetition (Van Petten, Kutas, Kluender, Mitchiner, & McIsaac, 1991).

The N400 is a negative component that peaks 300-500 ms following stimulus onset and is considered an index of semantic congruency (van Berkum, Hagoort, & Brown 1999) and the accessibility of discourse concepts in situation models. Words that provide a better semantic match with antecedent discourse concepts elicit smaller N400s relative to words with a poorer match (Anderson & Holcomb, 2005). Furthermore, content nouns that are repeated in a discourse have reduced N400s relative to content nouns that are not repeated (Anderson & Holcomb, 2005; Burkhardt, 2006). The extended N400 region (500-650 ms) has also been shown to reflect continuation in integration costs associated with failure, or extreme difficulty, to update a discourse concept into the situation model (Burkhardt, 2006; Ferretti et al., 2008) and will therefore also be examined.

The late positivity, or Late Positive Component (LPC) typically appears between 600-1000 ms after the onset of words. It is sometimes referred to as a group of positivity called the post-N400 positivity (PNP) (Delong & Kutas, 2016). In the following experiments the timeframe of 750-1000 ms following stimulus onset will be examined. This component is an index of integration costs associated with anaphoric complexity and situational updating (e.g., Burkhardt, 2005; Ferretti et al., 2008) and is a gauge of the increased memory demands during syntactic and semantic reanalysis. An increase in positivity reflects an increase in integration costs, and the process of updating the situation model.

Definite vs. Indefinite Article

As previously mentioned, the article used to modify discourse concepts can influence how readers incorporate concepts into their situation models. Definite articles are more likely to be used to reactivate previously encoded referents in the discourse (Haviland & Clark, 1974), but indefinite articles tend to introduce new referents (Kidd & Bavin, 2007; Murphy, 1984). It has been found that, when using a definite noun phrase, readers will take less time to comprehend "given" information than when no antecedent is provided ("new" information; Haviland & Clark, 1974). The present research will be expanding on this work of "given" versus "new" information, by comparing three different types of "given" information (match, mismatch, general category) and the "new" information (indeterminate), as was discussed. Adding new referents to a text, by use of the indefinite article, has also been found to lead to longer comprehension times than when referring to an antecedent (Murphy, 1984). Previous research has also shown that in ambiguous situations, a definite article can become an obstacle for processing (e.g., when shown an image containing multiple cubes, being asked to mark *a* cube vs. mark *the* cube), leading to slower responses and higher perceived difficulty of processing (Strohner, Sichelschmidt, Duwe, & Kessler, 2000). DeLong, Urbach, and Kutas (2005) found that readers use the articles to estimate the approximate likelihood of upcoming words. They examined the indefinite article and the phonological regularity it contains ('a' preceding consonant sounds and 'an' preceding vowel sounds) and through measurements of ERPs it was found that the brain processes the article shown and pre-activates individual words. The amount of pre-activation could actually be estimated from previously measured probability ratings for each upcoming word. More recently, Calloway and Perfetti (2020) showed that the use of the different articles lead to different responses in terms of how new information was assimilated

with the ongoing mental representation. Specifically, the definite article (*the*) triggered the integration process whereas the indefinite article (*a/an)* triggered a structure building process whereby a new model is constructed.

Other research has found that in almost half of speakers the simple use of a definite article did not identify a unique referent (Brown-Schmidt & Tanenhaus, 2008) and that when speaking people do not consistently introduce new referents using the indefinite article (Anderson & Boyle, 1994; Anderson, Clark, & Mullin, 1991). Although these findings do refer to the use of certain articles when communicating aloud, they should still be taken into consideration for the present research. This is because references associated with definite articles may be ambiguous, although less so than for indefinite articles, and if people do not consistently use indefinite articles, then it is not clear exactly how sensitive people will be to their usage in the present research, even though it is known that people are already sensitive to them. As two of the experiments within this dissertation implement a sentence completion task, it is possible that similar insights may be revealed. By examining how participants complete these sentences themselves when only provided with the target and relation to the antecedents, further insight can be gained into how readers actually incorporate discourse concepts into their situation model as the degree of "match" with potential antecedents is varied. This adds to the importance of these sentence completion studies, which are intended to complement the ERP findings of the EEG experiments.

Hemispheric Involvement in Language Processing

Within the field of psycholinguistics there has been extensive evidence that the left hemisphere (LH) is involved in discourse processing and is regularly considered the dominant hemisphere for language (e.g., dos Santos et al., 1991). As it stands, there is a large amount of

evidence that the right hemisphere (RH) also contributes to language processing (e.g., Beeman 1993; Johns et al., 2008), and that both the LH and RH work together to provide successful discourse comprehension (Delong & Kutas, 2016; Wlotko & Federmeier, 2007). Prior research has also shown that there are, in fact, certain language processes that the RH performs better than the LH, such as semantic summation (Beeman, 2005), response time to associated primed words (e.g., priming "cry", "foot", and "glass" vs. priming "dog", "church", and "phone" for the word "cut", Beeman et al., 1994), and distinguishing integrated versus unintegrated targets (e.g., providing instructions that would lead to the drawing of a flower followed by an image of the same flower vs. an image with each of the elements shown, such as a line for the stem and the shapes of the petals, but omitting all spatial relations, Male & Gouldthorp, 2020). Clearly the role of the RH in language cannot be dismissed. Thus, the present research aimed to investigate higher-level discourse processing that involves coreferential processing and situation model construction in both hemispheres.

There has been some previous research that has examined the roles of each hemisphere in referential processing. This research has shown that the LH and RH may be specialized to carry out different processes when generating inferences (e.g., Beeman, Bowden, & Gernsbacher, 2000; Virtue, van den Broek, & Linderholm, 2006), and that the RH is necessary to referential processing (Albyn Davis, O'Neil-Pirozzi, & Coon, 1997). Also, while the RH has a distinct role in making inferences, both hemispheres work in harmony to successfully draw inferences (Ferstl, Walther, Guthke, & von Cramon, 2005). Other researchers have found selective engagement of the LH temporal areas during inferential tasks (e.g., Marconi et al., 2013). Furthermore, when processing inconsistent inference-related information the RH has been shown to have stronger facilitation during text comprehension than the LH (Virtue & van den Broek, 2005). Virtue and

Joss (2012) have further noted that it is not the difficulty of information, but rather the consistency that drives hemispheric differences during inference generation.

As the four relations in this research (match, mismatch, general category, and indeterminate) have never been directly contrasted before, the current work aimed to provide novel neurocognitive data on how people update situation models during language processing. Examining differences between definite and indefinite articles will provide insight into the importance of grammatical nuances on influencing the activation and integration of discourse concepts into situation models. The manipulation of the VHF will provide important insight into how these four relations compare when processed within each hemisphere individually.

Current Research

The goal of this dissertation was to investigate electrophysiological response generated when text ideas vary in consistency with the situation models constructed during online language comprehension. The purpose of the current research was to establish a better understanding of the four types of referential relations on situation model development. By examining the electrophysiological responses during online processing insight can be gained into these relations. It will examine the neural correlates of discourse processing through the use of sentence pairs, removing the chances of other variables impacting the results. Further behavioural responses will provide insight into *how* readers integrate targets with different coreferential relations into their existing situation models.

In Chapter 2, two experiments are presented. Experiment 1 used ERP methodology to investigate readers' interpretation of two-sentence sequences, looking specifically at the antecedent-target relationship. The short narratives captured the relations/conditions described earlier. Three features of this experiment were incorporated specifically to provide new insights

concerning the stages of situation model updating and text integration (see Table 1): First, the four relations examined are compared directly within a single experiment for the first time. Second, providing the sequences as two-sentence events made the critical antecedent concept more readily available in working memory when the target sentence was read. This removed the need for searches of long-term memory (LTM). Third, the larger number of stimuli compared to previous research was projected to minimize between-item variability.

Whereas Experiment 1 provided electrophysiological evidence for the ease or difficulty of integrating concepts into a situation model, Experiment 2 examined more directly how people incorporated the target concepts in Experiment 1 into their situation models. This experiment consisted of an online sentence completion task that was based on the sequences from Experiment 1 (see Table 1). Participants were shown one of the four relation examples and then asked to complete the second sentence in a way that sounded as natural as possible. The completion task was deemed as an optimal method as prior research had successfully analyzed behavioural data that complemented the ERP results of coreferential processing using a comparable sentence completion task (see Ferretti, Rohde, Kehler, & Crutchley, 2009).

In Chapter 3, two experiments are presented that were identical to the experiments in Chapter 2 with the exception that the indefinite article (*a/an*) was used to refer to the key target term in each discourse (as seen in Table 1, Second Sentence Indefinite column). As definite articles are used when a particular concept is presupposed to exist and indefinite articles may be used when introducing novel concept to discourse, it was expected that the indefinite article would have a certain influence in advance, leaving the nature of relation between the target and antecedent more open to interpretation, as compared to the more distinct relations indicated by the definite article.

Chapter 4 investigated how the four relations are processed in the separate cerebral hemispheres when the target nouns follow determinate articles. This research employed the VHF technique (Banich, 2002), which enabled the first direct examination of how the separate hemispheres integrate and update discourse concepts into situation models for each of the coreferential relations examined.

Chapter 2: Definite Articles and the Electrophysiological Correlates of Text Integration

Successful reading comprehension relies on the construction of a mental representation, called the situation model (van Dijk & Kintsch, 1983). Situation models integrate numerous dimensions of context, such as spatial, temporal, causal, motivational, character information, and number (Dwivedi et al., 2018; Zwaan, Langston, & Graesser, 1995; Zwaan, Magliano, & Graesser, 1995).

The construction of an appropriate situation model relies on the reader's ability to integrate each consecutive text unit into the existing model. The present study was designed to examine the ability to integrate specific types of relations between given concepts. This research will build on previous findings on situation model integration or updating (Ferretti et al., 2008; 2013; Singer 2006). Previous research examined several types of relations (matching, mismatching, and null/indeterminate), as seen in the following example:

Ken and his brother ate (oranges/apples/0) as they cycled to football practice. (antecedent)

The coach established that it was oranges that Ken ate. (target)

The target sentence either matches (*oranges*) or mismatches (*apples*) the initial sentence/antecedent. However, when presented with the “0” or null version of the antecedent (in which no specific fruit or food was provided), the truth of the target sentence becomes uncertain ("indeterminate"). In 2013, Ferretti et al. utilized ERPs to examine readers’ understanding of these types of relations. Their results showed that, depending on the presented relation type, readers had to either integrate the target and antecedent, reconcile contradictions between them, and/or update their situation model. As the present study aims to build upon the previous research, it will have similar methodology. However, there are a number of key differences.

First, in Ferretti et al.'s (2013) study, the target stimuli were embedded within longer texts. In comparison, the current research will present the discourse as two-sentence sequences, to specifically focus on the relationship between antecedent and target. Second, the current research will present a significantly larger number of stimulus texts to participants. This is to allow for more data for analysis and is the common practice when implementing ERP methodology. Third, the stimuli of the current study involved a wider range of semantic relations between antecedent and target.

Constructing Situation Models

The detection of the different relations between the current text and antecedent text, as well as world knowledge, is what drives the development of situation models. Relations within a text can be indicated in a number of ways, such as explicit repetition, simple syntactic devices (e.g., the pronoun "*he*" linking the clauses in *Mira rewarded John because he won the race*), or complex syntactic devices (e.g., the article "*one*" in *Anne drove a red car and Mark drove a green one*, a nominal substitution indicating that Mark also drove a car).

However, is it usually semantic knowledge, instead of syntax, that establishes relations among clauses or sentences of a text, such as a knowledge of synonyms (e.g., *The student asked the teacher. The instructor answered the question.*), categories (e.g., *Sam spotted a rose. The flower was a lovely shade of red.)*, and causation (e.g., *The parking brake disengaged. The car rolled down the hill.*). The coherence of text is reliant upon both syntactic and semantic signals of the relationships between the given concepts. If coherence is not present, the reader cannot integrate the current text into their developing situation model. Previous research has suggested that the detection of *incoherence* requires the completion of the current situational structure and the construction of a new one (e.g., Gernsbacher, 1990; Radvansky, 2012), and converging

analyses treat each of these situational structures as distinct events (Radvansky, 2012; Zacks, Speer, Swallow, Braver, & Reynolds, 2007; Zwaan, Magliano, & Graesser, 1995).

There is information embedded in discourse that act as indications of coherence, coreference, and disruptions of the situation. Research has found that reading time increases with the use of these embedded signals, such as use of the adverb *Next* in the sentence *Next, he jumped into the water* (in the context of a lifeguard rescuing a swimmer), versus without the inclusion of the adverb (Gernsbacher, 1990). This increase in reading times implies that the adverb acts as an indication of the completion of one temporal structure and the start of a new one. Other behavioural measures have shown that reading *Three days later, it began to rain* (in the context of a marathon) involves a structure change, but *Half an hour later, it began to rain* does not, due to the interpretation that in the "three days later" example the marathon is long over and therefore requires a new structure (Gernsbacher, 1990; see also Zwaan, Magliano, & Graesser, 1995).

Integrating Text Concepts

The continual incorporation of text ideas during reading can best be described by the construction-integration theory of Kintsch (1988). This theory postulates that during text processing in the construction stage, a network of ideas, which includes explicit ideas, text generalizations, and inferences connecting the input to the previous content (Till, Mross, & Kintsch, 1988), is extracted from the current text input. As such, this network covers a wide range of information related to the discourse (e.g., the network from *The bat ate the moth* might include *Some bats are carnivorous*). However, this means that it may also include irrelevant associations (such as ones pertaining to baseball bats, in the previous example) (Swinney, 1979).

Following the construction stage, activation occurs in the existing network. The principles of constraint satisfaction are applied during this process (Rumelhart, McClelland, & the PDP Research Group, 1986), establishing which text ideas that are the most highly interconnected with each other and world knowledge, as well as disregarding unrelated associations or minor, unimportant details.

Text integration has also been found to require validation of new ideas and updating the situation model (Nieuwland & Kuperberg, 2008; O'Brien & Cook, 2016; Richter & Singer, 2017; Schroeder, Richter, & Hoever, 2008; Singer, Halldorson, Lear, & Andrusiak, 1992), which are discussed next.

Validation. Validation refers to the reader's constant evaluation of the congruence, coherence, and accuracy of text. Validation is often a necessity in reading, as without it the reader cannot know or determine if tentative discourse interrelations are sensible (Singer et al., 1992). Referencing world knowledge to validate information plays an integral part of understanding, and therefore integration. For example, the two sentences of *The fire went out because Dorothy poured water on it* and *The fire grew hotter because Dorothy poured water on it* have similar features on the surface in their degree of interconnection, but with reference to world knowledge it becomes apparent that the second sentence is abnormal, or nonsensical.

Other research has provided further evidence in support of numerous properties of text validation (Singer, 2013). It has been found that the memory processes involved in validation show universal qualities related to memory in general, rather being exclusive to linguistics (O'Brien & Cook, 2016; Singer, 2006). Other research by Staub, Rayner, Pollatsek, Hyönä, and Majewski (2007) has shown that validation is immediate and evident within a few hundred milliseconds of the appearance of a critical word. In the example *Jenny heard the mountain lion*

pacing in its cage, eye fixations are impacted immediately upon the appearance of *mountain*, as "heard the mountain" presents a nonsensical situation, until the next word appears (Staub et al., 2007). It has also been found that validation is automatic and does not require the reader to use any special strategies (Isberner & Richter, 2013). It was found that in a yes/no judgement task, readers had longer response times to "no" than "yes" judgements while reading sensible sentences but found the opposite for anomalous sentences (Isberner & Richter, 2013).

Updating. Another integral aspect of text processing is the process of updating the situation model. If the current text has been validated then the updating will be more effective (Schroeder et al., 2008). In the indeterminate example "*Ken and his brother ate while they cycled to practice* (antecedent). *The coach established that it was oranges that Ken ate* (target)" a reader would update the model created in the antecedent to include the information about it being oranges that Ken and his brother ate (from the target), assuming that the author is considered to be telling the truth. Plausibility also impacts updating, so that integrating plausible novel information does not take as long as reconciling text information that contradicts the antecedent (Schroeder et al., 2008; Singer, 2009).

There are numerous factors that impact the processes of updating, and it, in turn impacts many other aspects of discourse processing. As was previously discussed, the detection of text incoherence involves updating, as it requires that the reader "closes" the ongoing structure and the begins a new one (Gernsbacher, 1990). Updating also involves both working memory and LTM processes. Radvansky and Copeland (2001) found that the availability in working memory of text ideas connected to abandoned representations is rapidly reduced (see also Magliano & Schleich, 2000). For example, in an event where a shopper puts down/picks up their bag, the readers showed improved reading time and memory performance for the "picks up" scenario

when the bag is referred to in a later sentence, due to the reduced availability of the bag in working memory if it was “put down” (Radvansky & Copeland, 2001). This process then transfers antecedent text ideas to LTM; or, in the case of skilled readers, efficient long-term working memories (Ericsson & Kintsch, 1995).

The prior updating of text information can also be measured by other factors, such as reading time. Rapp and Kendeou (2009) found that readers require more time to make lexical decisions related to a key term in the causal- than the simple-refutation condition (e.g., a text describing Greta taking a long time to find where she had parked her car but is later qualified by additional information that a truck blocked the view of the car (causal) or simply stating she did not have trouble remembering the location (simple). In this example, the key term was *forgetful*). This delay in decision-making was taken to be an indication of the situation model being updated in the causal-refutation condition (that Greta was not forgetful, but that other factors (the truck) influenced the situation, in the previous example).

Qualities of the text processing stages. There are a number of qualities of text processing stages that are important: First, the one-step analysis (stages are applied concurrently at all levels of linguistic analysis, including syntactic, semantic, and knowledge-based, Hagoort & van Berkum, 2007; Nieuwland & Kuperberg, 2008), which is supported by findings like those of van Berkum et al. (1999) showing that readers detect knowledge-based anomalies (e.g., *Dutch trains are white*, when in fact they are yellow) as quickly as semantic anomalies (*Dutch trains are sour*). Second, the basic processes of memory are not unique to linguistics (Kintsch, Welsch, Schmalhofer, & Zimny, 1990; O'Brien, Rizzella, Albrecht, & Halleran, 1998). Third, the execution of text-processing stages is parallel and asynchronous (Cook and O'Brien 2014, or cascading; McClelland, 1979). This can be shown by the concept that the computations of early

stages of processing may continue to occur after a later stage has begun, by the fact that the processing of each discourse word begins as soon as the word appears (Just & Carpenter, 1980), that the analysis of different words is concurrent rather than sequential, and processing of one sentence may overlap with, and therefore impact, the analysis of the next sentence (e.g., Albrecht & Myers, 1995; Cook, Guéraud, Was, & O'Brien, 2007; Murray, Klin, & Myers, 1993).

Electrophysiological Measures of Language Processing

As was previously discussed in Chapter 1, a widely used neural measure of cognition is the ERP. ERPs are EEG measurements recorded at certain time frames following a specific "event." The EEG signals are measured by attaching electrodes to the subject's scalp. The "event" refers to the presentation of a critical stimulus, such as a specific word. Thus, the ERP refers to the measurement of EEG at specific time intervals after the event.

Measuring ERPs has several distinct advantages in language processes research. It has high temporal resolution and can indicate the effects of syntactic and semantic manipulations almost immediately following an event. This compares favorably with behavioural measures, such as naming time and lexical decision time, and even with neural measures such as fMRI. As a result, examining ERPs allows the evaluation of a text manipulation on-line, or as it occurs. ERPs can also be used for some assessment of the location of brain activity, but as mentioned previously, is not nearly at the spatial resolution of fMRI.

In the present study, ERP signatures in the following time regions were of particular interest. They are as follows:

P2 (200-300 ms). The P2 component varies as a function of semantic expectancies (Federmeier et al., 2005; Ferretti et al., 2008); although it may be limited to processing in the LH (Federmeier & Kutas, 2002). The P2 has also been shown to be influenced by the repetition of

words in discourse which, although may have seem to be a leading edge of the N400, was actually found to be a different wave form with more anterior distribution than the N400 itself (Van Petten et al., 1991).

N400 (300-500 ms). The N400 is a negative response that is an indication of semantic congruency (Kutas & Hillyard, 1980; Kutas & Van Petten, 1994). For example, in *He dug the hole with a pizza*, *pizza* will yield a larger N400 than if the last word had been *shovel*. The N400 may also show differences in negativity based on the nature of a target word in comparison to an antecedent. A new target, having not been seen previously in a sequence, will elicit a more negative N400 than a synonym for an antecedent, or a repetition (Anderson & Holcomb, 2005).

Extended N400 (500-650 ms). The extended N400 reflects integration costs related to high semantic incongruency or expectancy (Burkhardt, 2006; Ferretti et al., 2008). Previous findings have shown that the extended N400 amplitudes for mismatching sequences were more negative than matching and indeterminate ones (Ferretti et al., 2013).

Late positivity (750-1000 ms). The Late Positive Component (LPC) occurs after an event, although its onset and location can be variable. A late positivity sometimes follows an N400 response and acts as an indicator of the integration costs associated with situational updating (Burkhardt, 2005, 2006; Ferretti et al., 2008). It shows the elaboration and integration of text with information from LTM (Van Petten & Luka, 2012).

Experimental Design

Previous research noted systematic and interpretable ERP responses to target sentences in coherent texts. Consider again the sequence:

> Ken and his brother ate (oranges/apples/0) as they cycled to football practice.
>
> The coach established that it was oranges that Ken ate.

With the match (*oranges*), mismatch (*apples*), and indeterminate (0) antecedents, Ferretti et al. (2013) found a triple dissociation in ERP measurements. In the N400 window, the mismatch and indeterminate conditions were more negative than the match condition, which was interpreted to reflect differences to both of those target sentences as compared to the antecedent. In the extended N400 window, however, the mismatch condition was more negative than the match and indeterminate conditions, which were similar. This indicated that only the mismatch target was considered to be incongruent with its antecedent. This would indicate that there is nothing abnormal about learning, in the indeterminate condition, that what Ken ate was oranges. However, it is important to note that the results were from stimuli that followed factive verbs (e.g., *established*, above) that strongly presuppose the truth of their complements. This creates a highly constraining context, and as a result, the findings are influenced by this high level of constraint.

Finally, at the LPC the indeterminate ERPs were more positive than the other conditions, which were approximately equal. This late positivity is taken to reflect situational updating (Burkhardt, 2006; Ferretti et al., 2008; Ferretti et al., 2013). Indeterminate targets presented new information that would require integration into the situation model. In contrast, the matching condition would not require updating and the mismatch condition would not strongly sanction it.

The present study had several goals that expanded on the latter findings. First, more target-antecedent relations were examined than had been previously studied. Second, these relations were incorporated in two-sentence sequences rather than extended texts. This was to minimize the variability of ERP responses that might result both from resource-demanding memory searches and from heterogeneous semantic roles of the critical concept. Third, the study

presented a relatively large number of stimuli (in comparison with the previous works), as is typical in ERP investigations.

Preview of conditions and method. In Experiments 1 and 2, target-antecedent relations were examined. An example is shown in the sequence:

Alex spent 20 minutes watching his favourite (bear/lion/animal/0) at the zoo.

The bear was both beautiful and entertaining.

There are several important differences between this example and the previous example of *Ken and his brother*. First, this sequence introduced the new condition in which the target and antecedent are linked by general category relations (*Alex spent 20 minutes watching his favourite ANIMAL at the zoo. The bear was both beautiful and entertaining)*. For the *animal* version of the antecedent, the target sentence is easily comprehended by determining that *bear* belongs to the category *animal*. Category names (*bear-ANIMAL*) and category instances (*animal-BEAR*) encompass familiar anaphors in coherent discourse (Singer, Revlin, & Halldorson, 1990). However, the processes of resolving *bear* to *animal* are likely to be different from those of identity (*bear-BEAR*), and other matches.

Second, in comparison with the materials used by Ferretti et al. (2013), the target sentence did not have the form of a main verb plus complement (e.g., *The coach established that it was oranges that Ken ate*). This difference was intended to place the target anaphor (*The bear; The lion; etc.)* as close to its antecedent as possible. Another reason that this was altered was that the main verbs of Ferretti et al. (2013) were either factive or nonfactive in nature. Factive verbs (e.g., *know*) require the truth of their complements whereas nonfactive verbs (e.g., *believe*) do not (Halliday, 1967). The ERP results of Ferretti et al. (2013) discussed earlier were observed with factive verbs, providing a highly constraining context. The current research did not

manipulate factivity, and as such the presented stimuli does not contain the same high level of contextual constraint. However, the predictive nature of the conditions is controlled to a certain degree by using the definite article (*the*) when referring to the target concept, which is discussed further below. Third, half of the stimuli presented focused on spatial relations between antecedent and target, as shown by:

The diver snorkeled [in his favorite (river/bay/area)]/0.

The river was the perfect temperature.

The four versions of the antecedent above show the same antecedent-target relations as the example of *Alex and his favourite animal*. However, while the *Alex* example presents critical concepts that fill a semantic case of the antecedent sentence, this sequence refers to a locative adjunct of the antecedent. These differences discussed further in the next section.

Previous research has shown that readers are sensitive to the article used to reference a target. A definite article presupposes that a concept already exists within the situation model, as they are used when there is already a particular concept that the reader is familiar with (Singer, 1976). Definite articles (e.g., *the*) indicate that a noun is coreferential with its antecedent, whereas indefinite articles (e.g., *a, some*) do not (Anderson & Holcomb, 2005; Lyons, 1977). In the current study focusses on target nouns that are modified with a definite article.

An ERP experiment and a norming experiment were conducted. Like in previous research (Ferretti et al., 2013), Experiment 1 presented several counterbalanced lists, each of which had an equal number of stimulus sequences in each experimental condition. Across the lists, each stimulus appeared once in each condition. ERPs were monitored as the subjects read the target sentences.

Experiment 2 examined how people might interpret the target sentences (e.g., the target sentences of the previously discussed *Alex* and *diver* sequences). For example, one might assume that a reader would interpret the *bear* of *Alex spent twenty minutes watching his favourite LION at the zoo. The bear was both beautiful and entertaining* as an erroneous, mismatching continuation. To test these assumptions, Experiment 2 participants were instructed to write sentence continuations for stimuli such as *Alex spent twenty minutes watching his favourite lion at the zoo. The bear* _____. It was expected that the pattern of continuation responses would guide the interpretation of the Experiment 1 ERP findings.

Verb-entailed cases versus the locative. The stimulus presented critical concepts that, in the first sentence, either (a) filled one of several semantic cases relative to the main verb or (b) specified the location of the main action. The case-filling frames reflected the linguistic analysis that each semantic case occurs, at most, once in a sentence (Fillmore, 1968). Cases of this sort include the agent, object, instrument, and benefactive (e.g., *brother* in *John gave the books to his BROTHER*).

Location information functions as a semantic case (Fillmore, 1968). However, locatives frequently take the syntactic form of sentence adjuncts rather than the involved roles of their verbs (Lyons, 1977). For example, *The horticulturalist planted trees in the sunny orchard* includes the locative adjunct *in the sunny orchard*. Removing an adjunct from its main sentence does not impact the syntax of that sentence. *The horticulturalist planted trees* is grammatically acceptable[1]. Adjuncts perform an adverbial function, equivalent to individual words such as *there* (*The horticulturalist planted trees THERE*) and *energetically* (Lyons, 1977).

Because of the difference in grammatical expression of locatives versus cases such as object instrument, separate sets of sequences were created for the two. In all instances[2], the

locative information was expressed as a phrase (e.g., *through the grass*), rather than as a single word or a complete clause (Lyons, 1977).

Experiment 1

Experiment 1 used ERP methodology to inspect readers' integration of two-sentence (antecedent-target) sequences. Those sequences contained the relations described earlier as matching, mismatching, general category, and indeterminate. Several features of the experiment were designed to provide new insights into the text-integration processing stages. First, expressing the experimental conditions as two-sentence sequences made it highly likely that the critical antecedent concept remained within the working memory when the target sentence was read. This excluded any need for time-consuming searches of the LTM. Second, the relations between the target and antecedent sentences were more specifically defined than in previous studies containing brief narratives. Third, the significantly larger number of stimuli was intended to minimize between-item variability.

Predictions

Unlike previous research (e.g., Ferretti et al., 2013), it was not predicted that a significant difference would be found at the P2 component between the conditions. This is due to the lack of a factivity manipulation within the current study. Although the definite article does add a certain level of prediction to each sequence, it is not expected to be strong enough to elicit a P2 response. However, for comparison purposes this component will still be analyzed.

For the match, mismatch, and indeterminate conditions it was predicted that a triple dissociation similar to that shown by Ferretti et al. (2013) would be found. This outcome would support and possibly refine their analysis. The general category condition would exhibit an intermediate N400 response, reflecting the need for its integration in the form of anaphoric

resolution. However, it was predicted to elicit no extended N400 response (incongruence) nor an LPC response (updating). It was also possible that, due again to the lack of factivity, there would not be a late positivity for any of the conditions. Without the added impact of *knowing*, the necessity to elaborate and integrate information into the situation model may be diminished. It was generally predicted that the same pattern of responses would be found for both the case-filling and the locative materials. However, it could be argued that the locative is adjunctive information, and therefore it may not be as predictive. If that is the case, it is possible that the case-filling stimuli would lead to stronger differences between the relations than the locative.

Methods

Participants. The participants were 72 right-handed undergraduate students (27 males, 45 females, ages ranging from 17 to 27, M = 19.04) from Wilfrid Laurier University. A total of 81 participants were tested, with nine participants being eliminated due to excessive eye-movements, failure of attention checks (detailed below), incomplete data, or equipment error. All participants had English as their first language and had normal or corrected-to-normal vision. Participants received either partial course credit or monetary compensation.

Materials. The experimental materials were 136 two-sentence sequences[3]. Sixty-eight sequences highlighted critical concepts that filled semantic cases such as object, instrument, and benefactive (Fillmore, 1968). The other 68 sequences focused on locative concepts.

Thirty-two of the semantic-case sequences were based on passages originally examined by O'Brien, Plewes, and Albrecht (1990; see also Ferretti et al., 2008; Singer, 2006). These sequences were derived from antecedent-target sentence pairs embedded in narrative passages of O'Brien et al. One such sequence (the *diver* set) was examined earlier. The remaining 36 semantic-case sequences were newly composed. The locative sequences were also composed for

the purpose of this experiment and were similar in length to the semantic-case sequences. Randomly interspersed throughout the experimental passages were 40 filler sequences to distract participants from the format of the experimental trials.

From these materials, four experimental lists were constructed. In list 1, 17 sequences of each type were randomly assigned to each of the match, mismatch, general category, and indeterminate relations. The sequences were randomly assigned to list position. Each relation was represented approximately equally in each half of the list.

In the remaining lists, the passages were cycled across the four relations following a Latin-square scheme. As a result, each list included an approximately equal number of sequences in each of the eight Relation X Sequence-Type conditions; and each passage occurred once in each of the four Relation conditions. There were four practice sequences before the start of the experimental sequences, which were similar in nature to the experimental trials. Each sequence was two sentences in length with 2000 ms between them. The sentences flashed in the centre of the screen one word at a time (500 ms total, 300 ms/word, 200 ms blank screen).

Procedure. Participants were shown an example of the visual stimuli that would be presented to them throughout the study and were instructed to not blink or move their eyes during the presentation of the stimuli sentences. Each trial began with a "Ready?" screen, and the participants needed to press a button to start the trial. Once the button had been pressed a "+" fixation point appeared for 2000 ms, followed by a blank screen for 500 ms, before the sequence began. To start, participants were presented with four practice trials that were similar in nature to the experimental trials. Two of the practice sequences included yes-no comprehension questions, which were administered throughout the experiment (60 in total, 50% "yes") to ensure participants were reading carefully and act as attention checks. After completing the practice

trials participants were given the opportunity to ask any questions or clarifications of the process and the instructions were reiterated. Participants were informed that they could take a break at any time between trials to rest for brief periods. Each experimental session was no longer than 2 hours, with an approximate average time of 1 hour and 20 minutes.

Recording and analysis. The electroencephalogram (EEG) was recorded with a cap that contained 64 Ag/AgCl electrodes that were distributed across the scalp. A total of 25 electrodes were examined for analysis: prefrontals from left lateral to right lateral (AF3, FP1, FPZ, FP2, AF4), frontals from left lateral to right lateral (F7, F3, FZ, F4, F8), centrals from left lateral to right lateral (T7, C3, CZ, C4, T8), parietals from left lateral to right lateral (P7, P3, PZ, P4, P8), and occipitals from left lateral to right lateral (CB1, O1, OZ, O2, CB2) (Figure 1). Eye-movements and blinks were monitored by placing electrodes on the outer canthii and the left infra and supra orbital ridge of each participant's eye. Electrode impedances were kept below 5 KΩ, and the EEG was processed through a Neuroscan Synamps2 amplifier set at a bandpass of 0.05-100 Hz and digitized at 250 Hz.

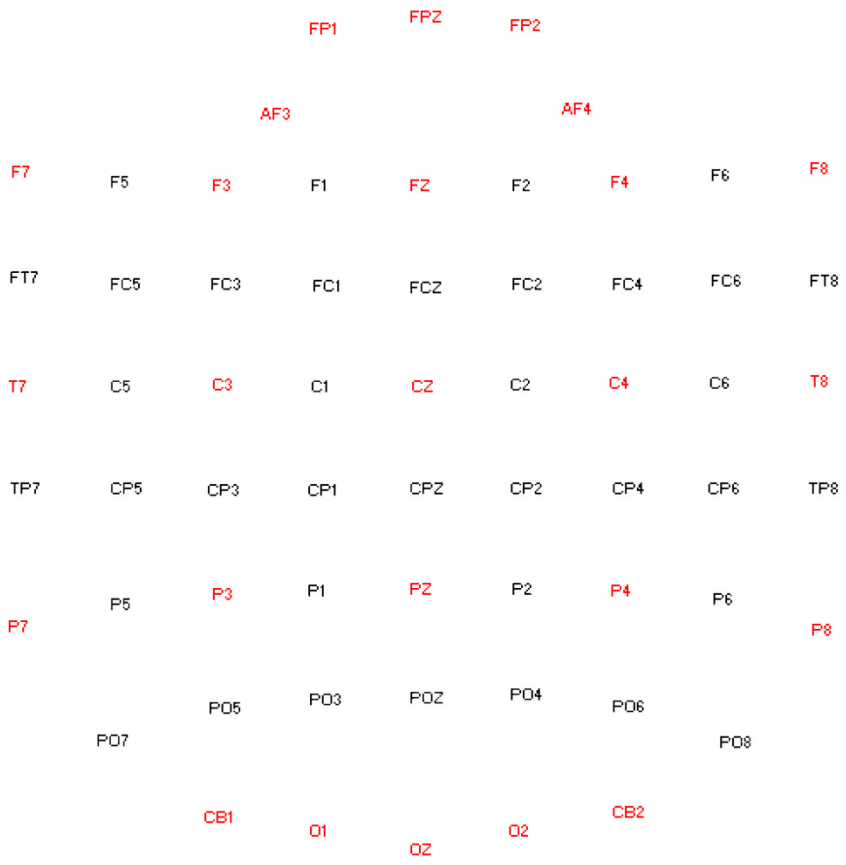

Figure 1. Topographical map of EEG electrodes examined (red) in all ERP experiments of this dissertation.

Design. Separate 4-way ANOVAS were conducted for the mean amplitudes at the P2 region (200-300 ms), N400 (300-500 ms), extended N400 (500-650 ms), and Late Positivity (750-1000 ms). The main variables of interest were Type of Relation (Match, Mismatch, General Category, Indeterminate), Anteriority (prefrontal, frontal, central, parietal, occipital), and Laterality (left lateral, left medial, midline, right medial, right lateral). All these variables were within-participants. Experimental List was a between participant variable that was included to help stabilize variance caused by assigning participants across the four lists (Pollatsek & Well, 1995). Note that the List variable has no theoretical interest and is not discussed in the results presented below. Results for the topographical variables are only discussed when they interacted

with relation type. All *p*-values below are reported after Epsilon correction (Huynh-Felt) for repeated measures with greater than one degree of freedom. All analyses were performed separately for the two different sets of items (semantic-case and locative) but the general pattern of results were similar and there was no effect of set, $F(1, 70) = .17$, $p = .69$. As a result, the two sets were combined to increase statistical power (i.e., 34 versus 17 items per condition). These results are reported below.

Results

The EEG data was re-referenced off-line to the average of the right and left mastoids. A low-pass filter set at 30 Hz was applied to remove high frequency noise. ERPs to the target word in the second sentence were epoched from 100 ms before target to 1000 ms after its onset. All trials contaminated by excessive muscle activity, eye-movements, and blinks were removed before averaging (10.06% of trials). Figure 2 shows the results at the different electrode sites used in the analysis, and Appendix A, Tables 2-6 show the means and results of the ANOVAs.

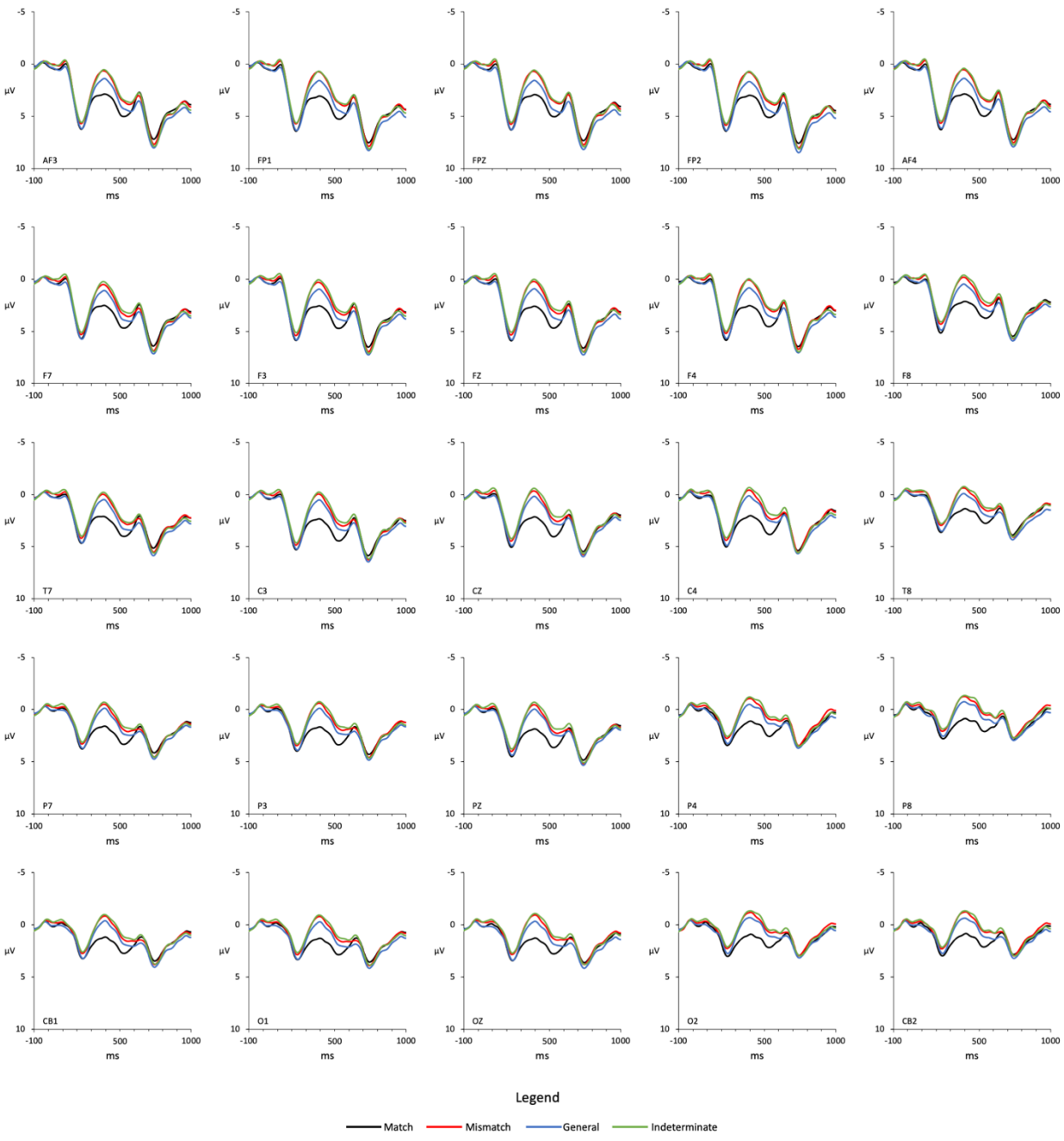

Figure 2. Mean EEG amplitudes at each electrode location for target stimuli following definite articles.

P2 (200-300 ms). In this temporal region, there was a significant main effect of relation, $F(3, 204) = 4.37$, $p < .006$, $\eta_p^2 = .06$. Mean amplitudes to matching targets were significantly more positive ($M = 4.14$ μV) than mismatching ($M = 3.58$ μV), $F(1, 204) = 5.60$, $p < .02$, $\eta_p^2 =$

.03, and indeterminate targets (M = 3.42 μV), $F(1, 204) = 9.40$, $p < .003$, $\eta_p^2 = .04$. Amplitudes for general category targets (M = 4.04 μV) were also more positive than for indeterminate targets (M = 3.42 μV), $F(1, 204) = 6.85$, $p < .02$, $\eta_p^2 = .03$, and mismatching targets (M = 3.58 μV), $F(1, 204) = 3.68$, $p < .06$, $\eta_p^2 = .02$. No other comparisons were marginal or significant.

N400 (300-500 ms). The main effect of relation type was significant, $F(3, 204) = 30.19$, $p < .001$, $\eta_p^2 = .31$. Mean amplitudes to matching targets were significantly more positive (M = 2.34 μV) than general category targets (M = 1.02 μV), $F(1, 204) = 31.59$, $p < .001$, $\eta_p^2 = .13$, mismatching targets (M = 0.48 μV), $F(1, 204) = 62.64$, $p < .001$, $\eta_p^2 = .23$, and indeterminate targets (M = 0.34 μV) $F(1, 204) = 72.78$, $p < .001$, $\eta_p^2 = .26$. Amplitudes for the general category targets were significantly more positive than for the mismatching targets, $F(1, 204) = 5.27$, $p < .03$, $\eta_p^2 = .03$, and indeterminate targets, $F(1, 204) = 8.47$, $p < .005$, $\eta_p^2 = .04$. No other comparisons were marginal or significant.

Extended N400 (500-650 ms). The extended N400 showed a significant main effect of relation, $F(3, 204) = 5.8$, p <.001, $\eta_p^2 = .08$. Amplitudes were significantly more positive for matching (M = 3.08 μV) than mismatching (M = 2.24 μV), $F(1, 204) = 8.24$, $p < .005$, $\eta_p^2 = .04$, and indeterminate targets (M = 1.98 μV), $F(1, 204) = 14.26$, $p < .001$, $\eta_p^2 = .07$. Mean amplitudes for general category targets (M = 2.76 μV) were marginally more positive than mismatching targets, $F(1, 204) = 3.14$, $p < .1$, $\eta_p^2 = .02$, and significantly more positive than indeterminate targets, $F(1, 204) = 7.16$, $p < .01$, $\eta_p^2 = .03$. No other comparisons or main effects were marginal or significant.

Late Positivity (750-1000 ms). In this time frame, mean amplitudes were most positive for the general category targets (M = 3.44 μV) and indeterminate targets (M = 3.12 μV), followed by the matching (M = 3.02 μV) and mismatching (M = 3.00 μV) targets. However, the

main effect of relation did not reach significance, $F(3, 204) = .68$, $p > .57$. No other comparisons or main effects were marginal or significant.

It is important to note that Experiment 1 had a distinct lack of interactions between the relations condition and the topographical variables. This shows that the differences in the ERP components were distributed broadly across the head.

Discussion

It was demonstrated that P2 amplitudes were significantly greater for both matching and categorical targets in comparison to indeterminate and mismatching targets. Although the significant finding was not predicted, the pattern that emerged is not unexpected. The indeterminate items would be less expected by the reader, since a new discourse token is being introduced, and the matching conditions would be the most expected semantically, followed by the general category condition. As the P2 has been shown to be sensitive to semantic expectancy (e.g., Federmeier & Kutas, 2002) and word repetition (Van Petten et al., 1991), the matching and categorical targets showing greater amplitudes during this time frame coincides with previous research. The categorical targets were processed as more "expected" than the mismatching sequences. However, as P2 effects tend to be more frontal/central (e.g., Ferretti et al., 2013), which was not seen in the current experiment. As such, it is believed that this finding is not a genuine P2 but rather the leading edge of the N400, unlike in Van Petten et al. (1991).

The N400 amplitudes showed that the targets in the indeterminate and mismatch conditions had the least semantic congruency with the developing situation model. These results suggest that semantically incorporating a completely new concept with no possible antecedent into a situation model is as difficult as when there is a possible antecedent that mismatches the target conceptually. As expected, the target concepts in the general category and match

conditions were more semantically congruent with the situation model, with greatest congruency found for the match condition. This was expected as it has been shown that words providing a poorer semantic match with antecedents elicit larger N400s relative to words with a better semantic match (Anderson & Holcomb, 2005).

The extended N400 results were the most negative for the indeterminate relations, followed by the mismatching, and then the general category and matching conditions (which did not differ significantly). These findings indicate that the integration costs were highest for the indeterminate condition, when no prior antecedent is presented, and that the matching and underspecified but categorically similar antecedents were equivalent in relation to integration costs. These results aligned with the hypothesized outcome.

The late positivity amplitudes trended towards being the most positive for the general category target concepts and least positive for matching and mismatching target concepts. However, none of the differences between conditions reached significance. Thus, the present study shows no clear differences in situational updating, even though there were clear differences in semantically integrating the targets across conditions. This is not surprising as the stimuli in the present study was not as constraining, and therefore less predictive, than seen in previous research due to factivity not being manipulated (Ferretti et al., 2013).

Experiment 2

The goal of Experiment 2 was to examine *how* readers incorporate the target concepts presented in Experiment 1 into their situation model. The experiment consisted of an online survey that involved a sentence completion task that was based on the sequences from Experiment 1. Experiment 2 was created to provide clarification as to whether people are truly altering their mental representations of the scenario presented to them or if they are simply

incorporating the new information with the old. Previous research has investigated coreferential processing using a similar sentence completion task to analyze behavioural data to complement the ERP results (see Ferretti et al., 2009).

Based on the results of Experiment 1, it was hypothesized that sentence completions for matching and general category sequences would most frequently consider the target to be specifically referring to the same discourse token as the antecedent. For mismatching and indeterminate sequence completions it was predicted that participants' responses would introduce the target token of the second sentence as either a new discourse item or, potentially, as referring to another discourse item introduced in the first sentence that was not the antecedent. Although there was a potential for readers to consider a mismatching target as referring to the same antecedent, given that both are from one type of category and would share a number of features, it was expected that this would be uncommon due to distinctly different targets being presented.

Methods

Participants. The participants were 191 individuals recruited through Amazon Mechanical Turk (MTurk). Seventy-one participants were removed due to not meeting qualifications, poor quality responses, or incomplete data, leaving a total of 120 native-English speaking participants (66 males, 54 females) included in the analysis. The age ranged from 19 to 60 years of age, with an average age of 37.03 years. Monetary compensation was provided upon completion of the experiment.

Materials. This experiment was an online survey created in Qualtrics and posted on MTurk. The survey materials included 176 trials: 40 filler trials and 136 experimental trials. The stimuli were adapted from those used in Experiment 1. From these stimuli, eight experimental

lists were created. The lists were the same as the four lists used in Experiment 1: each split into two lists. This was done to diminish the length of time required by participants to complete the experiment. The average completion time was just under 2 hours per participant. Each experimental item was presented to 20 participants, and they were asked "For each of the following, please write a continuation that you feel makes the second sentence sound the most natural." The participants were provided with the first sentence of the passage, followed by "The" and then the target concept, as shown below.

Dan drove past a bus that had been in a minor accident.

The truck… _____.

The continuations were coded into four response types based on whether the target concepts in participant responses were taken to be:

Coreferential with relevant antecedent: Coreferential with the *relevant* concept/antecedent (i.e., bus) in the first sentence.

Example: Norm was shocked to see that the house had been destroyed by a windstorm. (general category)

The tornadoes… *wreaked havoc throughout town*.

Coreferential with different antecedent: Coreferential with a *different* concept/antecedent in the first sentence.

Example: At night, the sound lulled Jane to sleep. (indeterminate)

The hawk…*screech brought her out of a deep sleep*.

Same event, new discourse token: Associated with the *same event* in the first sentence and incorporated as a *new discourse token*.

Example: The RCMP planned to arrest the politician in the case. (general category)

The senator… *was glad it wasn't him they caught*.

Different event, new discourse token: Associated with a *different event* and incorporated as a *new discourse token*.

Example: The bride danced around the bedroom. (mismatch)

The stage… *had many lights*.

Coding was performed individually by two separate coders, which led to a 79.53% agreement rate. Once individual coding was complete, any differences in coding type were examined and a consensus coding type was decided. These combined results were then normalized before statistical analysis. Of the included participant data, a total of 147 trials (1.35%) were unanswered or rated as unacceptable responses and were excluded.

Design. Separate 2-way ANOVAS were conducted for the mean scores of each coded category (coreferential with relevant antecedent, coreferential with different antecedent, same event, new discourse token, and different event, new discourse token). The main variable of interest was Type of Relation (Match, Mismatch, General Category, Indeterminate). This was a within-participant variable. As in Experiment 1, Experimental List was used as a between participant variable but has no theoretical interest and is not discussed.

Results

See Appendix A, Tables 7-8 for the percentage of completions for each type and the ANOVA results.

Completions coreferential with relevant antecedent. There was a significant main effect of Relation for completion responses that were coreferential with the relevant concept/antecedent in the first sentence, $F(2, 224) = 1574.26$, $p < .001$, $\eta_p^2 = .93$. The mean proportion of completion responses for matching targets were significantly higher ($M = 0.98$)

than for mismatching targets (M = 0.32), F(1, 224) = 2870.70, p < .001, η_p^2 = .93, and general category targets (M = 0.83), F(1, 224) = 152.64, p < .001, η_p^2 = .41. The proportion of completion responses for the general category targets were significantly higher than for the mismatching targets, F(1, 224) = 1699.43, p < .001, η_p^2 = .88. The indeterminate condition was not examined in the coreferential with relevant antecedent analysis because there was no antecedent to refer to in first sentence.

Completions coreferential with different antecedent. There was also a significant main effect of Relation for responses that were coreferential with a different concept/antecedent than the target concept in the first sentence, F(3, 336) = 23.94, p < .001, η_p^2 = .18. The mean proportion of completion responses for mismatching targets was significantly higher (M = .07) than for matching targets (M = .02), F(1, 336) = 70.14, p < .001, η_p^2 = .16, general category targets (M = .04), F(1, 336) = 21.18, p < .001, η_p^2 = .06, and indeterminate targets (M = .036), F(1, 336) = 28.23, p < .001, η_p^2 = .08. The completion responses for general category targets were significantly higher than for the matching targets, F(1, 336) = 14.23, p < .001, η_p^2 = .04 and the proportion of completion responses for the indeterminate targets were also significantly higher than for matching targets, F(1, 336) = 9.38, p < .004, η_p^2 = .03. No other comparisons were significant or marginal.

Completions that refer to same event and add a new discourse token. There was a significant effect of Relation for responses associated with incorporating the target as a new discourse token in the event mentioned in the first sentence, F(2, 224) = 2132.44, p < .001, η_p^2 = .95. The proportion of completion responses for indeterminate targets was significantly higher (M = .87) than for mismatching targets (M = .48), F(1, 224) = 1042.54, p < .001, η_p^2 = .82, and general category targets (M = .07), F(1, 224) = 4264.71, p < .001, η_p^2 = .95. The proportion of

responses for the mismatching targets were significantly higher than for the general category targets, $F(1, 224) = 1090.08$, $p < .001$, $\eta_p^2 = .83$. The matching condition was not examined for this completion type because, although it is possible to take a matching target to be a new discourse token, it was highly unlikely. In the current research such a continuation did not occur.

Completions that refer to different event and add a new discourse token. The completion responses that were associated with a different event and incorporated the target as a new discourse token showed a significant main effect of Relation, $F(3, 336) = 62.94$, $p < .001$, $\eta_p^2 = .36$. The proportion of completion responses for mismatching targets was significantly higher ($M = .14$) than for matching targets ($M = .005$), $F(1, 336) = 178.90$, $p < .001$, $\eta_p^2 = .35$, general category targets ($M = .06$), $F(1, 336) = 57.78$, $p < .001$, $\eta_p^2 = .15$, and indeterminate targets ($M = .09$), $F(1, 336) = 20.88$, $p < .001$, $\eta_p^2 = .06$. The proportion of responses for the indeterminate targets was significantly higher than for the matching targets, $F(1, 336) = 77.55$, $p < .001$, $\eta_p^2 = .19$, and general category targets, $F(1, 336) = 9.19$, $p < .005$, $\eta_p^2 = .03$. The proportion of responses for the general category targets were also significantly higher than those of matching targets, $F(1, 336) = 33.34$, $p < .001$, $\eta_p^2 = .09$.

Discussion

Match. When provided with discourse sentence pairs in which the target item in the second sentence was a complete match to a corresponding item in the first sentence, participants almost always considered the target to refer to the corresponding item. In comparison, few completions contained target items that were coreferential with a different antecedent in the first sentence, and even fewer target items were interpreted as being part of a completely different event with a new discourse token. As expected, these results show that when the key discourse tokens are the same, they are overwhelmingly taken to be the same target, as was hypothesized.

Mismatch. When participants were presented with target items that mismatched the corresponding concept in the first sentence (e.g., bus/truck), the completions revealed much more variation in interpretation. Almost half of the completions included the target item as a new token in the same event. Perhaps most surprising was that almost a third of the completions involved interpreting the mismatching targets as the same concept as the relevant concept in the first sentence (i.e., bus = truck). Even fewer completions involved interpreting the mismatching item as a new token that is also part of a new event, and this occurred approximately twice as often than when they were taken as coreferential with a different antecedent in the first sentence.

The fact that participants most often considered a mismatching token to be a new token within the same event was as expected. However, the percentage of completions whereby the mismatching items was taken as coreferential with the relevant antecedent was surprising. This result may have been due to a number of factors. Participants could be considering the mismatching term as being an error, and that the overall concept of the discourse event was stronger than the response to the individual word. It is also possible that, due to the mismatching concepts still being of the same category, they also contained shared features (e.g., bus and truck both contain the standard features of a vehicle) and as such it is easier to consider them as being the same token rather than adding a new token or searching for another referent. This could also be a result of the "Moses illusion" (i.e., "*How many animals of each sort did Moses put on the Ark?*" when it was Noah who built the Ark), in which something with enough shared or similar features is mistaken as being the same (Erickson & Mattson, 1981; Van Oostendorp & De Mul, 1990). As well, since the target stimuli is preceded by the definite article "the", these results suggest that the definite article, which presupposes a concept exists in the model, is constraining enough that readers are willing to take mismatching concepts with shared features of a target to

be coreferential event even though they are clearly different concepts. Another potential source of this outcome is that it is a result of shallow processing, resulting in a "good enough" representation, in this case showing that deeper processing was not required and therefore not implemented to assess the proper association of the mismatching target (Dwivedi, 2013; Ferreira, 2003).

General Category. Presenting participants with sentences in which the antecedent concept is a general category term that becomes more specific (e.g., vehicle to truck) led to a very high number of completions that had the two concepts as coreferential. This was followed by completions with the target item being considered as completely new, but within the same event, albeit much less frequently. A relatively similar number of completions involved taking the target items to be a new token within a new event. Finally, very few completions had target items that were coreferential with a different concept within the original event. These results were as hypothesized, as it was expected readers would consider the newly presented specific information as being an updated version of the relevant antecedent.

Indeterminate. When the target item was a concept with no relevant antecedent in the first sentence, it was almost always considered to be a new token in the same event. This aligns with our hypothesis, as the sentence pairs were related and having no relevant token for coreference in the first sentence, it was natural for participants to consider a novel concept to be new to the same event, and not referring to a concept in a different event. Finally, the fewest completions involved considering the indeterminate concept as being coreferential with an antecedent in the first sentence.

In summary, when presented with a matching relation, readers were more likely to consider the target to be coreferential with the relevant antecedent. A mismatching token resulted

in the target being considered to be a new token within the pre-existing event for almost half of the completions. Indeterminate targets often led to the being a new token as well, but at a much higher frequency. The general category relation led to relatively similar results as the matching relation, with most completions associating the given token with the relevant antecedent, although significantly less so than the matching condition. On average, it was quite rare for readers to consider any tokens to be entirely unrelated to the current situation/event (but when they did it was most likely to occur in the mismatching and indeterminate relations), and it was even less frequent for a token to be considered as coreferential with a different antecedent in the first sentence. All the off-line sentence continuation results provide insight into the ERP results from Experiment 1. These relationships are further explored in the General Discussion.

General Discussion

The results of the current research extend previous research in several ways. First, the results examined the different components known to be related to referential processing costs under four different referential contexts (match, mismatch, general category, and indeterminate). These four types of relations have been examined in the past (e.g., Cook, Myers, & O'Brien, 2005; Ferretti et al., 2008, 2013; Singer, 2006, 2009), but never together in one study. Second, this research examined these relations in sequences of only two sentences. This allowed the critical antecedent concept to reside in working memory when the target sentence was read and avoid the necessity for searches of LTM. As such, it was possible to directly contrast relative referential integration cost for different types of situation model updating. Third, the sentence completion task provided insight into how readers incorporate discourse concepts into their situation model as the degree of "match" with potential antecedents varied.

It was not hypothesized that a significant effect of the P2 would be found between relations. Contradictory to this, such an effect was present. However, as was previously discussed, it is most likely that this finding is simply a leading edge of the N400 response and not a true P2. Previous research has shown that the P2 effects are often more frontal and central topographically (e.g., Ferretti et al., 2013) and no interaction with the topographical areas was found in this research.

As hypothesized, the N400 amplitudes indicated that the indeterminate and mismatch target conditions were the most difficult to integrate into the situation model, followed by the general category condition and then the match condition, aligning with previous research that found new information elicited greater N400 amplitudes than previously provided information (Burkhardt, 2006) and that mismatching stimuli elicited more negative N400 responses than both matching and indeterminate targets (Ferretti et al., 2013). The N400 amplitudes also showed that the indeterminate and mismatch conditions were equally difficult to semantically integrate into the situation model. These findings suggest that incorporating a completely new concept (with no relevant antecedent) into a situation model is as difficult as when there is a relevant antecedent, but it mismatches the target conceptually. It may have been expected for the mismatching target to be easier to integrate than an indeterminate one, however the indeterminate condition has the least constraining context because no exemplar or general term is provided. The target may still be inferred and elaborated in the situation model, but this is less likely to occur or be more variable across the contexts.

The results of the sentence completion task revealed that participants almost always incorporated the matching target as coreferential with the same concept in the first sentence. This was expected, as participants were presented with two identical terms. This result aligned with

the ERP results in Experiment 1, in which the P2, N400, and extended N400 results reflected that the matching relations had the least cost of referential integration.

Approximately half of all completions with mismatching targets involved incorporating the target into the same event as the first sentence, but as a new token in the situation model. This indicates that when provided with inconsistent target information, half of the time participants incorporated the new token as being involved in the same event previously described, thus indicating an update of their current situation model. However, despite being a different concept than the relevant antecedent in the first sentence, approximately a third of completions were coreferential with the antecedent. This shows that the use of the definite article "the" is constraining enough, and the features of the mismatching antecedent and targets overlap enough, that at times people are willing to take the concepts as coreferential. To further understand these findings, the extended N400 results are examined. In the present research, the extended N400 effect to the mismatching items is at least partially due to ambiguity caused by the targets having features that clearly overlap and do not overlap with the antecedent. Resolving this ambiguity would lead to adding the target as a new token in the situation model in some cases and lead to coreference with the antecedent at other times (as illustrated by the completion data). The fact that sometimes readers are treating these targets like a new token and sometimes as the same token could have impacted why no clear late positivity effects were found, although it was not expected that such an effect would occur anyway.

The completions for the general category targets typically involved considering the targets as coreferential with the relevant antecedent in the first sentence, although less than was found for the matching condition. According to the informational load hypothesis, sometimes people will consider a target word as a new discourse token in situations when the antecedent is

more general than the anaphor (The *bird* laid an egg. The *robin* sat on the egg until it hatched.) – but not when the antecedent is specific, and the anaphor is general (The *robin* laid an egg. The *bird* sat on the egg until it hatched. Traxler, 2012, p. 259). However, this can be ruled out in the present research, as the completion results suggest that people treated the target as a new discourse token only approximately 14% of the time. The general category target most frequently being considered coreferential with the relevant antecedent (but less so than matching concepts) also aligns with the N400 findings of Experiment 1 that showed a greater negativity for the general category than matching targets, indicating the integration cost of going from a general concept to a specific target, but still had more conceptual congruency than the mismatching targets.

When no prior concept was presented (indeterminate), participants typically incorporated the target items as a new concept in the event described in the first sentence. It was expected that the indeterminate condition would produce considerable integration costs due to the lack of a relevant concept in the first sentence. The very low portion of completions to different antecedents in the first sentence for indeterminate targets confirm this hypothesis. As such, the integration costs likely come from the process of adding a new token to the situation model (as suggested by the completions to be the most common outcome), and this cost is reflected in the amplitudes of the N400 and extended N400 regions.

Conclusion

The present investigation provided both electrophysiological and behavioural evidence of the processes involved in conceptual integration and situation model updating. Several key findings were established in these experiments: the definite article provides enough “certainty” to a token’s degree of matching with an antecedent to show influences as early as 100-200 ms

following the target onset. Sentence completion and ERP results (P2, N400, Extended N400) reflected that the matching relations had the least cost of referential integration, and that indeterminate and mismatching were the costliest. This is due to the indeterminate targets requiring the addition of a new item into the situation model, and the mismatching having a certain amount of ambiguity to process as a result of shared, but not identical, features with the antecedent. A general category term is most likely to be considered coreferential with a provided antecedent, rather than a new discourse token, and therefore requires less integration cost. In conclusion, this research has built upon the previous research of situation model updating (Ferretti et al., 2013; Singer, 2006; Zwaan & Madden, 2004) and provided a baseline of the neurological correlates involved in updating situation models during short discourse processing, as well as insight into how comprehenders actually integrate these different types of relational targets into the situation model.

Chapter 2 Footnotes

1. In contrast, deleting the locative "complement" *in the park* from *The parade was in the park* leaves the ungrammatical **The parade was in*.
2. Three sequences were removed after testing and before the analyses due to improper formatting. Sentence two did not start with *The item* and instead the key term was the first word of sentence two.
3. In one of the locative items the actual location was the object of the verb (*The maid vacuumed the condo*).

Chapter 3: Indefinite Articles and the Electrophysiological Correlates of Text Integration

Chapter 2 investigated the electrophysiological response generated to discourse concepts that covaried semantically (repetition to no semantic overlap) with concepts that already existed in the situation model. Furthermore, these concepts were always introduced in a manner that implied the concepts already existed in the situation model by the use of the definite article "the" (Haviland & Clark, 1974; Singer, 1976). These results revealed the relative ease/difficulty of integrating the target concepts up to the first 1000 ms after their onset. Additionally, a sentence completion task was implemented that provided insight into how people incorporated the discourse concepts into the models. The research in Chapter 3 extends these results by examining how people integrate the same concepts into situation models when they are introduced with indefinite articles (*a/an*) that are typically used to introduce new discourse referents (Anderson & Holcomb, 2005; Kidd & Bavin, 2007; Murphy, 1984).

Previous ERP research has investigated the impact of the use of a definite versus indefinite article during discourse processing. For example, Anderson and Holcomb (2005) presented participants with two-sentence passages in which the target nouns were preceded by a definite (*The*) or indefinite (*A*) article. The first sentence contained either the same word or a synonym of the target word that appeared in the second sentence (e.g., Tony patched up the rip/tear in the sail. The/A rip was found.). The results showed that although there were differences in the ERP components elicited to the articles themselves, the different articles had no impact on the magnitude of the N400 difference for nouns that were repeated versus synonyms (i.e., synonyms were more negative than repetitions to some degree). However, there was a difference in the left anterior negativity/LAN (300-600 ms) elicited to nouns that followed the definite article. The authors suggested that this LAN could reflect an increase in working

memory load from participants taking the nouns as coreferential with the relevant nouns in the first sentence. Evidence that people had more difficulty integrating the content in the second sentence following the indefinite article was found at the final word of those sentences. At this word, the N400 (and extended N400) were more negative when sentences began with the indefinite article versus definite article. Note that similar to the late positivity results reported in Chapter 2, Anderson and Holcomb (2005) found no differences in late positive potentials as a function of semantic match (repetitions versus synonyms) or type of article.

The results of Anderson and Holcomb (2005) suggest that in the present research it may be expected that a similar pattern of N400 responses to the match (i.e., repeated) and general category conditions as seen in Chapter 2, that included the definite article "*the*", will emerge. However, because their study only examined repeated nouns and synonyms, it is not clear how using an indefinite article will influence the relative ease/difficulty of integrating mismatching concepts (e.g., bus/truck) or completely novel concepts into situation models. As well, it is unclear if the general category will be treated the same as a synonym. Synonyms have much more semantic overlap than the stimuli presented in the general category condition of the current research.

In a more recent ERP study, Calloway and Perfetti (2020) also examined ERPs to investigate the definite article (*the*) and indefinite article (*a/an*) as a cue for integration. Critical sentences began with one of the articles which was then followed by a repeated noun from a preceding sentence, or a novel noun. The results showed that repeated nouns elicited a smaller N400 response than novel nouns. It was also found that when nouns were preceded by the definite article, an early frontal LPC was produced compared to nouns that followed an indefinite article (Calloway & Perfetti, 2020). When examining the article effects, it was shown that after a

definite article all nouns elicited a less negative N400 response than the nouns that were preceded by an indefinite article. This finding was contradictory of previous research (Anderson & Holcomb, 2005), however, as this result was seen across both repeated and novel nouns it was suggested that there is a distinction between integration process, triggered by the definite article (*the*), and a structure building process, triggered by the indefinite article (*a/an*) (Calloway & Perfetti, 2020). These findings provide evidence that readers are sensitive to grammatical cues, such as definite or indefinite articles, for coreferential integration.

The discussion above shows that ERP research on the differences between integrating discourse concepts that follow indefinite and definite articles is limited. Furthermore, there has been no research that has contrasted how mismatching and indeterminate concepts are integrated following the indefinite article. Thus, the present research investigates matching, mismatching, general category, and indeterminate relations when they follow indefinite articles. Previous research has shown differences to the lexical response to the articles themselves, which makes it difficult to contrast the brain potentials that follow the different articles. For this reason, it is better to investigate the integration of the different concepts separately for the indefinite articles. Directly contrasting the articles within the same study would also lead to much smaller number of items per condition, thereby significantly lowering statistical power, or to a significant increase to the time of the study, leading to poor data from participant fatigue. However, the definite article results from Chapter 2 and indefinite article results from the current chapter will be directly compared at the end of this chapter, following the presentation of the results.

Experiment 3

As in Chapter 2, the present experiment used ERP methodology to inspect readers' integration of two-sentence (antecedent-target) sequences. The sequences used were identical to

the sequences used in Experiment 1, with the exception that an indefinite article (*a/an*) preceded the critical concept in the second sentence.

The predictions for this study are based on the results of Experiment 1 and on previous research that has examined the indefinite article *a/an*. For the present research it was predicted that no significant P2 amplitudes would be found. When the indefinite article was used the context becomes less predictive, and therefore unlikely to elicit a P2, and although Experiment 1 did see a P2 response, it is believed to have only been a leading edge of the N400. It was expected that the N400 results would show a more negative response for the mismatch relations, followed by the indeterminate, general category, and then match relations. However, it was predicted that these differences would be less prominent than those found in Experiment 1 (see Anderson & Holcomb, 2005).

The definite article results from Experiment 1 showed that, at the N400, targets in the indeterminate and general category conditions had the least semantic congruency with evolving situation models. It is expected in this experiment that overall, there will be less negativity during the N400, as the lower level of constraint induced by the indefinite article will allow for less perceived incongruency amongst all target relations. However, a similar pattern is still expected to emerge between the four relations as previous research has indicated that article type may not actually influence the effect of the relations (Anderson & Holcomb, 2005).

For the extended N400 it was predicted that the mismatch would result in the highest cost of integration, rather than the indeterminate condition as when the definite article is used. This is because the indefinite article eliminates the presupposition of the existence of the target, and therefore when indeterminate condition would no longer induce the same amount of conflict and

required resolution. Instead, the mismatching targets, although still requiring less integration cost on average, would still have the potential of being conflicting with the provided antecedent.

As there were no significant results found for the LPC in Experiment 1 or other research (e.g., Ferretti et al., 2013), it is not expected that any significant findings will emerge.

Methods

Participants. Seventy-three right-handed undergraduate students participated in the study for course credit or monetary compensation. A total of 13 were eliminated due to excessive eye-movements, failure of attention checks, incomplete data, or equipment error, leaving 60 participants (15 males, 45 females, ages ranging from 18 to 23, M = 18.52) included in the analysis. All participants had English as their first language and had normal, or corrected-to-normal, vision.

Materials. The experimental materials were the same 136 two-sentence sequences applied in Experiment 1, with the second sentence of each trial adjusted to use the indefinite article.

Procedure. Participants were shown an example of the visual stimuli that would be presented to them throughout the study and were instructed to not blink or move their eyes during the presentation of the stimuli sentences. They were instructed to press a button to start the trial. Following the button press, a "+" fixation point appeared for 2000 ms, followed by a blank screen for 500 ms, before the sequence began. Participants first received four practice trials that were similar in nature to the experimental trials. Two of the practice sequences included yes-no comprehension questions, which were administered throughout the experiment (60 in total, 50% "yes") to ensure participants were reading carefully. After completing the practice trials participants were given the opportunity to ask any questions or clarifications of the process and

the instructions were reiterated. Randomly interspersed throughout the experimental passages were 40 filler sequences to distract participants from the format of the experimental trials. Participants were informed that they could take a break at any time between trials to rest for brief periods. Each experimental session was no longer than 1 hour and 30 minutes, with an approximate average time of 1 hour and 15 minutes.

Recording and Analysis. The electroencephalogram (EEG) was recorded with a cap that contained 64 Ag/AgCl electrodes that were distributed across the scalp. The same 25 electrodes examined for analysis in Experiment 1 were used (Figure 1). Eye-movements and blinks were monitored by placing electrodes on the outer canthii and the left infra and supra orbital ridge of each participant's eye. Electrode impedances were kept below 5 KΩ, and the EEG was processed through a Neuroscan Synamps2 amplifier set at a bandpass of 0.05-100 Hz and digitized at 250 Hz.

Design. The main variables of interest were type of Relation (Match, Mismatch, General Category, Indeterminate), Anteriority (Prefrontal, Frontal, Central, Parietal, Occipital), and Laterality (Left Lateral, Left Medial, Midline, Right Medial, Right Lateral), each of which was a within-participant variable. Experimental List was a between participant variable that was included to help stabilize variance caused by assigning participants across the four lists (Pollatsek & Well, 1995). The List variable has no theoretical interest and is not discussed in the results presented here. Results for the topographical variables are only discussed when they interacted with relation type. All *p*-values below are reported after Epsilon correction (Huynh-Felt) for repeated measures with greater than one degree of freedom.

Results

The EEG data were re-referenced off-line to the average of the right and left mastoids. A low-pass filter set at 30 Hz was applied to remove high frequency noise. ERPs to the target word in the second sentence were epoched from 100 ms before target to 1000 ms after its onset. All trials contaminated by excessive muscle activity, eye-movements, and blinks were removed before averaging (22.13% of trials). Figure 3 shows the results at the different electrode sites used in the analysis, and Appendix B, Tables 9-13 show the means and list the results of the ANOVAs.

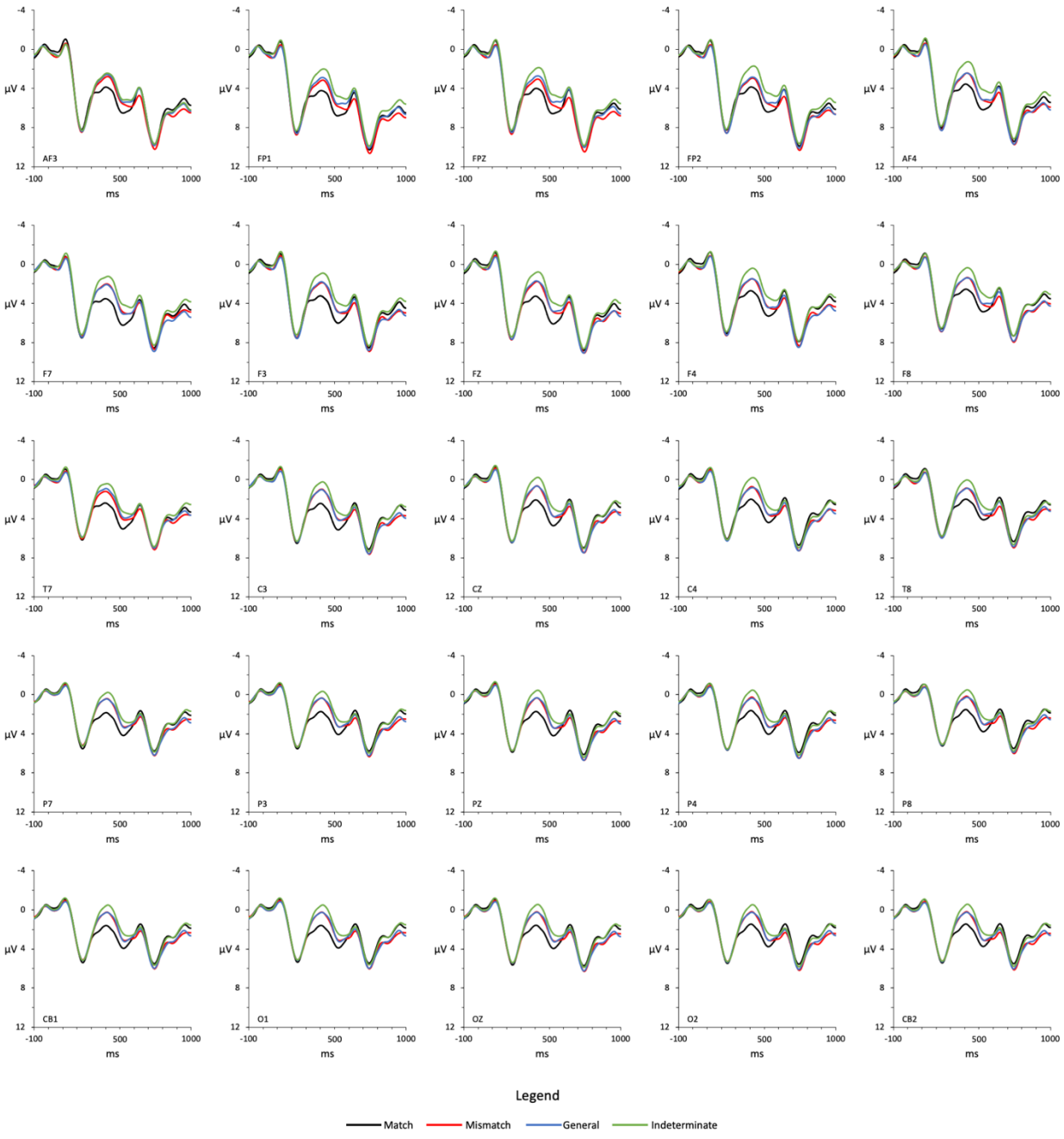

Figure 3. Mean EEG amplitudes at each electrode location for target stimuli following indefinite articles.

P2 (200-300 ms). There were no significant or marginal effects in this temporal region.

N400 (300-500 ms). The main effect of Relation was significant, $F(2, 168) = 13.57$, $p < .001$, $\eta_p^2 = .20$. Mean amplitudes to indeterminate ($M = 1.25$ μV) targets produced significantly

more negative responses than the matching (M = 3.06 μV), F(1, 168) = 39.36, p < .001, η_p^2 = .19, mismatching (M = 2.01 μV), F(1, 168) = 6.58, p < .02, η_p^2 = .04, and general category (M = 1.9 μV) targets, F(1, 168) = 4.69, p < .04, η_p^2 = .03. Amplitudes to the mismatching targets were also more negative than for the matching amplitudes, F(1, 168) = 13.75, p < .001, η_p^2 = .08. Amplitudes to the general category were significantly more negative than the amplitudes of the matching targets, F(1, 168) = 16.89, p < .001, η_p^2 = .09. No other comparisons were marginal or significant.

Extended N400 (500-650 ms). There was a significant main effect of Relation, F(2, 168) = 15.76, p < .001, η_p^2 = .22. Amplitudes were more positive for the matching (M = 4.03 μV) than general category targets (M = 1.90 μV), F(1, 168) = 37.75, p < .001, η_p^2 = .18, and indeterminate targets (M = 3.16 μV), F(1, 168) = 5.71, p < .02, η_p^2 = .03. Mean amplitudes for mismatching targets (M = 3.87 μV) were more positive than for general category targets, F(1, 168) = 32.89, p < .001, η_p^2 = .16, and indeterminate targets, F(1, 168) = 3.92, p < .05, η_p^2 = .02. The indeterminate amplitudes were also more positive than for the general category targets, F(1, 168) = 14.1, p < .001, η_p^2 = .08.

The interaction of Relation and Anteriority was significant, F(12, 672) = 58.26, p < .04, η_p^2 = .04. At all electrode sites the match targets produced significantly more positive mean amplitudes than the general category and Indeterminate targets (all p's < .001), but not the mismatch targets (with the exception of the frontal electrodes, p < .04). The mismatch targets had significantly more positive mean amplitudes than the general category and indeterminate targets at all electrode sites (all p's < .003). The indeterminate relations had significantly more positive mean amplitudes at all electrode sites than the general category relations (all p's < .001).

Late Positivity (750-1000 ms). In this time region, the mismatch condition (M = 2.38 μV) was marginally more positive than the indeterminate condition (M = 2.13 μV), $F(1, 168) = 3.07$, $p < .09$, $\eta_p^2 = .02$, but the main effect of Relation did not reach significance. All other effects were not significant or marginal.

Discussion

The main goal of this experiment was to contrast each of the relations when targets were modified by an indefinite article instead of a definite article. It was expected that the indefinite article would lead to less pronounced differences between the relation types than was seen in Experiment 1, as the less constraining context allows for more fluid interpretation by the reader, and therefore less effort of processing and integration.

The P2 component differs as a function of semantic expectancies (Federmeier et al., 2005; Ferretti, Kutas, & McRae, 2007) and can be influenced by the repetition of words (Van Petten et al., 1991). Although a P2 effect was found in the previous chapter (with amplitudes being significantly greater for both matching and categorical targets, compared to indeterminate and mismatching targets), it was likely simply a leading edge of the N400. That effect of the definite article was most likely due to it being more constraining but was still not a true P2. In the present experiment there was no significant P2 results. Still, it is clear that the indefinite article greatly reduced the impact of the semantic expectancy on these relations within the discourse, due to the indefinite articles tendency to be used to introduce new referents (Kidd & Bavin, 2007) and providing less constraint. Thus, the N400 effect did not have such an early leading edge when the indefinite article was utilized.

For this experiment it had been predicted that the N400 would produce a more negative amplitude for the mismatch relations, followed by the indeterminate, general category, and

match relations (similar to Anderson & Holcomb, 2005), as previous research has shown that integrating plausible novel information is easier than reconciling information contradictory to antecedents (Schroeder et al., 2008; Singer, 2009). However, it was expected that these differences would be less pronounced than those found in Experiment 1 as definite articles lead to the presumption that the target already exists in certain form whereas indefinite articles lead to readers being more open to a mismatch, as they are used to introduce new token (Kidd & Bavin, 2007). The N400 results showed a significant main effect of Relation, with novel target items not previously seen in the sequence producing the most negative N400, followed by general category concepts, those that mismatched the original target concept, and then target concepts that matched that of the initial sentence. These findings indicate that when presented with an indefinite article, targets in the indeterminate condition had the least semantic congruency with developing situation models. This is in comparison to when a definite article was used in Experiment 1, in which case the mismatch and the indeterminate conditions were equally incongruent. As there was no antecedent of the target concept in the indeterminate relation conditions, this is an unsurprising result. It is also the most ambiguous condition when the indefinite article is applied, as it becomes more likely to be part of a new event/model while still fitting with the previous model. As well, since the N400 provides a measure of semantic congruency and expectancy (Kutas & Hillyard, 1980) and an entirely new key item introduced into the discourse should produce a strong N400 effect. The mismatching relations being less incongruent than the indeterminate when an indefinite article is applied is a likely indication that the effect of the mismatch between the target and antecedent is mitigated by the more “open” nature of the indefinite article, leading to minimal priming for the mismatch condition. As it is

not implying a specific, pre-existing concept is being referred to, participants are more able to interpret it in whichever manner is easiest to process.

The extended N400 results showed the most negative amplitude was provoked by the general category relation, followed by the indeterminate, mismatch, and then match. Since the extended N400 reflects continuation of integration cost for highly unexpected words (Burkhardt, 2006; Ferretti et al., 2008), this could imply that the indefinite article is lowering the expectancy of the category referents, as it is more ambiguous, and less obvious to be referring to that same, specific concept. This would lead these general category relations to require more costly integration into the situation model, more so even than the indeterminate and mismatching items, which, as was previously discussed become more acceptable to add or revise in the current model due to the indefinite article.

The LPC, which acts as an indication of the cost of updating information into the current discourse model (Burkhardt, 2005, 2006; Ferretti et al., 2008) and shows the elaboration and integration of text with information from the LTM (Van Petten & Luka, 2012), was not expected to show any significant findings. Although in Experiment 1 it was seen that general category discourse information was slightly more likely to produce an LPC than the other relations when a definite article was employed, no significant results were found. In the current experiment the main effect of relation did not reach significance at the LPC, as was expected, but the results showed that when presented with an indefinite article there was a marginal effect where mismatching targets led to more positivity than indeterminate targets. This is interesting as both targets present novel information, but in the mismatching condition there seems to be more situation model updating occurring.

It has now been seen that the indeterminate condition has the most negative N400, extended N400, and LPC. Together, it appears that readers struggle more with the indeterminate target and making it fit the situation model than the mismatching target – but only following indefinite articles.

Experiment 4

Experiment 4 was performed to gain insight into *how* readers incorporate the target concepts presented in Experiment 3 into their situation model. As in Experiment 2, the present online survey involved a sentence completion task that assessed the different ways that specific target/antecedent relationships influence the construction of situation models. Importantly, the current study will also provide additional insight into how differences between indefinite and definite articles influence the contents of situation models.

Based on the results of Experiment 3, it was hypothesized that sentence completions for match and general category sequences would consider the target word to refer to the same token as the antecedent in sentence one, albeit to various degrees. Matching relations involve identical concepts, and this is expected to lead to the most completions whereby the target is considered the same token as the antecedent concept in the first sentence. The general category predictions are based on the LPC results of Experiment 3, as these relations were found to be updated more frequently in the situation model. The mismatching completions are expected to be a mix of the target being considered the same token and a new token in the event. The nature of mismatching concepts means they can be interpreted as the same token due to feature overlap, however they will also have features that do not directly match the antecedent. As such, they may be equally likely to be taken as a same or a new token. For indeterminate sequence completions it was

predicted that participants' responses would either introduce the token as a new concept into the same scenario as provided or would introduce both a new token and new scenario entirely.

Methods

Participants. One-hundred and sixty-nine participants were recruited through Amazon Mechanical Turk (MTurk). Forty-nine participants were removed because they did not have English as their native language, were outside the age range, had poor quality responses, or had incomplete data. The results presented below are based on the remaining 120 individuals (45 males, 75 females). The age ranged from 19 to 60 years of age, with an average age of 37.01 years. Monetary compensation was provided upon completion of the experiment.

Materials. The online survey was created in Qualtrics and posted on MTurk. The survey materials included 176 trials, 40 filler trials and 136 experimental trials. The stimuli were adapted from those used in Experiment 3. Eight experimental lists were created, and these included the four lists used in Experiment 3, each split further into two lists. This was done to diminish the length of time required by participants to complete the experiment and to ensure comparability with Experiment 2. As with that experiment, the average completion time was just under 2 hours per participant. Each experimental item was presented to 16 participants, and they were asked "For each of the following, please write a continuation that you feel makes the second sentence sound the most natural." The participants were provided with the first sentence of the passage, followed by "A" or "An" (as grammatically appropriate) and then the target concept, as shown below.

Jerry used the hammer to repair the windowsill.

A wrench… _____.

The continuations were coded into the same four response types used in Experiment 2, which are based on whether the target concepts in participant responses were taken to be:

Coreferential with relevant antecedent: Coreferential with the relevant concept/antecedent (i.e., hammer) in the first sentence.

Coreferential with different antecedent: Coreferential with a different concept/antecedent in the first sentence.

Same event, new discourse token: Associated with the *same event* in the first sentence and incorporated as a *new discourse token*.

Different event, new discourse token: Associated with a *different event* and incorporated as a *new discourse token*.

Coding was performed individually by three separate coders. Once individual coding was complete, any differences in type were examined. When all coders had chosen the same condition for a trial then that coding was automatically assigned, which occurred in a total of 32.29% of trials. If two of the three coders had separately agreed on a type, then that was the coding assigned. This occurred in 56.37% of trials. If all three responses were different, then the item was further examined, and a consensus coding type was decided (11.25% of trials). These combined results were then normalized before statistical analysis. Of the included participant data, a total of 127 trials (1.48%) were unanswered or rated as unacceptable responses and were excluded.

Design. Separate 2-way ANOVAS were conducted for the mean scores of each coded category (coreferential with relevant antecedent, coreferential with different antecedent, same event, new discourse token, and different event, new discourse token). The main variable of interest was Type of Relation (Match, Mismatch, General Category, Indeterminate). This was a

within-participant variable. As in Experiment 3, Experimental List was used as a between participant variable but has no theoretical interest and is not discussed. All *p*-values below are reported after Epsilon correction (Huynh-Felt) for repeated measures with greater than one degree of freedom.

Results

The percentage of completions for each response type and the ANOVA results are shown in Appendix B, Tables 14-15.

Completions coreferential with relevant antecedent. There was a significant main effect of Relation for responses that were coreferential with the relevant concept/antecedent in the first sentence, $F(2, 224) = 588.01$, $p < .001$, $\eta_p^2 = .84$. The proportion of these completions for matching targets were significantly higher ($M = .80$) than for mismatching targets ($M = .27$), $F(1, 224) = 1152.24$, $p < .001$, $\eta_p^2 = .84$, and general category targets ($M = .60$), $F(1, 224) = 162.54$, $p < .001$, $\eta_p^2 = .42$. The completions for the general category targets were significantly higher than for the mismatching targets, $F(1, 224) = 449.26$, $p < .001$, $\eta_p^2 = .67$. No other comparisons were significant or marginal. The indeterminate condition was not examined in the coreferential with relevant antecedent analysis because the relevant antecedent was not provided in this condition.

Completions coreferential with different antecedent. There was a significant main effect of Relation for completions that were coreferential with a different antecedent in the event described in the first sentence, $F(3, 336) = 16.17$, $p < .001$, $\eta_p^2 = .13$. Mismatching targets ($M = .07$) were significantly more likely to lead to such completions than general category ($M = .039$), $F(1, 360) = 17.29$, $p < .001$, $\eta_p^2 = .05$, matching ($M = .038$), $F(1, 336) = 18.89$, $p < .001$, $\eta_p^2 = .05$, and indeterminate ($M = .02$) targets, $F(1, 336) = 47.12$, $p < .001$, $\eta_p^2 = .12$. General category

relations were more significant than indeterminate, $F(1, 336) = 7.32$, $p < .01$, $\eta_p^2 = .02$. Matching relations led to significantly more of this type of completion than indeterminate relations, $F(1, 336) = 6.34$, $p < .02$, $\eta_p^2 = .02$. No other comparisons were marginal or significant.

Completions that refer to same event and add a new discourse token. There was a significant main effect of Relation for completion responses that included targets interpreted as a new token in the same event, $F(2, 224) = 668.04$, $p < .001$, $\eta_p^2 = .86$. Indeterminate relations ($M = .82$) were more likely to lead to this outcome than both mismatch ($M = .49$), $F(1, 224) = 374.48$, $p < .001$, $\eta_p^2 = .63$, and general category relations ($M = .20$), $F(1, 224) = 1334.50$, $p < .001$, $\eta_p^2 = .86$. The mismatching targets led to these completions more often than the general category targets, $F(1, 224) = 295.13$, $p < .001$, $\eta_p^2 = .57$. The matching condition was not examined in this analysis as, although it is possible to take a matching target to be a new discourse token, it was highly unlikely. In the current research such a continuation did not occur.

Completions that refer to different event and add a new discourse token. No comparisons were marginal or significant. There was a slightly higher of more responses of this type for mismatching ($M = .17$), followed by matching ($M = .163$), general category ($M = .161$), and then indeterminate ($M = .157$) relations.

Discussion

Match. It was hypothesized that sentence completions for match sequences would most often consider the target to be coreferential with the relevant antecedent in the first sentence. The results showed that, when presented with a matching antecedent-referent relation, participants incorporated the target concept as coreferential with the same concept in the first sentence the majority of the time when an indefinite article preceded the target concept. As the ERP results of Experiment 3 showed during the extended N400, the matching targets were significantly more

positive than the general and indeterminate conditions but did not differ significantly from the mismatching condition. Together these results indicate that the matching referent is not as obviously coreferential to the antecedent to readers, and in fact may be interpreted in a number of different ways, affecting the potential integration costs.

Mismatch. It was predicted that when presented with the mismatching relation the responses could equally be to consider the referent to be coreferential with the antecedent or as a new discourse token within the event, based on the LPC results of Experiment 3 which showed a trend in the means that those relations may be updated more frequently into the situation model. For the mismatching target, the majority of responses considered the target concept to be a new discourse token within the already existing event. Slightly less than one-third of responses considered the target to be co-referential with the relevant antecedent. It was also found that, when presented with an indefinite article, the mismatching concept was found to be considered a new token and a new event more than 17% of the time.

These findings support the ERP findings of Experiment 3, which showed that the mismatch relations did not produce the largest N400, indicating that when an indefinite article is employed the incongruency of the mismatching item is lessened. This may be due to the indefinite article leading participants to start a structure building process, as shown by Calloway and Perfetti (2020), rather than attempting to integrate it as the same discourse token. The LPC results, which showed that mismatch relations required the highest cost of updating, also back up this idea. If the token is taken to be an entirely new object, it must be added to the current, ongoing situation model, and this comes with a cost.

General Category. Similar to the matching sequences, it was expected that the general category targets would be considered to be coreferential with the relevant antecedent in the first

sentence most frequently, although less so. It was found that when an indefinite article preceded a discourse token that was in the general category of the relevant antecedent, participants typically produced continuations that were coreferential with the relevant antecedent in the first sentence, but almost 20% considered the general category target to be a new token being added to the existing event. The extended N400 results showed that the general category relations were most difficult of all the conditions to integrate into the situation model, which was supported by the completions results, as considering the target to be coreferential with the general category antecedent requires reconciliation of the two targets into one.

Indeterminate. When an indeterminate referent was presented, it was expected that participants would either introduce the token as a new concept into the existing event, or they would introduce the new token into a new event. The results showed that when an indeterminate relation between the relevant antecedent and the target token followed an indefinite article, the majority of continuations incorporated the target concepts as a new concept in the event described in the prior sentence. As the indeterminate token is novel to the discourse, the fact that it was considered to be a new token in the same event is unsurprising. However, over 15% of completions considered the indeterminate relation of the antecedent and referent to indicate that the target token was actually part of an entirely new event. This was likely affected by the indefinite article, as it does not enforce a high level of constraint on the context, and it may have made it easier to imagine it to be unrelated entirely to the current situation model being constructed. These results are supported by the N400 results, as the same trend in processing was found, with the indeterminate condition producing the largest N400 response. As Strohner et al. (2000) showed that establishing the semantic relations was integral to resolution of ambiguous

references, perhaps this finding should not have been unexpected, given that the indeterminate condition provides the most ambiguous relation, with no prior antecedent.

Overall, these sentence completion results provided insight into how readers incorporated discourse concepts into their situation model as the degree of "match" with potential antecedents varied. In general, it was found that the indefinite article leads to a slightly increased level of variability in how concepts are integrated into the situation model.

Definite vs. Indefinite Article

In the following section, the results of the experiments with the definite article in Chapter 2 were directly compared to the present results with the indefinite article in an ANOVA. These analyses for the ERP and sentence completion data were identical to the analyses reported in Chapter 2, with the exception that Article Type was added as a between-participant variable. The main theoretical interest in this analysis is the interaction between Article Type and Relation Type. Interactions with topographical variables (i.e., Anteriority, Laterality) are only discussed if they involve both Article Type and Relation Type.

The present findings show main effects of Article. The most likely explanation for this effect is that each between-participant/group went through its own analysis with their own baseline, which happened to be more positive for the group in the indefinite experiment than for the definite experiment group. As a result, this discussion will not go into detail on the main effects of Article in between analysis in the ERP data (because they are uninterpretable) and will focus on the relative differences between the relations within each form of Article. However, full ANOVA results can be found in Appendix B, Tables 16-19, and Figures 4-11.

ERP Analysis. Based on the findings of previous research (Anderson & Holcomb, 2005; Calloway & Perfetti, 2020), the positivity observed in the present results seen across each region

is likely an unrelated phenomenon caused by having two different groups of participants (see Figures 4-7). As although these previous studies have shown evidence of more frontal/LAN negativity for nouns following the definite article than the indefinite article, it is difficult to fully compare given that the differences in the starting point of the region of interest (time locking to the article vs. time locking to the key target word).

In the P2 region, there was a main effect of Article Type, $F(1, 124) = 17.56$, $p < .001$, $\eta_p^2 = .12$, with the indefinite article leading to more positive amplitudes than the definite article in general (see Figure 4). Recall that in the definite article results, differences were found between the different types of relations, with the match and general category conditions having similar amplitudes, but both having amplitudes that were more positive than the mismatching and indeterminate conditions. In the indefinite article results, there were no differences between the relations. These differences were reflected in a marginal three-way interaction between Article, Relation, and Laterality, $F(12, 1488) = 2.00$, $p < .07$, $\eta_p^2 = .02$. The interaction with laterality occurred because the Article x Relation interaction in the definite article results was slightly larger over the right and right lateral locations, whereas smaller differences were seen at other lateral locations (midline, left lateral, and left).

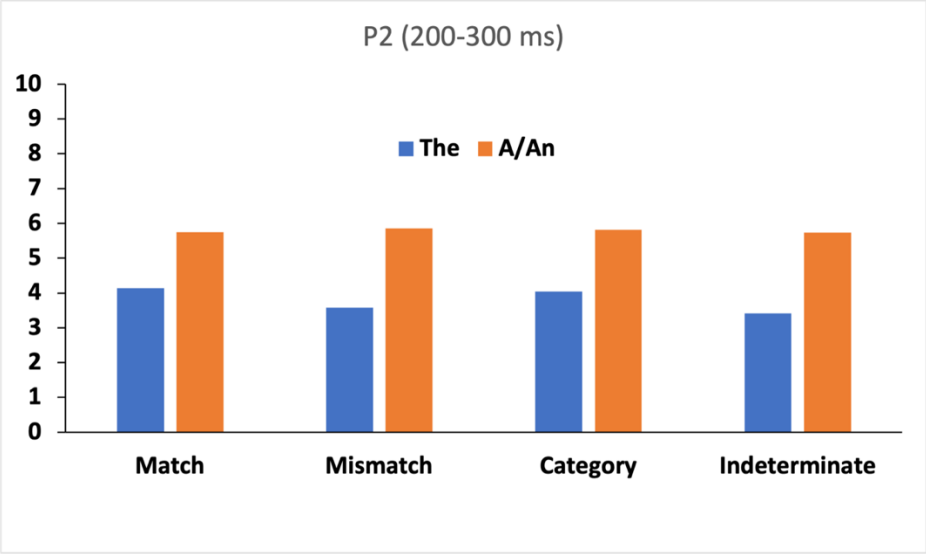

Figure 4. The comparison between the ERP results at the P2 when the definite or indefinite article was used. Y-axis shows mean amplitudes (μV).

These results show that when the article is more predictive towards the content of the current situation model, as with the definite article, the expectancy for specific discourse concepts appears earlier than when the indefinite article is used. Such early differences between the articles have been seen in previous research where such differences were visible as early as 150 ms following the onset of the article (Anderson & Holcomb, 2005). However, note that the expectancy for a target concept following the definite article is not as specific as seen in the N400 region, where significant differences emerge between the match and general category conditions (see below).

In the N400 region, the main effect of Article Type was significant, $F(1, 124) = 6.40$, $p < .02$, $\eta_p^2 = .05$. As shown in Figure 5, the definite article led to more negative amplitudes than the indefinite article. Although the interaction between Relation and Article did not reach significance ($p < .14$), this trend was a result of N400 differences between the articles that was clear in the separate article analyses. For both articles, the smallest N400 amplitudes were found

for the matching condition. However, differences emerged between the articles for the other three conditions. Specifically, when the definite article was used there was no difference in amplitudes between the mismatch and indeterminate conditions, and the general category condition was more positive than both. Conversely, following indefinite articles the general category condition elicited similar amplitudes as the mismatching condition, and amplitudes for the indeterminate condition were significantly more negative than for the mismatching and general category conditions.

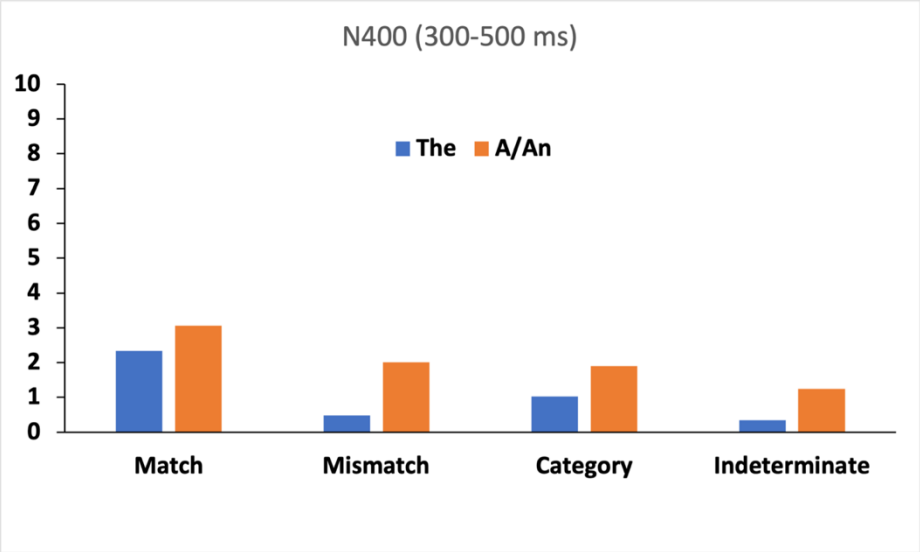

Figure 5. The comparison between the ERP results at the N400 when the definite or indefinite article was used. Y-axis shows mean amplitudes (μV).

These differences indicate that amplitudes varied as a function of Article Type as they transitioned from the P2 region through the N400 region. When the definite article was used, amplitudes for the general category relation were significantly more negative relative to the matching relation (showing refinement in expectancy), whereas amplitudes for the indeterminate and mismatching conditions do not change from the P2 to the N400 region. When the indefinite

article was used, the transition from the P2 region through the N400 region showed the onset of sensitivity to the different conceptual properties of the targets, and these variances were different from the definite article results. Specifically, the mismatching condition was easier to conceptually integrate into the situation model in the indefinite condition and becomes on par with the general category condition. This result shows that the indefinite article does not create as much of an expectancy for concepts in the current situation model as the definite article, and this leads to the mismatching condition being more acceptable.

In the extended N400 region, there was a marginal effect of Article Type, $F(1, 124) = 3.29$, $p < .08$, $\eta_p^2 = .03$, as the definite article led to more negative amplitudes than indefinite articles (see Figure 6). Importantly, the interaction between Relation and Article was significant, $F(3, 372) = 12.01$, $p < .001$, $\eta_p^2 = .09$. When the definite article preceded the target concept, the amplitudes for the general category condition in the N400 region were more negative than for the matching condition, but they became more similar to each other in the extended N400 region, and both of these conditions remained more positive than the mismatching and indeterminate conditions (that continued to be similar). These results suggest that the difficulty of conceptually integrating the general category concepts that was shown in the previous N400 region was quickly resolved in the extended N400 region, whereas integration difficulty remained for the mismatching and indeterminate conditions.

In contrast, when the indefinite article preceded the target concepts, the matching and mismatching conditions had similar amplitudes in the extended N400 region, and both of these conditions were more positive than the indeterminate and general category conditions, although the general category condition was significantly more negative than all of the other conditions. These changes indicate that when the indefinite article is used, the expectancy for specific targets

in the situation model are not as strong, which results in less integration difficulty for target concepts that do not overlap as much with the other concepts in the model.

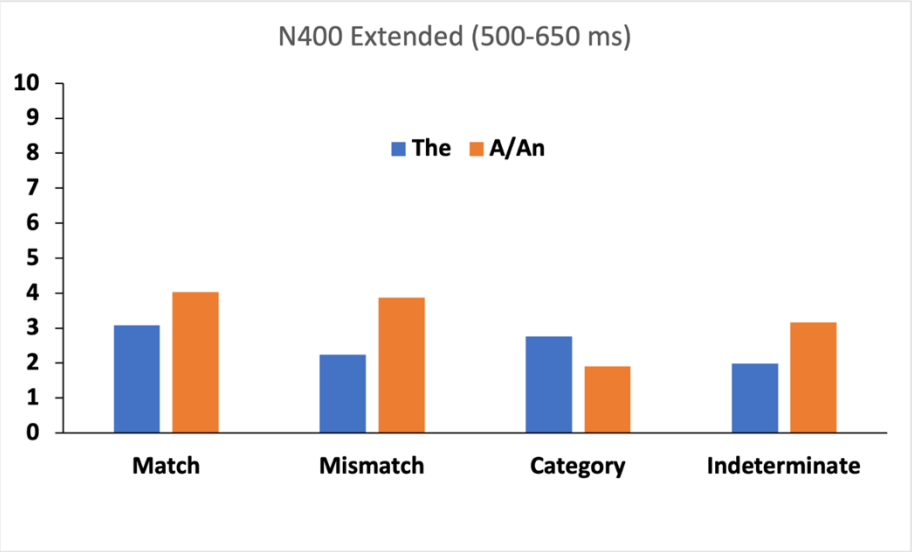

Figure 6. The comparison between the ERP results at the extended N400 when the definite or indefinite article was used. Y-axis shows mean amplitudes (μV).

A significant three-way interaction between Relation, Laterality, and Article was also found in the extended N400 region, $F(12, 1488) = 3.03$, $p < .009$, $\eta_p^2 = .02$. When the definite article preceded the target term amplitudes were more negative over the RH than the LH, with the most negativity seen in the right and right lateral regions, particularly in the indeterminate and mismatching conditions. In particular, the indeterminate condition led to the most negativity, even for the midline, left lateral, and left regions, although the trend of more negativity in the right locations is seen, and becoming more positive towards the left regions. The mismatch and general category conditions led to the widest range of amplitudes when using the definite article, although on average the mismatch was more negative than the general category relations. Both followed the same trend of being the most negative for the right lateral and right regions and

becoming more positive across the midline and to the left lateral and left. The match was the most positive condition overall, with only slightly more negative amplitudes seen in the right lateral and the right, followed by the left lateral, midline, and left. Overall, each relation showed the same trend with the right and right lateral locations being more negative and becoming less negative across the head to the midline and the left and left lateral locations. When an indefinite article was presented, the results again showed a clear pattern with the most negativity showing in the right and right lateral regions and becoming more positive across the head from the midline to the left lateral and left areas. However, unlike with the definite article, the indefinite article led to a very distinct pattern based on the type of relation, in which the general category relations were the most negative and were more negative at all lateralities than the indeterminate relation, which was more negative at each laterality than the mismatching relations. At the right and right lateral locations, the mismatching and matching relations led to similar amplitudes, but this divided across the midline, and in the left and left lateral regions, with the mismatching being more negative than the matching.

The three-way interaction between Relation, Article, and Anteriority was also found in the extended N400 region, $F(12, 1488) = 2.44$, $p < .04$, $\eta_p^2 = .02$. The results for the definite article showed a pattern of more negative amplitudes in the occipital region, then becoming more positive across the parietal and towards the frontal and prefrontal regions was found. When the definite article was used the occipital and parietal regions showed the most negativities, followed by the central, frontal, and then the prefrontal regions. For all regions the indeterminate relations resulted in the most negative amplitudes, followed by the mismatch, general category, and then matching relations. The different relations each had a large range of amplitudes cross these regions, with the indeterminate and mismatching relations tending to be the most negative,

however there was a significant amount of overlap between them. In comparison, when an indefinite article preceded the target word, the same overall pattern at the different anteriority regions emerged (more negative in the occipital and becoming more positive across the parietal to the frontals). When the indefinite article was used the occipital and parietal regions also showed the most negativities, followed by the central, frontal, and then the prefrontal regions. For all regions the general category condition led to the most negative amplitudes, followed by the indeterminate, mismatch, and then match. However, the general category relation had the most negative amplitudes, whereas the other relations were closer in amplitude to each other within each region. The general category was more negative than all other relation and anteriority combination, with the exception of the prefrontal region.

Interestingly, the general category condition overwhelmingly had the most negative amplitudes at the extended N400. This indication of integration difficulty could be a result of the general category condition becoming ambiguous between being associated with the current event versus a new event. For example, participants will try to fit concepts in the general category condition into a new event as result of the indefinite article, but the concept is also semantically consistent with a concept in the current situation model (e.g., vehicle - truck). In comparison, the definite article creates an expectancy for a target in the current event, which results in less integration difficulty for the general category condition because a semantically consistent concept is available in the situation model.

Finally, at the LPC region, the main effect of Article was significant, $F(1, 124) = 7.14$, $p < .009$, $\eta_p^2 = .05$, but there was no interaction between Article and Relation (see Figure 7). This latter result is not unexpected given that this region did not vary by relation for either article when examined separately.

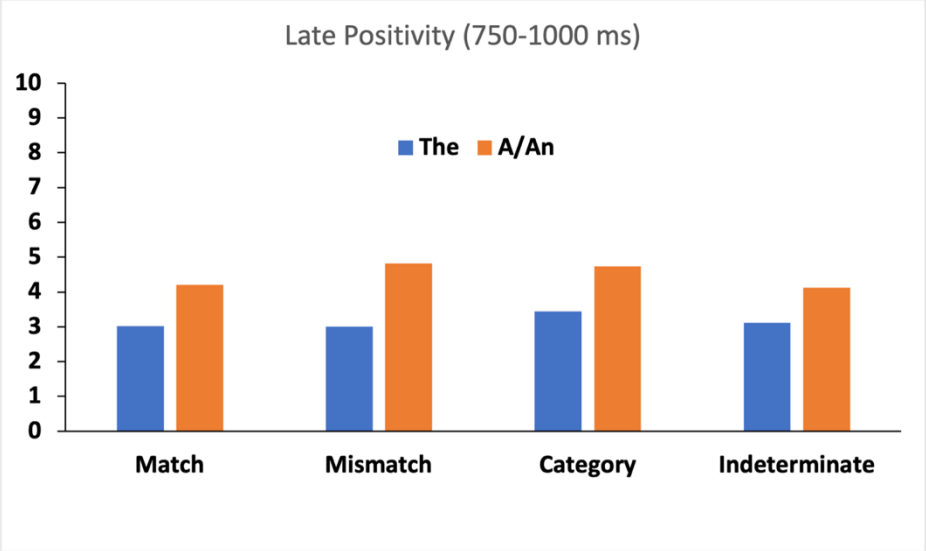

Figure 7. The comparison between the ERP results at the LPC when the definite or indefinite article was used. Y-axis shows mean amplitudes (μV).

Sentence Completions. The ANOVA completion comparison results can be seen in Appendix B, Table 20 and 21.

The results for sentence completions that were coreferential with the relevant antecedent showed that the definite article led to considerably more completions than the indefinite articles, $F(1, 231) = 109.04$, $p < .001$, $\eta_p^2 = .32$ (see Figure 8). The interaction between Article Type and Relation was also significant, $F(2, 462) = 38.02$, $p < .001$, $\eta_p^2 = .14$. Although the matching condition produced the most completions for both articles, followed by the general category condition and then the mismatch condition, the relative difference between these conditions showed some variation by article type. As shown in Figure 8, the matching and general category conditions had more completions relative to the mismatching condition following definite than indefinite articles. These results show the definite article leads readers to take the target concept as coreferential with a specific concept in the preceding sentence to a greater degree than the indefinite article, which also makes the mismatching condition more acceptable relative to the

other conditions following indefinite articles. Note that these findings align with the N400 results that showed the matching and general category conditions were more positive than the mismatching condition following definite articles, whereas the mismatching condition had amplitudes that were more similar to the general category condition following the indefinite articles.

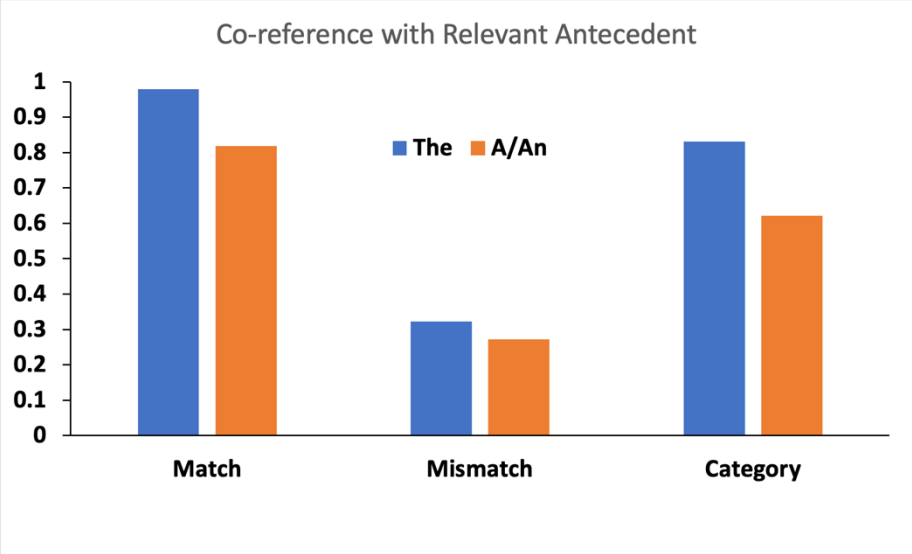

Figure 8. The comparison between completions that were coreferential with the relevant antecedent when preceded by the definite or indefinite article. Y-axis shows the percentage of proportions of this completion type.

The results for completions that were coreferential with a different antecedent in the same event did not find a significant main effect of Article, $F(1, 231) = .05$, $p = .828$ (see Figure 9). However, the Article by Relation interaction was significant for these completions, $F(3, 693) = 5.16$, $p < .002$, $\eta_p^2 = .02$. Following both types of articles, the mismatch condition produced the most completions followed by the general category condition. However, following definite articles the general category and indeterminate conditions elicited a similar number of completions and the matching condition produced the fewest. Alternatively, following indefinite

articles the general and matching condition were similar and the indeterminate condition had the fewest completions.

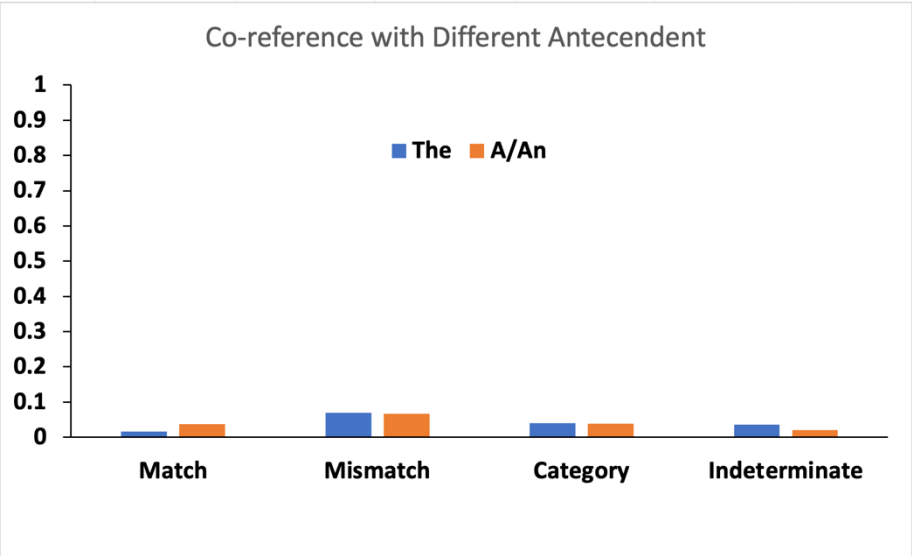

Figure 9. The comparison between completions that were coreferential with a different antecedent than the target one when preceded by the definite or indefinite article. Y-axis shows the percentage of proportions of this completion type.

The results for the completions with target concepts that were taken to be coreferential with the same event, but as an entirely new token, did not demonstrate a main effect of Article, $F(1, 231) = 1.89$, $p < .18$ (see Figure 10). This was a surprising result, as the definite article is more likely to highlight the current situation model, and it would be expected to lead readers to be more likely to continue building upon the pre-existing model, compared to the indefinite article.

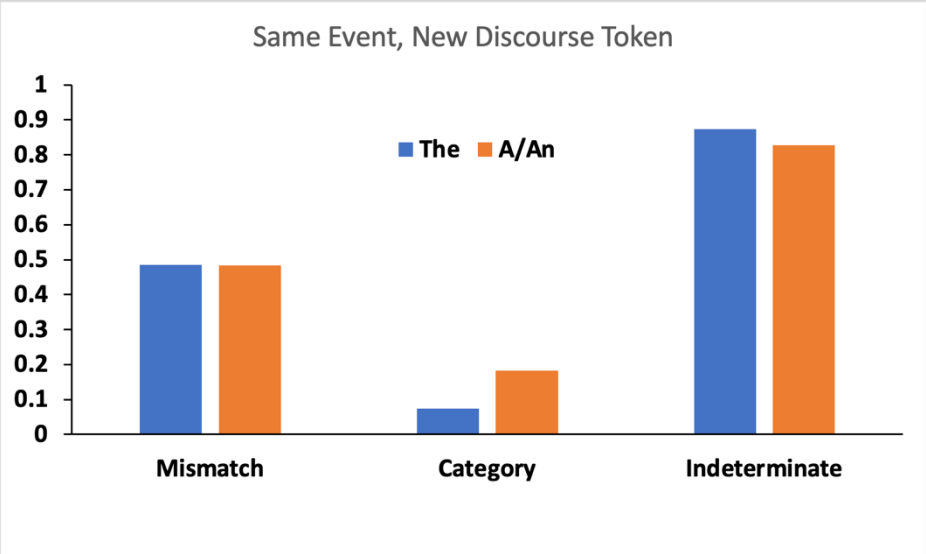

Figure 10. The comparison between completions that were taken as being the same event with a new discourse token when preceded by the definite or indefinite article. Y-axis shows the percentage of proportions of this completion type.

However, the interaction between Relation and Article was significant, $F(2, 462) = 28.65$, $p < .001$, $\eta_p^2 = .11$. For both articles, participants produced the most completions for the indeterminate condition, followed by the mismatch condition and then the general category condition. However, the difference between the general category condition relative to the indeterminate condition and especially the mismatch condition was much larger following indefinite than definite articles. As the indeterminate condition does not have any co-relevant antecedent in the preceding sentence, this result is as expected for both articles. However, the fact that the definite article elicited much more of these completions for the indeterminate condition shows that, although there is no antecedent provided, the nature of the definite article signifies to readers that it must still be a part of the same event.

Overall, general category relations led to this type of completion the least and this is likely the result of this relation being the only one in which you have an ill-defined target which can then become a specific item based on the new information. It was clearly a concept from the

same category provided and this would lead to less same event, new token completions overall, but especially for the definite article, where the pre-existing nature of the target is emphasized.

The results for completions with target concepts that were taken as a new token in a different event also demonstrated a main effect of Article, $F(1, 231) = 28.32$, $p < .001$, $\eta_p^2 = .11$, as indefinite articles led to more completions than definite articles (Figure 11). Given that the indefinite article is commonly used to introduce new discourse tokens, it is not surprising that it led to more of these completions than the definite article.

The Article by Relation interaction was also significant, $F(2, 693) = 19.96$, $p < .001$, $\eta_p^2 = .08$. For both articles, the most completions were found for the mismatching condition, but that is where the similarities end. Specifically, when the definite article was used there were almost no completions for the matching condition, whereas the matching condition had almost the same number of completions as the mismatching, general category, and indeterminate conditions when they followed indefinite articles. This result shows that the indefinite article led participants to be more open to taking the concept in not only the matching condition, but all conditions, to be a new token in a completely new event.

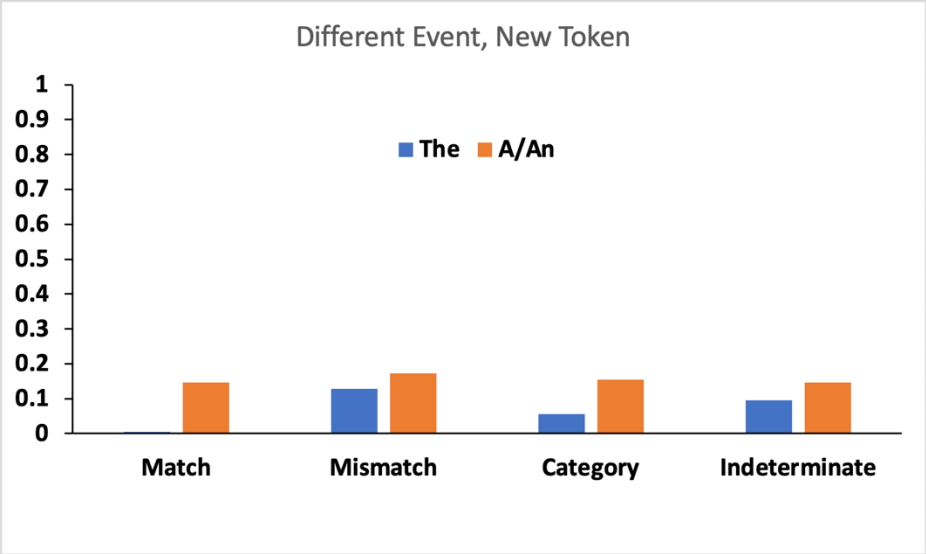

Figure 11. The comparison between completions that were a different event and a new discourse token when preceded by the definite or indefinite article. Y-axis shows the percentage of proportions of this completion type.

Conclusion

Experiments 3 and 4 examined the impact of the indefinite article on the process of updating situation models by using ERP methodology and an off-line sentence completion task. Similar to Experiments 1 and 2, the current studies examined four different types of relations between antecedents and referents: match, mismatch, general category, and indeterminate. As the four conditions in this research being directly contrasted together is entirely novel, the current research continues to provide original neurocognitive data on how people update situation models during language processing. Adding the definite/indefinite article factor allowed for investigation into the importance of grammatical nuances on the ease of mental processing of both the information read as well as how it may influence what information is integrated in the situation model and what is discarded.

Experiments 1 and 2 found that when a definite article is used novel and mismatching concepts were the least semantically congruent with the developing situation model. It was also

found that the integration costs were highest when no prior antecedent is presented, and that the matching and underspecified but categorically similar antecedents did not differ in terms of integration cost. Experiment 3 showed that when an indefinite article is used entirely new concepts are the most difficult to semantically integrate (as shown by N400 and extended N400 results), more so than the mismatching relations. The survey completions of Experiment 4 showed that the indefinite article led to somewhat more variability in how concepts are integrated into the situation model, particularly for the general category relation, compared to the definite article. Together, the ERP and completion findings showcase that the use of the indefinite article led readers to have more varied interpretation, and therefore ease of integration, compared to when the definite article was used.

Chapter 4: Hemispheric Contributions to Different Forms of Co-reference

Chapters 2 and 3 investigated the electrophysiological responses generated when text ideas co-varied in four different ways (match/mismatch/general category/indeterminate) with the situation models constructed during online language comprehension. The present chapter extends these results by examining how the cerebral hemispheres independently process these different coreferential relations. The chapter begins with a discussion of known hemispheric contributions to discourse processing, followed by a discussion of the present research. As will be showcased below, both the RH and the LH have been implicated in discourse and referential processing. In general, there are not a lot of consistencies between the studies, which have used different methodologies. There are large differences between behavioural and ERP studies that employ the visual half field (VHF) technique. This technique involves presenting the target stimuli to a participant in either their right visual field (RVF) or left visual field (LVF), which ensures the target is processed first within the LH or RH, respectively (Banich, 2002). As discussed below, the behavioural and ERP research implicate that both hemispheres process conceptual information in different ways.

Hemispheric Contributions to Discourse Processing

There has been substantial psycholinguistic research of the LH involvement in discourse processing, and it is often considered the dominant hemisphere for language (e.g., dos Santos et al., 1991). However, evidence of the RH's contribution to language processing has also been found to be important in a number of ways (e.g., Johns et al., 2008; St George, Kutas, Martinez, & Sereno, 1999). Previous research has shown that the LH and RH work together during discourse comprehension. For example, Wlotko and Federmeier (2007) found that both hemispheres are sensitive to message-level information provided by the discourse context, with

the LH using top-down processing to prepare for the processing of upcoming stimuli and the RH implementing a more bottom-up approach, assessing the fit of word presented compared to the words that came before. More recent ERP research, which is discussed in detail below, by Delong and Kutas (2016) has shown that the LH and RH are similarly sensitive to sentence continuations of differing expectancy levels, and that the LH is more sensitive to unexpected continuations in highly constraining contexts during later stages of word processing. Such findings suggest that each hemisphere is involved in predictive sentence comprehension, but that the level of involvement at different stages of word processing varies.

Evidence has also been found that for a full range of language functions to ensue, processing resources that are distributed across both hemispheres may be required. There are several explanations as to why such differences across the two hemispheres occur, including the 'coarse coding hypothesis', which suggests that semantic activation is direct and robust in the LH and broader but weaker in the RH (Beeman & Chiarello, 1998; Beeman, 2005). The coarse coding hypothesis states that activation spreads further to less related topics in the RH, and this is indicated by research which shows the RH is better at semantic summation (associating several, weakly related words to a target) in comparison to the LH (e.g., Beeman & Chiarello, 1998; Beeman, 2005; Beeman et al., 1994). Beeman et al. (1994) employed the VHF technique to examine the differences between each hemisphere during language comprehension, assessing how the hemispheres responded to word-pairs (associated vs. unassociated). It was found that people made lexical decisions faster when the associated pairs were presented to the RVF/LH than when presented to the LVF/RH, particularly for strong associated pairs.

Although it may appear at times that the RH simply plays a supporting role to the LH for discourse processing, there is evidence that the RH has its own specific functions. Research on

unilateral brain damage has indicated numerous roles played by the RH in comprehension, including drawing and revising inferences (Beeman, 1993). Male and Gouldthorp (2020) found that although both hemispheres access a mental representation that embodies the elements described in a passage, they do so differently. During discourse processing only the RH accessed a mental representation that embodied the proper spatial relationships between elements, as well as the individual imagined elements, showing that the RH contributes uniquely to the integration of perceptual information during language comprehension (Male & Gouldthorp, 2020).

Robertson et al. (2000) used FMRI methodology to contrast the impact of integrating sentences in passages that begin with definite (*The*) and indefinite (*A*) articles in passages. This manipulation led to successive sentences to either cohere (with *The*) or not (with *A*). The results showed that integrating successive sentences with indefinite articles led to greater activation in the frontal lobe of the RH than LH, whereas there were no differences between the articles in the LH. These results show that the RH is involved in establishing coherence, particularly when the linguistic cues (such as indefinite articles) are not helpful for indicating how elements of discourse are to be mapped together (Gernsbacher, 1990).

Taken together, the results discussed above show that both hemispheres play a role in the integration of discourse concepts into situation models, albeit differently across different linguistic contexts.

Referential Processing in the Cerebral Hemispheres

Inferring how a word is related to previously mentioned concepts is an integral part of discourse comprehension. There is evidence that the LH and RH are specialized to carry out different processes when generating inferences (e.g., Albyn Davis et al., 1997, Beeman et al., 2000; Virtue et al., 2006). One common way to study the role that the RH plays in inferential

processing is by examining patients with right hemisphere damage (RHD) (see Johns et al., 2008 for review). Research has found that RHD impeded the process of lexical ambiguity resolution by creating deficits in the ability to use local contextual information (Grinrod & Baum, 2003), and that RHD patients had slower responses to inference-related words than to unrelated words (e.g., "overflow" versus "operate" when a story mentioned leaving the bathtub running), suggesting that they lacked semantic information required to draw inferences (Beeman, 1993). In general, there are two hypotheses of RHD and inferences: that RHD prevents activation of information necessary to make inferences (e.g., Beeman, 2005), and that if discourse processing relies on limited capacity system, RHD results in disruption of suppression (rather than of activation), leading to impairment of a correct discourse model (Tompkins, Fassbinder, Blake, Baumgaertner, & Jayaram, 2004).

Despite the impacts of RHD on referential processing, it has been found that those with RHD can still make referential inferences (e.g., Ferstl et al., 2005; Leonard, Waters, & Caplan, 1997). Although there is a certain amount of degradation while inferencing after RHD, the LH increases neural activity when inferences are drawn (Ferstl et al., 2005). This indicates that while both hemispheres work in tandem to draw inferences, the RH plays an important role that, in cases of RHD, the LH must work harder to compensate for the damage. If the RH was not necessary for inferencing, the LH would not require such an increase of neural activity to compensate.

Context is integral to referential processing and building a mental model, but sometimes these processes are interrupted. A coherence break is a sentence or phrase that interrupts the logical train of a story (Beeman et al., 2000). When this occurs, different inferences are used to fill in the gaps (coherence inferences). We "fill in missing information to resolve a contradiction

between a premise and a changed state" (Beeman et al., 2000, p. 311). Beeman et. al.'s research demonstrated that the LH had a slight advantage for coherence inferences over the RH, but the activation of these inferences was sustained in both hemispheres. It was concluded that both hemispheres are involved in drawing inferences. As well, both hemispheres must cooperate to fully understand discourse, with coarse semantic coding (weak activation of many distantly related semantic concepts) occurring in the RH and fine semantic coding (strong activation of only closely related concepts) happening within the LH. This makes the LH more likely to incorporate coherence inferences than the RH when presented with a coherence break.

Making inferences is also key when lexical ambiguity is present. Faust and Chiarello (1998) used a lexical decision task to examine the differences between the hemispheres in resolving lexical ambiguity within sentence contexts. Participants read a priming sentence which contained an ambiguous word at the end, having two definitions (e.g., "He could not wait for even a second."). After reading the sentences, the participants were shown a target word (either strongly related to the ambiguous word given the context, less related, or not related. For the above example, the target word could be "time", "number", or "sound") or a nonword in either the LVF or RVF. They were instructed to indicate as quickly as possible if the word seen was a real word or a nonword. It was found that in the RVF/LH targets related to the sentences were facilitated, and unrelated targets were not primed. This was in comparison with the LVF/RH, which showed that related targets were facilitated regardless of the sentence context (Faust & Chiarello, 1998). These findings indicate that the LH is essential for selecting the contextually appropriate word meaning and that the RH sustains the multiple meanings of a word.

Virtue and Joss (2012) examined causal connections, and how inferences are made using the presented context. They investigated how the hemispheres process information consistent or

inconsistent with an inference. Participants read a series of sequences and were then presented with a target word (e.g., “hammer” or “saw”) or a nonword to either the LVF/RH or RVF/LH. The inference-related target word was either consistent or inconsistent with an anaphor in a preceding sentence, and both had been mentioned in the sequence that was read (e.g., “After arriving at the construction site, Samuel used his hammer and saw. As he was working, he pounded the wood with it.”). However, only the consistent target was inferentially correct (“hammer”, in the above example). Participants performed a lexical decision task in which they decided as quickly as possible if the word shown was a real word or a nonword. They found that information consistent with an inference led to faster lexical decisions when the target word was presented to the LH than the RH (Virtue & Joss, 2012). These results show that it is the consistency of information, rather than difficulty, that drives hemispheric differences during inference generation.

Previous research has also revealed that both hemispheres elicit high levels of facilitation by way of increased response time and accuracy to a lexical decision task when shown targets that are consistent with intended inference, but only if the targets are presented with strongly constrained text conditions. However, the RH has demonstrated stronger facilitation during text comprehension than then LH when processing inconsistent inference-related information (Virtue & van den Broek, 2005). To delve into this, Silagi, Radanovic, Conforto, Mendonca, and Mansur (2018) examined the performance of participants with right- and left-hemisphere lesions (RHL, LHL) on an inference reading comprehension task. Short passages were read and then five types of questions (*explicit*, *logical*, *distractor*, *pragmatic*, and *other*) that required different types of inferential reasoning were presented. Their results showed that people with RHL performed more poorly than the LHL group on *logical*, *pragmatic* and *other* questions. Overall, it was

found that lesions in either hemisphere may cause difficulties in making inferences during discourse processing. However, it was more difficult for patients with RHL than for those with LHL to process more complex inferences, suggesting that the RH plays an important role in inference tasks with higher comprehension demands (Silagi et al., 2018).

In another experiment in which referential processing between the hemispheres was studied, Marconi et al. (2013) examined the pattern of brain activity through fMRI associated with "referential" (picture naming, word-to-picture matching) and "inferential" (naming to definition, word-to-word matching) tasks. The results showed selective engagement of the LH temporal areas during inferential tasks. Specific activation of the right fusiform gyrus was also found to be associated with the referential tasks. Overall, the inferential tasks prompted additional processing resources assisted by the LH language areas involved in lexical retrieval. In comparison, the referential tasks recruited the RH areas generally associated with nonverbal conceptual and structural object processing (Marconi et al., 2013).

To summarize, it has been found that although the LH is dominant for language the RH also contributes significantly (e.g., Johns et al., 2008; St George et al., 1999) and sometimes the LH and RH will work together during discourse comprehension (e.g., Delong & Kutas, 2016; Wlotko & Federmeier, 2007). However, the RH has been found to play numerous roles in comprehension, including making and revising inferences (e.g., Albyn Davis et al., 1997, Beeman, 1993; Silagi et al., 2018; Virtue & Joss, 2012; Virtue & van den Broek, 2005). There is also evidence that the LH and RH carry out separate and different processes when generating inferences (e.g., Beeman et al., 2000; Virtue et al., 2006).

Electrophysiology of Processing Within the Hemispheres

Federmeier, Wlotko, and Meyer (2008) have noted several advantages to using ERP methodology in conjunction with the VHF technique to measure hemispheric differences in language:

1. ERPs can be measured as participants are simply reading, without any further processing beyond comprehension (e.g., doing a simultaneous judgment task). This allows researchers to bypass the potential issue of separating hemispheric differences in language processing from asymmetric abilities on different kinds of tasks.
2. Due to the electrodes placed near the eyes, eye movement can be measured and used as a means for determining that participants maintained their fixation on the central point during individual trials. As measuring ERPs allows researchers to eliminate this concern, it permits longer presentation durations. The presentation duration is important to hemispheric studies as RH word apprehension may be less effective than LH and has the potential of showing a disadvantage during brief stimuli presentations.
3. The N1, an ERP component, can be examined to ensure that words are presented laterally. Federmeier et al. (2005) found that overall, larger negativities were elicited and sustained in the hemisphere contralateral to the visual field of presentation, meaning that more initial and sustained effort of processing occurs in those contralateral hemispheres. Transfer between hemispheres does not alter which specific brainwave components are elicited, and the peak amplitude of waveforms is not delayed when presented to one hemisphere.
4. ERPs measure the size, timing, and spatial distribution of effects, which offers a method to inspect the underlying nature of any hemispheric differences which may result from the VHF technique. As well, simultaneous and specific recording of asymmetries

between the hemispheres during multiple processing levels can be obtained. This allows for further understanding of precisely when and how differences arise, as opposed to simply knowing that the hemispheres process information differently.

Taking these into account, it is clear that ERPs can be reliably used as a measure of hemispheric activity and have advantages over other common measures such as lexical decision tasks.

The current research will examine the same ERP components in the previous chapters (P2, N400, extended N400, and the LPC). Previous research has shown that some of these components are preferentially processed across the hemispheres. The N1 component (approximately 100-200 ms following stimulus onset) will also be examined. It is thought to reflect extrastriate visual processing. Typically, the N1 has more negative amplitudes when a visual stimulus is detected. As discussed above, this component can be used to confirm stimulus lateralization by examining differences between LVF/RH and RVF/LH presentation at contralateral electrodes (Federmeier et al., 2005; Federmeier et al., 2008). As such, the appearance of an N1 amplitude in the current research will be used to verify the effectiveness of the VHF presentation.

In an ERP study that examined the N400 (Federmeier & Kutas, 1999), it was found that message-level information impacts processing in both VFs/hemispheres similarly, but that the nuances of the type of congruency affect each hemisphere differently. Participants in this study read pairs of sentences for comprehension, with the final word being presented to only one visual field. There were three types of sentence-final word pairs: expected exemplars (e.g., *palms* when the context was what was planted along a driveway to make a hotel look like a resort), between-category violations (e.g., *tulips* in the previous example), or within-category violations (e.g., *pines*). In both hemispheres, the N400 responses were equally affected by congruency, being less

negative for expected exemplars relative to between-category violations, indicating that both hemispheres were sensitive to the message of the discourse. However, the N400 elicited for within-category violations (unexpected words from the same semantic category as the expected endings, e.g., *pines*) showed differences between the hemispheres. For the RVF/LH, presentation of within-category violations produced intermediate amplitude N400s. In the LVF/RH, responses to these items were no different from responses to the between-category violations. This indicated that the LH showed greater sensitivity to the feature overlap of the within-category violations, and to the general plausibility of the between-category violations. These N400 results suggest that message-level information impacts processing in both hemispheres, but differently for each (Federmeier & Kutas, 1999). The LH was predictive, distinguishing between within-category violations and between-category violations, whereas the RH was not predictive, but still showed an advantage for the expected exemplars.

In 2005, Federmeier et al. used the VHF technique and ERP methodology to examine how the different hemispheres interpret more versus less expected words in discourse. In this study, participants read sentences for comprehension that had a target word at the end that was either strongly or weakly expected by the sentence context (e.g., “She was suddenly called back to New York and had to take a cab to the AIRPORT.” or “She was glad she had brought a book since there was nothing to read at the AIRPORT.”). The P2 results showed more positive amplitudes for stimuli that was most expected based on the context of the sentence. Importantly, there was no difference in the P2 for expectancy in the RH, only in the LH. This is evidence that the LH processes such semantic congruencies more strongly and is more predictive. However, it was found that both hemispheres showed similar sensitivity to congruency, as indexed by the

N400 amplitudes (Federmeier et al., 2005). This indicated that message-level information was not differentially important for the semantic integration of words presented to either hemisphere.

In another ERP study, Meyer and Federmeier (2007) examined the N400 in the separate hemispheres. Participants decided if a centrally presented target was related in meaning to a lateralized ambiguous or unambiguous prime (e.g., *sweet-candy* or *bank-deposit*). The related or unrelated centrally presented context word was presented before the prime word pairs (e.g., *taste-sweet-candy* or *river-bank-deposit*). In general, it was found that, in both hemispheres, the N400 decreased when the target word was preceded by related, versus unrelated, context words. However, in unrelated contexts the N400 responses were more positive in all ambiguous conditions (e.g., *river-bank-deposit*) except when targets were presented to LVF/RH rather than the RVF/LH. This result signified that without biasing context information, the hemispheres seem to be differentially affected by meaning frequency, with the LH maintaining multiple meanings, leading to a weaker N400 response as the semantic incongruency is not as prevalent, and the RH selecting the dominant meaning, resulting in a more negative N400 than in the LH. Overall, the results of Meyer and Federmeier (2007) showed that both hemispheres use context to guide meaning selection, but the LH is more likely to focus activation on a single, contextually relevant sense as the processing in the LH of the ambiguous primes were context-dependant.

The LPC, or late positive component, which has been shown to index integration costs of situational updating, is an imperative component to examine. It is sometimes considered as a larger set of positive components called post-N400 positivity (PNP), which have been found in circumstances when unexpected but still acceptable continuations of sentences occur (e.g., Coulson & Van Petten, 2007; Federmeier, Wlotko, De Ochoa-Dewald, & Kutas, 2007). These PNPs have been shown to index the integration costs associated with anaphoric complexity and

situational updating (Burkhardt, 2005, 2006; Ferretti et al., 2008). Both the late positivity's potential presence and lack of response to stimuli can help us glean important insight. However, ERP studies do not consistently show late positivity in hemispheric investigations of the integration of concepts in sentences that vary in how predictive they are for the concepts (e.g., Coulson, Federmeier, Van Petten, & Kutas, 2005; Delong & Kutas, 2016; Wlotko & Federmeier, 2007). For example, Wlotko and Federmeier (2013) examined the N400 and the LPC to determine what effects, if any, manipulations of contextual predictability had in the separate hemispheres. In this study, sentence-final words that varied over the full range of sentence-level predictability (cloze probability) were presented to the RH and LH (e.g., "The little girl refused to go to sleep until he told her a **story**." (high expectancy), "Jim was saving boxes for a friend who was **moving**. (medium expectancy)", "The candidate had spent most of his funds on **drugs**." (low expectancy)). When the words were presented to the RH, the results showed that both highly predictable and completely unexpected items showed similar responses in each hemisphere. However, reduced N400 amplitudes showed that the RVF/LH items were facilitated over a broader range of predictability (versus LVF/RH). Wlotko and Federmeier (2013) also found an LPC effect, with the LVF/RH presentation leading to more positivity than the RVF/LH, but the size of the difference was not significantly distinct across the hemispheres. This indicated that there were no asymmetric late positivity effects. As a result, Wlotko and Federmeier conclude that the processing within both hemispheres together shape the way context is used during comprehension.

When examining the potential difference between hemispheres when using sentence context to predict and resolve message-level meaning during online language comprehension, Delong and Kutas (2016) also examined both the N400 and late positivity using the VHF

technique. As in Wlotko and Federmeier (2013), sentences were presented with key terms of either high, medium, or low cloze probability. Delong and Kutas also manipulated the level of context constraint (high, medium, or low. Some example combinations: *High constraint/high cloze probability:* Bart did not clean his wound properly. He ended up getting an **infection** soon after. *Medium constraint/low cloze probability:* The cat climbed up the bird feeder. When he reached the top he saw a **squirrel** and pounced on it. *Low constraint/high cloze probability:* Valerie did not know what to make for dinner. At the supermarket she bought a **chicken** and a roast). At the N400 they found an increased negativity for lower cloze probability when constraint levels were medium or high, however there was no interaction with the VF of presentation, indicating no differences between the hemispheres for processing varying levels of expected sentence completions. This was, notably, in contradiction with previous research (e.g., Federmeier & Kutas, 1999; Coulson et al., 2005). However, this lack of distinction did not continue into the late positivity, as it was found that there was a difference between the hemispheres. The LH, but not the RH, showed a more positive response from the low than high cloze probability sentences when constraint levels were high (indicating a constraint violation), at anterior sites. Overall, Delong and Kutas' (2016) findings show that although both hemispheres have similar involvement in meaning construction, there is a LH bias for processing constraint violations.

As the extended N400, which has been shown to reflect integration costs related to high semantic incongruency or expectancy (Burkhardt, 2006; Ferretti et al., 2008, 2013), was examined in previous chapters of this dissertation it will once again be analyzed. However, before this study there has been no hemispheric research that has investigated or shown distinct

extended N400 examinations. As such, the present research will be entirely novel in its study of the extended N400 between the hemispheres.

Experiment 5

The discussion above illustrates that although researchers have investigated coreferential processing in the separate hemispheres, there is a distinct lack of research that directly contrasts different forms of coreference. The goal of this experiment is to examine referential processing in the LH and RH, as well as investigate the construction of situation models in the separate hemispheres. Specifically, the current research contributes to the present gap in knowledge by examining the same four relations as investigated in the previous chapters: match, mismatch, general, and indeterminate. As these relations had not been examined together in one study prior to Experiment 1, these relations have also never been examined together specifically by hemisphere, and therefore it is unknown how the hemispheres process these different forms of reference. Using the same stimuli from Experiment 1, with the definite article preceding each target stimulus, will also allow us to study how the properties of the definite article (i.e., presupposing that the noun it modifies already exists in the situation model) is processed by each hemisphere.

Predictions

As there are no previous hemispheric studies that have examined the four relations together, the predictions made for this study are based on the definite article results of Experiment 1, and by electrophysiological research that has investigated how the separate hemispheres use sentential context to constrain the semantic integration of words. For example, if both hemispheres are equally sensitive to sentential constraints and use it in a similar manner

to help resolve coreference then it is possible that the results in both hemispheres will mimic those found in Experiment 1.

Although it has been shown that the RH participates in the cohesion aspects of processing and referential processing (Beeman et al., 2000; Robertson et al., 2000), the finer details, such as how the relations examined in the current research affect the RH and how specifically they may impact processing within the LH, are not known. The current research is exploratory from the hemispheric aspect, as it is not known how the two hemispheres will react when presented individually with the specific relations that are being examined. Based on the prior research within this dissertation the default assumption would be that both hemispheres would show the same pattern as found in Experiment 1 (as was previously discussed). Alternatively, if the LH is more predictive of upcoming discourse concepts than the RH (e.g., Federmeier & Kutas, 1999; Federmeier et al., 2005), then differences in how the hemispheres process the distinct relations may be expected. The impacts that this may have on the different ERP components are discussed below (see Table 22 below for comparative predictions).

N1 (100-200 ms). The N1 will be examined so that it can be determined that the stimulus was presented laterally as intended. Therefore, it is expected that a more negative N1 response will be visible in the LH, as compared to the RH, when stimuli are presented to the RVF/LH (and vice versa, with the N1 response being more prominent in the RH than the LH when stimuli are presented to the LVF/RH), as the N1 is being examined to verify that target words are initially processed in the contralateral hemisphere (Federmeier et al., 2005, 2008).

P2 (200-300 ms). If the P2 results mimic the centralized findings in Experiment 1, then there will be more positive amplitudes for the matching than mismatching and indeterminate conditions, and the P2 amplitudes for the general category condition should also be more

positive than for indeterminate and mismatching conditions. However, Federmeier et al. (2005) found that in the LH the P2 component was more positive for stimuli that was most expected based on the context of the sentence. The current experiment uses the definite article “the” to start the target sentence and therefore indicates what comes next is presupposed to exist within the situation model. However, it is still not as constraining as presenting a word that has a very high cloze value, as was done in Federmeier's studies. Nonetheless, if the expectancy for the matching concepts is very high in the present study, then more positive P2 amplitudes for these concepts relative to the other target concepts in the LH would be expected. No difference is expected at the P2 in the RH (Federmeier et al., 2005).

N400 (300-500 ms). It is possible that the N400 results will not see differences between the hemispheres, as Delong and Kutas (2016) found no hemispheric differences at the N400. If that should be the case, then it is expected that the findings would emulate the centralized findings in Experiment 1. If so, it would be expected that the N400 amplitudes in response to the mismatching and indeterminate conditions will not differ significantly, but both the mismatching and indeterminate conditions will elicit more negative responses at the N400 than the general category condition, followed by the matching condition. These predictions would be further supported by Delong and Kutas (2016), as they found an increase in N400 negativity with a decrease of cloze probability.

If the findings were to show differences between the hemispheres, it is predicted that in the LH the indeterminate relations will have the most negative N400 response, followed by the mismatching, general category, and then matching relations (Federmeier & Kutas, 1999; Federmeier et al., 2005). This is due to the stronger semantic incongruency in the indeterminate and mismatching conditions, as compared to the general category and matching. However,

Federmeier and Kutas (1999) demonstrated that the LH is sensitive to such a gradient, processing the distinction between identical, within-category, and between-category targets. As such, the indeterminate condition, in which no prior concept is presented and therefore no shared features can be elicited prior to the target concept, is predicted to produce the strongest N400 response. More so than the mismatching condition, where although the concept is different, there are from the same category and will share a number of similar features.

It is predicted that in the RH, unlike in the LH, there would be no advantage for the mismatching concepts over the indeterminate concepts. This would be because in both cases the concepts would be completely novel when they are encountered, but the indeterminate concept may be more plausible overall with the context than the mismatching concepts. The general category and the matching relations may also be equivalent to each other, as the RH is not sensitive to the gradient of matching, within-category, and between-category targets in the same way that the LH is (Federmeier & Kutas, 1999). However, the RH is sensitive to plausibility and can tell when something unexpected (Federmeier & Kutas, 1999), which is why there is still some expected differences amongst the N400 effects.

Extended N400 (500-650 ms). If the results mimic those of the centralized findings in Experiment 1, it would be expected that during the extended N400 the indeterminate condition will produce the most negative amplitudes, followed by the mismatch, general category, and then matching conditions.

There is a strong possibility that no extended N400 significance will be found. This is due to the lack of expectancy strength within the relation manipulation. Although the relations of match, mismatch, general category, and indeterminate in combination with the use of the definite article do provide some level of prediction to the readers (e.g., Anderson & Holcomb, 2005),

without the manipulation of the factive or nonfactive nature of the information presented, as seen in Ferretti et al. (2008), the strength of this expectation is significantly decreased. As such, a strong extended N400 response would not be expected. However, as the LH is more predictive than the RH, it would be expected that this would lead to a somewhat stronger response within the LH over the RH. This would be particularly noticeable in the mismatch and general category relations, compared to the indeterminate, as those conditions provide the readers with an antecedent in which to build predictions from.

LPC (750-1000 ms). Based on what was observed in Experiment 1 it may be expected that on average the General condition will produce a slightly more positive LPC than the indeterminate condition, followed by the mismatching and then the matching conditions, but the differences would not reach significance. However, if the LH is more predictive, and the RH more integrative (Federmeier & Kutas, 1999), it would be expected that the LPC will not be as positive in the LH as the RH, even when the LH processes the relational nuances better. In contrast, as it was found by Delong and Kutas (2016) that the LH elicits a late positivity at anterior sites when constraint violations occur, as positivity not found in the RH, it is also possible that the relations that resemble such constraint violations (mismatching) the LH may show a stronger late positivity than the RH. Still, it is not expected that any of these outcomes will reach statistical significance.

Table 22. *Predictions for the resulting response from each ERP component, based on centralized or by hemisphere responses*.

ERP	Centralized Predictions	Left Hemisphere Predictions	Right Hemisphere Predictions
N1	• N/A	• More negative N1 response will be visible in the LH, as compared to the RH, when stimuli are presented to the RVF/LH.	• More negative N1 response will be visible in the RH, as compared to the LH, when stimuli are presented to the LVF/RH.
P2	• More positive P2 amplitudes for Matching than Mismatching and Indeterminate conditions. • Amplitudes for General condition will also be more positive than for Indeterminate and Mismatching conditions.	• More positive P2 amplitudes for higher expectancy conditions (Match, General) relative to the other target conditions (Mismatch, Indeterminate) in the LH.	• No difference expected at the P2 in the RH.
N400	• N400 amplitudes in response to the Mismatching and Indeterminate conditions will not differ significantly. • Both Mismatch and Indeterminate will elicit more negative responses than the General condition, followed by the Matching condition.	• Mismatching relations will have the most negative N400 response, followed by the Indeterminate, General, and then Matching relations in the LH.	• In the RH the N400 response will be more negative for the Mismatching than the Indeterminate relations, followed by the General and Matching relations. • However, the General and Matching relations will elicit an equivalent response.
Extended N400	• Extended N400 results will be the most negative for Indeterminate condition, followed by Mismatch, General, and then Matching conditions.	• No significant findings expected. • A stronger response will be found in the LH in the Mismatching and General relations.	• No significant findings expected. • A weaker response overall will be found in the RH.
LPC	• No significant differences predicted.	• No significant differences predicted. • Mismatching condition will lead to more positive LPC in the LH than the RH.	• No significant differences predicted. • The LPC will be more positive overall in the RH than the LH, except in the Mismatching condition.

Methods

Participants. The participants were 80 right-handed undergraduate students (25 males, 55 females, age range of 17-42, M = 20.48) from Wilfrid Laurier University. A total of 98

participants were initially enlisted, but 18 of them were eliminated due to excessive eye-movements, failure of attention checks, incomplete data, or equipment error. All participants had English as their first language and had normal or corrected-to-normal vision. Participants received partial course credit as compensation.

Materials. The experimental materials were the same 136 two-sentence sequences used in Experiment 1. From these materials, eight experimental lists were constructed. These were the same counterbalanced lists employed in Experiment 1, however in this experiment the VHF technique was applied. Thus, across the lists, the target word for every trial in each condition was presented to the left and right visual field. The target words were all presented with two degrees of visual angle to the left or right of the center of the screen. Two degrees is the minimal visual angle which is required to allow the linguistic processing load to be assumed by the hemisphere initially presented with the stimulus (e.g., Banich, 2002; Faust, Bar-Lev, & Chiarello, 2003; Schwint, 2007). There were 40 filler passages included to distract participants from the format of the experimental trials. There were also four practice trials at the beginning of each list and these trials were the same format as the filler trials (described below).

Procedure. Participants were shown an example of the visual stimuli that would be presented to them throughout the study and were instructed to not blink or move their eyes during the presentation of the words in the second sentences. Each trial began with the first sentence presented to participants in its entirety on the screen, which the participants were instructed to read in its entirety at their own pace. Once they had completed reading the first sentence, they pressed a button to start the rest of the trial. Following the button press, a "+" symbol appeared for 2000 ms, followed by a blank screen for 500 ms, before the sequence began. The second sentence was presented in the center of the screen, one word at a time (500

ms total, 300 ms/word, 200 ms blank screen), with the target word (second word of the sentence) being presented to the LVF or RVF. A fixation point was present for the entire duration of the sentence, just below the stimuli words and with a lower brightness. Participants were instructed to keep their eyes fixated on the center of the screen, using the fixation point as a guide, throughout the duration of the sentence. This was to ensure they did not move their eyes during the presentation of the lateralized target item. Randomly interspersed throughout the experimental passages were the 40 filler passages. In these passages, a word in the second sentence (that was never the second word) was presented to the LVF or RVF. This helped to reduce the predictability of the lateralized presentation of the target words. Comprehension questions were administered throughout the experiment (60 in total, 50% "yes") to ensure participants were reading carefully. After completing the practice trials participants were given the opportunity to ask any questions or clarifications of the process and the instructions were reiterated. Participants were informed that they could take a break at any time between trials to rest for brief periods. Each experimental session was no longer than 1 hour and 30 minutes, with an approximate average time of 1 hour and 15 minutes.

Recording and analysis. The EEG was recorded with a cap with 64 Ag/AgCl electrodes that were distributed evenly across the scalp. The same 25 electrodes examined for analysis in Experiments 1 and 3 were used (Figure 1). Eye-movements and blinks were monitored by placing electrodes on the outer canthii and the left infra and supra orbital ridge of each participant's eye. Electrode impedances were kept below 5 KΩ, and the EEG was processed through a Neuroscan Synamps2 amplifier set at a bandpass of 0.05-100 Hz and digitized at 250 Hz.

Design. Separate 4-way ANOVAS were conducted for the mean amplitudes at the N1 region (100-200ms), P2 region (200-300 ms), N400 (300-500 ms), extended N400 (500-650 ms), and Late Positivity/LPC (750-1000 ms). The main variables of interest were type of Relation (Match, Mismatch, General, Indeterminate), Visual Field/Hemisphere (LVF/RH, RVF/LH), Anteriority (prefrontal, frontal, central, parietal, occipital), and Laterality (left lateral, left medial, midline, right medial, right lateral). All these variables were within-participant. Experimental List was a between-participant variable that was included to help stabilize variance caused by assigning participants across the four lists (Pollatsek & Well, 1995). Note that the List variable has no theoretical interest and therefore is not discussed in the results presented below. Results for the topographical variables are only discussed if they interacted with relation type. All *p*-values below are reported after Epsilon correction (Huynh-Felt) for repeated measures with greater than one degree of freedom.

Results

The EEG data was re-referenced off-line to the average of the right and left mastoids. A low-pass filter set at 30 Hz was applied to remove high frequency noise. ERPs to the target word in the second sentence were epoched from 100 ms before target to 1000 ms after its onset. All trials contaminated by excessive muscle activity, eye-movements, and blinks were removed before averaging (14.87% of trials). Figures 12 and 13 show the results at the different electrode sites used in the analysis for each hemisphere, and Tables 23-30 in Appendix C list the mean amplitudes and results of the ANOVAs.

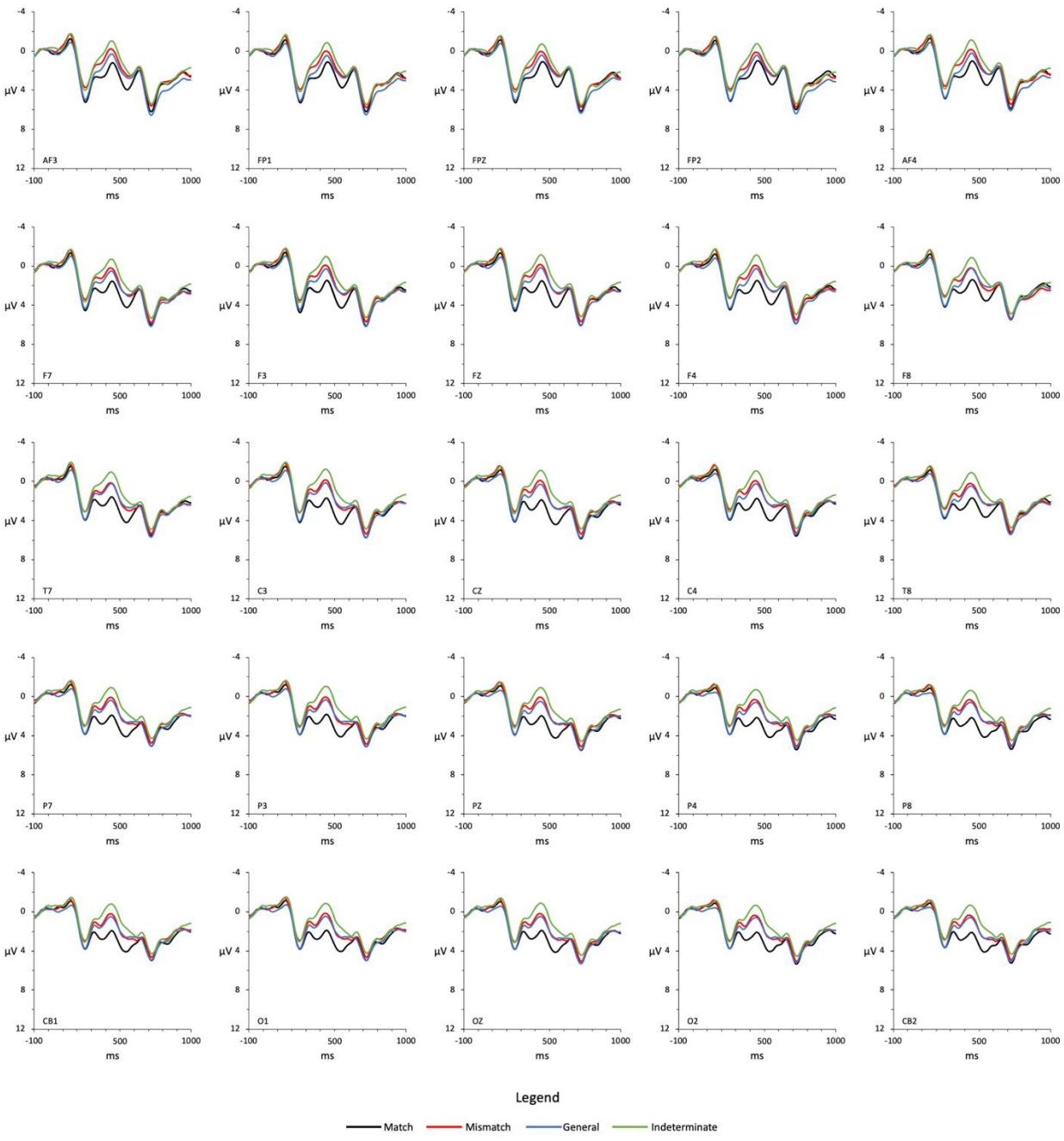

Figure 12. Mean EEG amplitudes at each electrode location for target stimuli presented to the left hemisphere.

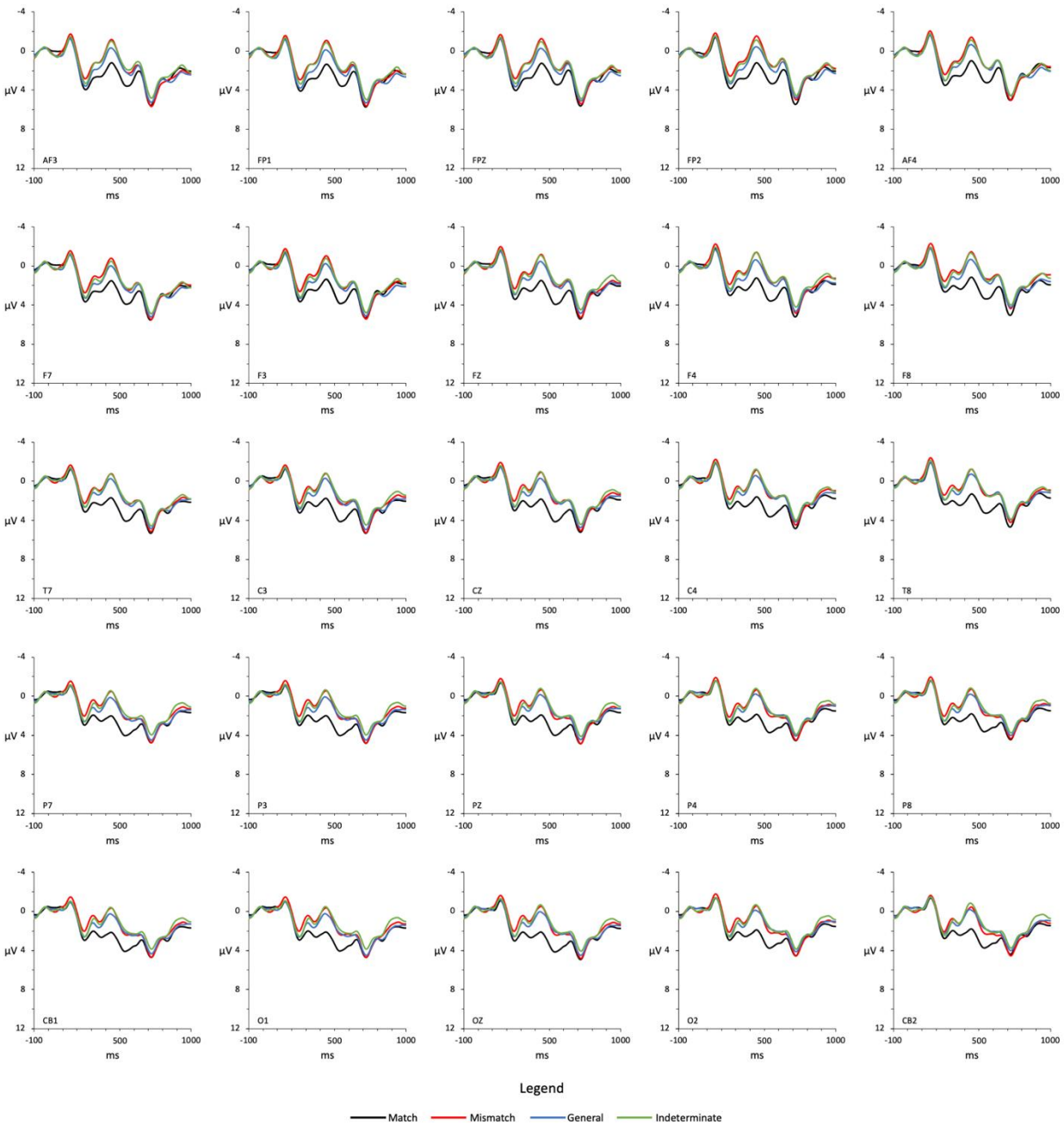

Figure 13. Mean EEG amplitudes at each electrode location for target stimuli presented to the right hemisphere.

N1 (100-200 ms). The N1 region was investigated to verify that target words were initially processed in the contralateral hemisphere. As expected, there was a significant interaction of Visual Field and Laterality, $F(4, 312) = 20.88$, $p < .001$, $\eta_p^2 = .21$. When targets

were presented to the LVF/RH, amplitudes were more positive for the left lateral (*M* = -.73 μV), followed by the left medial (*M* = -.746 μV), medial (*M* = -.89 μV), right medial (*M* = -1.04 μV), and right lateral (*M* = -1.11 μV) electrodes. When targets were presented to the RVF/LH, amplitudes were more positive for the right lateral (*M* = -.76 μV), right medial (*M* = -.75 μV), medial (*M* = -.82 μV), and then the left medial and left (*M* = -.91 μV) electrodes. This result indicates that the lateralization presentation was successful, and that those items presented to the LVF were initially processed in the RH, and vice versa for the RVF/LH.

P2 (200-300 ms). There were no significant or marginal effects involving the type of relation in this region.

N400 (300-500 ms). The main effect of Relation Type was significant, $F(2, 234) = 5.96$, $p < .001$, $\eta_p^2 = .07$. Mean amplitudes to matching targets were more positive (*M* = 2.24 μV) than general category targets (*M* = 0.94 μV), $F(1, 234) = 5.93$, $p < .02$, $\eta_p^2 = .02$, mismatching targets (*M* = 0.49 μV), $F(1, 234) = 11.00$, $p < .002$, $\eta_p^2 = .04$, and indeterminate targets (*M* = 0.15 μV), $F(1, 234) = 15.43$, $p < .001$, $\eta_p^2 = .06$. No other comparisons were marginal or significant.

The interaction of Relation and Anteriority was also significant, $F(12, 936) = 2.67$, $p < .04$, $\eta_p^2 = .03$. At all electrode sites, the matching targets produced more positive amplitudes than the general category, mismatch, and indeterminate targets (all p's < .006). The interaction itself was driven by the decreased difference between the general category and mismatch, and mismatch and indeterminate amplitudes at the posterior regions in comparison to the significant differences seen between those relations in the more frontal and central electrode sites. General category targets had significantly more positive amplitudes than both the mismatch and indeterminate targets in the frontal regions (all *p*'s < .02), and then continued to be significantly more positive than the indeterminate condition at the parietal (*p* <. 004) and occipital (*p* < .005)

sites. However, general category targets were only marginally more positive than mismatching at the parietal ($p < .06$) and occipital ($p < .07$) sites. The mismatch targets led to significantly more positive amplitudes at the prefrontal and central electrode sites than the indeterminate targets (all p's < .05) and were marginally more positive at parietal and occipital locations (all p's < .1).

Importantly, there was a marginal four-way interaction of Visual Field, Relation, Anteriority, and Laterality, $F(48, 3744) = 1.52$, $p < .08$, $\eta_p^2 = .02$. To further examine this interaction, separate analyses were performed for each VF/hemisphere.

LVF/RH. When targets were presented to the LVF/RH, there was a significant main effect of Relation, $F(3, 216) = 13.54$, $p < .001$, $\eta_p^2 = .16$. Matching targets produced more positive amplitudes ($M = 2.19$ μV) than general category ($M = 0.69$ μV), $F(1, 216) = 17.35$, $p < .001$, $\eta_p^2 = .07$, indeterminate ($M = 0.26$ μV), $F(1, 216) = 28.74$, $p < .001$, $\eta_p^2 = .12$, and mismatching ($M = 0.17$ μV) targets, $F(1, 216) = 31.54$, $p < .001$, $\eta_p^2 = .13$. No other comparisons were marginal or significant.

There was also a significant interaction of Relation and Laterality, $F(12, 864) = 2.13$, $p < .05$, $\eta_p^2 = .03$. At all locations, matching targets produced the most positive amplitudes, significantly more so than the general category targets (all p's < .001), the indeterminate (all p's < .001) and mismatching targets (all p's < .001). The general category targets led to significantly more positive amplitudes than the indeterminate (all p's < .04) and mismatching (all p's < .001) targets. However, the indeterminate targets produced significantly more positive amplitudes than the mismatching targets over the left and left medial (all p's < .04) but only marginally at the midline ($p < .07$), and there were no significant or marginal differences for the right and right medial.

There was a marginal three-way interaction between Relation, Anteriority, and Laterality, $F(48, 3456) = 1.52$, $p < .06$, $\eta_p^2 = .02$. At all electrode sites, matching targets led to more positive amplitudes than the general category, indeterminate, and mismatching targets (all *p*'s < .001). General category relations also resulted in significantly more positive amplitudes than the indeterminate and mismatch targets at all locations (all *p*'s < .003). At the prefrontal electrode sites, the indeterminate targets led to more positive amplitudes over the mismatching targets (all *p*'s < .08), with the exception of the left prefrontal which did not show a significant difference. At the frontal electrode sites, the indeterminate targets led to significantly more positive amplitudes over the mismatching targets at the frontal and medial frontal of the left and left medial (all *p*'s < .003), but only marginally so at the frontal midline ($p < .07$). At the occipital electrode sites, the mismatching targets led to significantly more positive amplitudes over the indeterminate targets in the right and right medial ($p < .03$). No other comparisons were marginal or significant. Thus, this interaction is the result of the significant differences between the indeterminate and mismatching relations amplitudes (with indeterminate leading to more positive amplitudes) at more frontal than anterior electrode sites (particularly over the LH), and because mismatching targets resulted in more positive amplitudes than Indeterminate targets towards the back of the head over the RH.

RVF/LH. There was a significant main effect of Relation, $F(3, 216) = 15.02$, $p < .001$, $\eta_p^2 = .17$. Matching targets produced significantly more positive amplitudes ($M = 2.29$ μV) than general category ($M = 1.2$ μV, $\eta_p^2 = .05$), mismatching ($M = 0.82$ μV, $\eta_p^2 = .08$), and indeterminate ($M = 0.03$ μV, $\eta_p^2 = .17$) targets (all *p*'s < .002). The general category targets led to more positive amplitudes than the indeterminate targets, $F(1, 216) = 11.52$, $p < .001$, $\eta_p^2 = .05$,

and the mismatching targets also elicited more positive amplitudes than the indeterminate targets, $F(1, 216) = 5.23$, $p < .03$, $\eta_p^2 = .02$. No other comparisons were marginal or significant.

There was also a significant interaction of Relation and Anteriority, $F(12, 864) = 2.79$, $p < .03$, $\eta_p^2 = .04$. There were significant differences between relations at all levels of anteriority following the trend of matching relations producing significantly more positive amplitudes than the general category (all p's < .001), followed by mismatching (all p's < .001), and then indeterminate targets (all p's < .001). Again, at all anteriority sites the mismatching targets led to significantly more positive amplitudes than the indeterminate targets (all p's < .001). The general category relations led to significantly more positive amplitudes than the mismatching (all p's < .05) and indeterminate (all p's < .001) relations. However, the comparison of the general category and mismatching targets are where the anteriority effects become apparent. Across each anterior location there are noticeable differences, with a pattern of a larger difference in the areas of the prefrontal, $F(1, 864) = 24.42$, $p < .001$, $\eta_p^2 = .03$, and frontal, $F(1, 864) = 12.83$, $p < .008$, $\eta_p^2 = .01$, to the central, $F(1, 864) = 8.11$, $p < .03$, $\eta_p^2 = .01$, and parietal, $F(1, 864) = 7.48$, $p < .03$, $\eta_p^2 = .01$, and becoming less different, although still significantly so, at occipital locations, $F(1, 864) = 5.39$, $p < .05$, $\eta_p^2 = .01$.

A significant three-way interaction between Relation, Anteriority, and Laterality was also found, $F(48, 3456) = 1.56$, $p < .05$, $\eta_p^2 = .02$. The matching targets produced significantly more positive amplitudes than the general category, mismatching, and indeterminate targets at all electrode sites (all p's < .001). As well, the general category targets were significantly more positive than the indeterminate (all p's < .001) targets, and the responses to the mismatching targets were also significantly more positive than the indeterminate (all p's < .001) targets. However, as was seen in the two-way interaction above, the general category and the

mismatching contrasts varied across electrode locations at anterior versus more posterior electrode locations. The general category targets always lead to significantly more positive amplitudes than the mismatching targets, with most *p*'s < .008. However, the size of the difference was much smaller at electrodes located centrally ($p < .05$). No other comparisons were marginal or significant.

Extended N400 (500-650 ms). The main effect of Relation Type was significant, $F(2, 234) = 3.66$, $p < .02$, $\eta_p^2 = .04$. Mean amplitudes to the matching targets were significantly more positive ($M = 3.32$ µV) than mismatching targets ($M = 2.2$ µV), $F(1, 234) = 6.37$, $p < .02$, $\eta_p^2 = .03$, general category targets ($M = 2.17$ µV), $F(1, 234) = 6.56$, $p < .02$, $\eta_p^2 = .03$, and indeterminate targets ($M = 1.78$ µV), $F(1, 234) = 8.71$, $p < .004$, $\eta_p^2 = .04$. No other comparisons were marginal or significant.

The interaction between Relation and Laterality was significant, $F(12, 936) = 2.56$, $p < .02$, $\eta_p^2 = .03$. At all electrode sites, matching targets produced a significantly more positive amplitudes than the general category, mismatching, and indeterminate targets (all p's < .001). General category targets produced more positive amplitudes than indeterminate targets at the left, left medial, and medial regions (all *p*'s < .03) and was marginally more positive at the right medial ($p < .06$). Mismatching targets were significantly more positive than indeterminate targets at the left, left medial, right, and right medial electrode sites (all *p*'s < .03). No other comparisons were marginal or significant.

There were no marginal or significant findings when compared with the Visual Field at the extended N400, indicating that there were no hemispheric differences during this time frame.

Late Positivity/LPC (750-1000 ms). The main effect of Relation did not reach significance, $F(3, 234) = 1.07$, $p = .36$. There was a trend whereby general category targets ($M =$

2.58 μV) produced the most positive amplitudes, followed by matching targets (*M* = 2.53 μV), mismatching targets (*M* = 2.38 μV), and indeterminate targets (*M* = 2.13 μV). Relation did not interact significantly or marginally with any other variable in this region.

Discussion

The main goal of this experiment was to examine referential processing between the hemispheres and investigate the construction of situation models in the separate hemispheres. In particular, how the four relations of match, mismatch, general category, and indeterminate may be processed differently in the left and right hemisphere. Towards this end the results showed distinct differences between the hemispheres in the N400 ERP region, which will be discussed in detail below.

An important point to make first is that the N1 component led to a significant interaction of Visual Field and Laterality. This is important to note as the N1 component presents more negative amplitudes when a visual stimulus is detected by the reader (Federmeier et al., 2005), and as the key stimuli in the present study was presented using the VHF technique this interaction provides evidence that the VHF technique worked as intended within the experiment.

As was previously mentioned, the main effect of interest in this experiment occurred during the N400 component. When examining the N400, a significant effect of Relation was found, with the match conditions producing a more positive amplitude than the general category, indeterminate, and mismatch targets. These results show that the most negativity was produced for the mismatch relations, indicating that having the target word in sentence two mismatch with the coinciding target in the first sentence was the least expected semantically, as the N400 is an indication of semantic congruency with antecedents (Anderson & Holcomb, 2005). This was followed by a less negative mean amplitude in the indeterminate condition, when no coinciding

target word was provided in sentence one, and then the general category condition, when the target word in sentence two was within the category provided in sentence one. Such findings align with the Relation findings from previous chapters in this dissertation as well as with prior research (Ferretti et al., 2013), as was predicted.

The current research found that when targets were presented using the VHF technique there was a significant main effect of Relation at the N400 in each hemisphere, although the pattern of amplitudes were different. When targets were presented to the LVF/RH the matching targets produced significantly more positive mean amplitudes than general category, indeterminate, and mismatching targets. As well, when targets were presented to the LVF/RH there was a significant difference between the relations at most lateral locations showing a trend of matching relations producing the most positive amplitudes, followed by general category, and then indeterminate and mismatch. Overall, when targets were presented to the RH, at most electrode sites there is no difference between the indeterminate and mismatch relations. This indicates that although the RH is also sensitive to semantic congruency, there is no difference in congruency between a target that mismatches with its relevant antecedent and when no antecedent being present at all. In this regard, the present N400 results for targets presented to the RH more closely resemble the results in Experiment 1 with central presentation of words.

A similar result was found when targets were presented to the RVF/LH, with significant differences between relations at all anteriorities following the trend of match relations producing the most positive amplitudes, followed by general category, mismatch, and then indeterminate. However, a key difference is that overall, when the targets were presented to the LH, the indeterminate relation was significantly more negative than the mismatch condition at all electrode sites. This finding suggests that unlike the RH, the LH is perceiving the difference

between a target mismatching with the previous antecedent, and when no antecedent was provided. There are several possible explanations for such a finding: as the LH is the dominant hemisphere for language processing (e.g., dos Santos et al., 1991), this result may be due to increased ability for distinction in discourse processing within the LH. It has also been found that the LH processes more locally and only keeps active the most recent concept (Gouldthorp, 2015). Since in the present research the target and relevant antecedent are in immediately occurring sentences, this result could be evidence of the LH's local processing of very recent concepts. However, as previous research has found that the LH is more predictive than the RH (e.g., Federmeier & Kutas, 1999, Federmeier et al., 2005), this is the most likely what is driving this difference between the hemispheres. The LH is using the provided features of the antecedent to predict the upcoming object within the situation model. Even when a mismatching term is provided, the LH still uses that information to form predictions over no information at all, as even with the mismatching relation the predicted object is still something of the same category and therefore has certain features that may be activated for expectation (e.g., truck and bus both fall into the category of vehicle and share features such as tires, steering wheel, doors, windows, mirrors). This predictive activation is not present during the same instances within the RH. As such, it can be concluded that the LH is indeed more predictive than the RH, even when the provided information conflicts with what was previously known.

No significant differences in P2 component were found in the current study. In past research, the P2 has sometimes been found when targets are presented to the LH in highly predictive sentence contexts (Federmeier et al., 2005). However, as was mentioned in our predictions, although the use of the definite article in this study adds a certain level of contextual constraint, overall, the sequences presented were not highly constrained.

The extended N400 results revealed that when presented with the match relations the mean amplitudes during this time frame were significantly more positive than the mismatch, general category, and indeterminate relations. As the extended N400 reflects the integration costs of high semantic incongruency or expectancy (Burkhardt, 2006; Ferretti et al., 2008), it was expected that the indeterminate condition would lead to more negative amplitudes than all other relations. However, there were no significant differences found between any of the indeterminate, general category, or mismatch relations overall. This may suggest that although all these relations are more difficult to integrate than a matching relation, due to the sematic incongruency, but there are no differences in difficulty between them for integration. This was as hypothesized, due to the lack of strength in the expectancy values within the relation manipulation. While the use of a definite article preceding the target stimuli does impart a certain amount of expectancy, it is not a strong enough constraint to elicit a true response during the extended N400.

A significant interaction between Relation and Laterality was also found during the extended N400. Generally, it was found that match targets produced higher mean amplitudes than general category, mismatch, and indeterminate targets at all electrode sites, indicating that the match relations do not involve as much integration cost as the other relations, which do not directly coincide with the antecedents, as expected. However, the general category relation produced more positive amplitudes than indeterminate at the left medial, and medial. This may indicate that the LH can process the connection between the general target and relevant antecedent with more ease than the RH, which has activation spreads further to less related topics (e.g., Beeman, 2005), thus requiring more processing costs. In the end, it is difficult to make

hemispheric conclusions for this component, as no significant interactions of the Visual Field presentation was found.

As with the previous studies in this dissertation, the effect of Relation did not reach significance during the LPC, which is an indication of the integration costs when updating information into the situation model (Burkhardt, 2005, 2006; Ferretti et al., 2008). The mean amplitudes showed that the general category sequences did produce the most positive amplitudes, followed by the match, mismatch, and indeterminate relations. The general category being the most positive aligns with the results Experiment 1, again implying that the process of updating the general category concepts to be more specific within the situation model produced more difficulty than when incorporating an entirely new discourse token. However, in the present study it was found that the indeterminate relation produced the least positive amplitudes, implicating that the least amount of updating occurred in this condition. This conflicts with the results of Experiment 1, which showed the indeterminate having the second most positive amplitudes, following the general category. This was also seen within the interaction of the Visual Field and Relation. This interaction of Visual Field and Relation also did not reach significance in the LPC. However, when presented to the RVF/LH there was a trend that aligned with the main effect of relation: general category was most positive, followed by match, mismatch, and indeterminate. Conversely, when the targets were presented to the RH it elicited a response pattern that does not align with the LH or even with the centralized target findings of Experiment 1. The LVF/RH condition saw a slight difference from the RVF/LH, with the match targets producing the highest mean amplitude, followed by the general category, mismatch, and then the indeterminate. This finding that in each hemisphere the indeterminate relations are not updated within the situation model may be an indication that both hemispheres are required to be

processing the indeterminate relation to antecedents simultaneously for it to be updated into the situation model. Kandhadai and Federmeier (2010) showed that at the LPC the LH had an advantage over the RH for low-predictability words. Beeman et al. (1994) found that the LH responds faster to strongly associated word-pairs than the RH, however, it has also been shown that the RH contributes to the integration of perceptual information during reading (Male & Gouldthorp, 2020). As the indeterminate condition in the current experiment provided a target with no prior antecedent, it may be that the hemispheres cannot process if appropriately without working together. This result supports previous research findings that both hemispheres work together for proper discourse comprehension, as the hemispheres cooperate in discourse processing when neither hemisphere can perform the task alone (Wlotko & Federmeier, 2007), and that both are involved in predictive sentence comprehension (Delong & Kutas, 2016).

To summarize, it was found that the VHF technique administered in this experiment was successful in ensuring that the targets were processed first within the corresponding hemisphere. No significant P2 effects were found, most likely due to the lack of constraining contexts within the current experimental stimuli. The N400 findings reinforced previous research that the LH is more predictive than the RH (e.g., Federmeier et al., 2005), as shown by the indeterminate relations eliciting significantly more negative responses than the mismatching relations in the LH but not the RH. The extended N400 results were as predicted, in that there were no significant differences seen between the mismatching, general category, and indeterminate conditions as a result of a weaker level of expectancy in the present stimuli than seen in previous research (e.g., Ferretti et al., 2013). Also as predicted, the LPC results did not reach significance. This mirrors the findings in Experiment 1 but could also be emphasized by the separation of the hemispheric

processing in the present study, as it has been shown previously that both hemispheres work in conjunction to perform successful discourse processing (e.g., Wlotko & Federmeier, 2007).

In conclusion, the present research provided unique understanding of how discourse processing within each hemisphere occurs. Further insight was gained into how each hemisphere processes targets with the relations of match, mismatch, general category, and indeterminate to antecedents in the sentence prior, and how these targets and their relations to the antecedents impact the potential updating of the present situation model at the neural correlate level. Novel results expanded upon the findings of the previous chapters in this dissertation to exemplify how each hemisphere processes these relations differently than when processing them in tandem. This research has added original information to the field of discourse processing and the study of hemispheric influences upon it.

Chapter 5: General Discussion

During reading a mental representation of the information in the text is built, called a situation model (van Dijk, & Kintsch, 1983). It has been shown that readers have more difficulty updating their situation models when new information is inconsistent with the current model under construction (Zwaan & Madden, 2004), which suggests that readers keep track of situations as they evolve and update their situation models accordingly. In this dissertation four coreferential relations were examined: when text ideas are consistent with the antecedent (match), when they are inconsistent (mismatch), when the original text ideas are underspecified (general category), and when no previous text idea is provided (indeterminate). Although these relations have been examined in previous works (e.g., Cook, Myers, & O'Brien, 2005; Ferretti et al., 2008, 2013; Singer, 2006, 2009), they had never been compared together within a single experiment before. This meant that prior to the current research the relative differences in integration costs, and how these relations are incorporated into the situation model, was unknown.

Electrophysiological Responses to the Different Relations

The present research investigated the electrophysiological response generated when text ideas varied in consistency with the situation models constructed during online language comprehension. The goal was to establish a better understanding of the four types of referential relations on situation model processing and updating. Examining the electrophysiological responses during online discourse processing provided insight into these relations. Throughout the research, the neural correlates of discourse processing were assessed through the use of sentence pairs, which reduced the possibility of other variables (such as LTM searches or

degradation of information with time, see Ericsson & Kintsch, 1995; Magliano & Schleich, 2000) impacting the results.

Another factor that was analyzed was the impact of the grammatical article used to refer to the target stimuli. Definite articles (such as *the*) tend to be implemented to reactivate specified referents already within the discourse, but indefinite articles (like *a/an*) are used to introduce new referents (Kidd & Bavin, 2007). This research explored the differences in discourse integration and situation model building for both definite and indefinite articles, with a specific focus on the four target-antecedent relations described above.

The final purpose of this dissertation was to examine how each hemisphere processes these four target-antecedent relations using the VHF technique (Banich, 2002). Both hemispheres have been shown to process language, separately and together (e.g., dos Santos et al., 1991; Johns, Tooley, & Traxler, 2008). As such, it was also a goal of this research to determine any differences that may be present between the left- and right-hemispheres during situation model updating, and if the different levels of matching between the target and the antecedents would be processed differently when not presented in a centralized fashion. The key findings of this dissertation are highlighted below.

P2. In Experiment 1, when a definite article preceded the target stimuli, the match and general category conditions elicited similar amplitudes, but both led to significantly more positive amplitudes than the mismatch and indeterminate conditions. However, as the P2 effects in Experiment 1 did not interact with the topographical regions, and true P2 effects are inclined to be more frontal and central (e.g., Ferretti et al., 2013), it was considered to be a leading edge of the significant N400 results found. As well, no P2 effect had been predicted as it is influenced by the level of truth and factivity in the discourse (Ferretti et al., 2008) and the present research

did not manipulate either. Nevertheless, the use of the definite article may still have influenced the P2, given that it does provide a level of presupposition to the target (Singer, 1976), leading to an earlier impact of the target's relation to its antecedent. In Experiment 3, when the indefinite article preceded the target, no significant differences between the four relations emerged at this component. There were also no significant P2 findings in Experiment 5 when the stimuli were presented laterally to each hemisphere. The lack of significant findings in these later chapters, particularly Experiment 5 which also used the definite article, emphasizes that the significant result seen in Experiment 1 was likely not a true P2 effect.

N400. The results of Experiment 1 showed that when the definite article is used the indeterminate and mismatch conditions were the least semantically congruent with the emerging situation model, suggesting that incorporating a novel concept into a situation model is equally as difficult as when there is a potential antecedent that mismatches the key target. The general category and match conditions were more semantically congruent with the pre-existing situation model, with the matching targets being the most congruent, as expected given that words with less semantic match elicit stronger N400 responses (Anderson & Holcomb, 2005).

With the use of the indefinite article, it was found that the indeterminate relations produced the most negative N400, and therefore the least amount of semantic expectancy (Kutas & Hillyard, 1980), followed by general category concepts, mismatching targets, and matching concepts. As the indeterminate condition is introducing an entirely new concept into the model, this finding was expected. The fact that the mismatching referents were considered more congruent than the indeterminate items showcases that the impact of the mismatch relation was mitigated by the fact that the indefinite article does not indicate a specific coreferential relationship with an antecedent (Anderson & Holcomb, 2005; Lyons, 1977).

When directly comparing the N400 results of the definite and indefinite article use it was found that overall, the definite article led to more negative amplitudes than the indefinite article. Although there was no significant interaction between Relation and Article Type, the pattern of the results indicated that the indefinite article creates less of an expectancy for concepts in the event than the definite article, and this will result in the mismatching condition being more acceptable within the model. This was emphasized by the leading edge of the N400 beginning earlier with the definite article (see P2 discussion above), but not the indefinite.

In Experiment 5 it was found that in the RH the mismatching and indeterminate relations led to the most negative N400 amplitudes, followed by the general category, and then matching concepts. The lack of difference between the indeterminate and mismatch concepts indicates that, even though the RH has been shown to be sensitive to semantic congruency (Federmeier & Kutas, 1999), these relations were not considered to have different congruencies within the RH. Comparatively, in the LH the most negative N400 response was found in the indeterminate condition, followed by the mismatch, general category, and matching. The key difference was that when a novel concept was introduced into the situation model there was significantly less semantic congruency than when a mismatching target was processed in the LH, unlike in the RH where they were equal. This difference suggests that the LH is sensitive to the difference between a target mismatching with the previous antecedent, and when no antecedent was provided, unlike the RH. This difference could be due to a number of reasons: the LH is more predictive than the RH (Federmeier et al., 2005), the LH is the dominant hemisphere of language processing (e.g., dos Santos et al., 1991) and therefore has an increased aptitude for distinction in discourse processing, or that the LH processes more locally and only keeps active the most

recent concept (Gouldthorp, 2015) and this result could be evidence of the LH's local processing of recent concepts (since the target and antecedent are in immediate sentence pairs).

Extended N400. When a definite article was used (Experiment 1) the most negativity at the extended N400 was seen in the indeterminate relations, followed by the mismatching, and then the general category and matching conditions, which were not significantly different. As such, the integration costs for adding an entirely new concept into the situation model was higher than all other conditions, likely due to the unexpected nature of a novel concept (Burkhardt, 2006; Ferretti et al., 2008). Interestingly, the required effort to integrate matching and underspecified but categorically similar antecedents into the model was the same, showing an ease of updating a general target to become a specific one.

In Experiment 3 it was found that, when the indefinite article preceded the target stimuli, the general category relation led to the most negative extended N400 response, followed by the indeterminate, mismatch, and then the matching relation. This signifies that the use of an indefinite article actually decreased the expectancy of the general category targets, leading to higher integration costs then seen with the definite article. It appears that the ambiguous nature of the indefinite article made it less obvious that the underspecified antecedent and the specific target were coreferential, leading to higher integration costs from the resulting search for the appropriate co-referent.

When comparing the definite and indefinite results at the extended N400, it was found that the definite article allowed the increased difficulty of integrating general category concepts seen in the N400 to become resolved quickly in the extended N400 region, however integration costs remained the same for mismatching and indeterminate concepts. On the other hand, having the indefinite article preceding the target lowered the expectancy levels for specific targets

within the situation model, resulting in an ease of integration for those targets that have less overlap with preciously introduced concepts. As such, the general category condition had the most negative amplitudes during this component. This could be due to the indefinite article leading to an increased level of ambiguity to the general category concepts, as they become less obviously connected to a particular antecedent and potentially representing a new token in the model, leaving a contradiction that the reader must resolve (Beeman et al., 2000).

The results of Experiment 5, when presenting the stimuli to each hemisphere, it was found that the matching relation was less negative than all other relations, indicating the lack of integration cost required as was expected. As a main effect, no significant differences emerged between the mismatching, general category, and indeterminate relations. This lack of difference between these relations at the extended N400 was most likely due to the stimuli in the current studies having lower levels of expectancy than previous research where factivity was manipulated (e.g., Ferretti et al., 2013). There was an interaction of relation and laterality, showing that the indeterminate concepts led to more negative amplitudes that the general category ones at the left and left medial electrode sides. As activation spreads further and to less related topics within the LH (Beeman, 2005), this finding could be an indication of this increased spread making it easier to process the general category concepts. However, it is important to note that no significant interaction with the Visual Field presentation was found, making it difficult to ascertain hemispheric conclusions for this component.

Late Positivity. At no point throughout this dissertation did the main effect of Relation reach significance at the LPC. However, in Experiment 3 a marginally significant comparison was found showing that mismatching relations resulted in more late positivity than indeterminate relations. This indicated that when following an indefinite article, a target that mismatched the

relevant antecedent is more likely to induce updating to the situation model, compared to when an entirely novel target is introduced (e.g., Burkhardt, 2005; Ferretti et al., 2008). No such distinction was seen when the definite article was used to refer to the target stimuli, or between the hemispheres.

Sentence Completion Interpretations of the Different Relations

The next major goal of this dissertation was to gain insight into *how* exactly it is that people are interpreting the discourse relations that led to the above electrophysiological responses. To achieve this, behavioural responses in the form of sentence completion surveys were examined to develop an understanding into how precisely it is that readers integrate the targets with either matching, mismatching, general category, and indeterminate relations to the antecedents into their pre-existing situation models.

Match. In Experiment 2 when the definite article was used, matching relations led readers to overwhelmingly be more likely to consider the target to be coreferential with the relevant antecedent, with hardly any responses taking the target to be coreferential with a different antecedent and almost no responses considering it as an entirely new token in an unrelated event. The use of the indefinite article in Experiment 4 did have an impact. The majority of match relations still leading the reader to consider the target as being coreferential with the relevant antecedent, however it was 18% less likely than when the definite article was used. Instead, there was an almost 16% increase in matching targets being considered to be wholly unrelated to the antecedent and even the original event.

Mismatch. When a mismatching token was preceded by the definite article in Experiment 2, approximately half of completions involved incorporating the target concept into the same event as the first sentence, but as a new token in the situation model. Despite being a

different concept than the relevant antecedent in the first sentence, approximately a third of completions were coreferential with the antecedent. When the mismatching relation was preceded by an indefinite article in Experiment 4 an almost identical pattern was seen as that shown in the results of Experiment 2, with only a small increase in the number of completions considering the target to be a part of a new event entirely.

General Category. People typically produced continuations that were coreferential with the relevant antecedent in the first sentence when a general category relation was combined with the definite article (Experiment 2), although they did so less than for the matching condition. In contrast, when the general category condition was paired with the indefinite article (Experiment 4) it led people to typically produced continuations to target concepts that were coreferential with the relevant antecedent in the first sentence, although much less than when definite article used. There was also a ≥10% increase in completions that considered the general category target to be a new token within the same event, or a new token in an unrelated event when presented with an indefinite article, compared to definite.

Indeterminate. When presented with a definite article in Experiment 2, indeterminate relations typically incorporated the target concepts as a new concept in the event described in the first sentence, in almost 90% of cases. In Experiment 4, when an indefinite article was implemented, most continuations incorporated the target concepts as a new concept in the event described in the first sentence, although less so than with the definite article. This difference was instead found in the increased number of completions considering the indeterminate target to be a new token in a new event.

Sentence Completions Insight into the ERP Results

Through the combined results of the electrophysiological data and the sentence completions it was found that the article implemented had an impact on both how readers comprehend and process discourse information. It was found that the definite article led readers to take the target concept as coreferential with a specific concept in the preceding sentence to a greater degree than the indefinite article. The N400 findings showed that mismatching relations were less congruent and expected semantically than then matching and general category ones when preceded by a definite article, in comparison to the mismatching and general category N400 responses being similar following an indefinite article.

Participants considered the targets to be coreferential with a different antecedent in the same event most often when presented with a mismatching relation, regardless of the article type that was implemented, although it was slightly more for the indefinite article in total. The observed extended N400 amplitudes align with this finding, as the indefinite article decreased the expectancy for specific referents in the situation model (Lyons, 1977) and led to reduced cost of integration. The considerably higher number of responses taking the target to be co-referent with a different antecedent when an indefinite article is used is due to the indefinite article allowing easier selection of an appropriate co-referent, which is represented in the lower integration costs.

Completions considering the target concepts as being the same event, but with an entirely new token were most frequently seen for the indeterminate condition, as would be expected when introducing a new concept into the model. This was true for both articles, although more so when the definite article was applied, indicating that the nature of the definite article has an influence on the readers understanding that the new token being introduced is in some way related to the current model. The ERP findings during the P2 and the N400 represent this well, as together they indicate how the definite article so strongly leads to expectations about the model

and involved targets that the processing begins at a significantly earlier stage than then the indefinite article is used.

Indefinite articles preceding the key stimuli led to more completions with target concepts that were taken as a new token in an entirely different event than the use of definite articles, with an almost equal amount of this response for all relations. This showed the impact of the indefinite article and how it increases the available interpretations of the proceeding targets. The mismatch condition resulted in this completion type the most for the definite article. When looking at the ERP results, the N400 amplitudes following targets with a definite article were the most negative in the mismatching condition, which could be due to it being considered a part of a new event, rather than a mismatch with the existing model, and therefore not as conflicting.

When taken all together these findings reveal that overall, the indefinite article led readers to interpret the discourse less consistently, particularly when presented with an underspecified target that became more specific, which appears to have eased the integration of information into the situation model. In contrast, the definite article constrained the context enough that a more rigid understanding led to somewhat less variability in the interpretation of the relations.

Limitations and Future Directions

One of the limitations of the present research is that although a mismatching relation was presented, the mismatching items were still always of the same category (e.g., *truck* and *bus*, or *apples* and *oranges*). This would result in the items sharing a number of certain categorical features (such as both the truck and bus having wheels, windows, mirrors, and other vehicle related features). Having mismatching items that are truly different, not sharing similar features, could lead to different outcomes. It is possible that the effects seen in the results of the current

research would be similar, however it is also possible that changes would arise. For example, a larger N400 or extended N400 may be elicited, particularly when the indefinite article was used, and the mismatching condition led to similar N400 results as the general category relations. Another possible difference in the results could be when the definite article was applied, the completion results showed that most mismatching targets were considered to be a new token within the already existing event. If a mismatching target that shared no similar features to the antecedent was presented, more readers may consider such a target to be entirely unrelated, and a part of a new event, seeing less need to connect it to the present situation. As such, an addition of a "true" or entirely mismatched relation could be a beneficial next step in this line of research.

The benefits and reasons for using ERPs to examine the relations within this research were discussed previously. Although ERPs are faster than fMRI for direct, online analysis of activity during reading, and they do allow for a certain level of localization (due to electrodes covering the entire scalp), they do not provide as accurate or precise results in this manner that fMRI would. Although the exact experiments could not be reproduced using fMRI, adjustments could be made that would allow for comparable examinations. Findings from such examinations would add significant elaboration and therefore better understanding to the present results.

Another potential limitation of this research is the difference in ages between the ERP study participants and the completion study participants. The ERP experiments only examined those who were in the university community, due to availability, and therefore participants were, on average, in their late teens to early twenties. The completion experiments were available to all qualified users of MTurk and as such, an older group of participants were tested (averaging in the late thirties). Although the age limit was set to 60 years old in the completion experiments, to control for any age-related linguistic decline, there is still the potential for some differences

between these groups, and their perception of the stimuli, due to the differences in age. Future research should consider expanding the age group of the ERP experiments to better compare to ERP and completion findings.

Conclusion

As the four conditions in this research (match, mismatch, general category, and indeterminate) had never been directly contrasted together before, this dissertation provides novel neurocognitive data on how people integrate discourse concepts into situation models during language processing, both across and between the cerebral hemispheres. By adding the definite/indefinite article factor, the importance of grammatical nuances on the ease of mental processing of both the information read as well as how it may influence what information is integrated in the situation model (and what is discarded) was investigated. Understanding how situation models are updated is integral, as they are the ultimate goal of language comprehension and understanding the world more generally. The current work also provided an innovative aspect to this field of research: the sentence completion results. This provided insight into how exactly readers were interpreting the four relations, and therefore also into what the ERP responses were true indications of. This has widespread implications for future research in discourse processing and ERP methodology.

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Appendix A

Table 2. *Mean Amplitudes (μV) of Relation following a definite article (Experiment 1) for each time region of interest.*

Time Region	Relation			
	Match	Mismatch	General	Indeterminate
200-300 ms (P2)	4.14	3.58	4.04	3.42
300-500 ms (N400)	2.34	.48	1.02	.34
500-650 ms (extended N400)	3.08	2.24	2.76	1.98
750-1000 ms (LPC)	3.02	3.00	3.44	3.12

Table 3. *ERP P2 (200-300 ms) ANOVA results following a definite article (Experiment 1).*

Effect	df	Sum Sq	Mean Sq	*F*
Relation	3,204	659.03	219.68	4.37**
Anteriority	4,272	8163.94	2040.99	78.34****
Laterality	4,272	650.98	162.74	23.96****
Relation X Anteriority	12,816	10.83	.90	.92
Relation X Laterality	12,816	5.15	.43	1.01
Anteriority X Laterality	16,1088	355.77	22.24	8.08****
Relation X Anteriority X Laterality	48,3264	4.70	.10	.69

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 4. *ERP N400 (300-500 ms) ANOVA results following a definite article (Experiment 1).*

Effect	df	Sum Sq	Mean Sq	*F*
Relation	3,204	4515.99	1505.33	30.19****
Anteriority	4,272	3694.80	923.70	63.00****
Laterality	4,272	378.66	94.67	22.85****
Relation X Anteriority	12,816	23.78	1.98	1.57
Relation X Laterality	12,816	7.19	.60	1.08
Anteriority X Laterality	16,1088	133.21	8.33	5.42****
Relation X Anteriority X Laterality	48,3264	10.21	.21	1.18

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 5. *ERP Extended N400 (500-650 ms) ANOVA results following a definite article (Experiment 1).*

Effect	df	Sum Sq	Mean Sq	*F*
Relation	3,204	1335.55	445.18	5.80****
Anteriority	4,272	5523.77	1390.94	67.30****
Laterality	4,272	822.46	205.62	43.98****
Relation X Anteriority	12,816	28.11	2.34	1.27
Relation X Laterality	12,816	12.09	1.01	1.18
Anteriority X Laterality	16,1088	247.21	15.45	8.01****
Relation X Anteriority X Laterality	48,3264	8.74	.18	.69

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 6. *ERP Late Positive Component/LPC (750-1000 ms) ANOVA results following a definite article (Experiment 1).*

Effect	df	Sum Sq	Mean Sq	*F*
Relation	3,204	221.31	73.77	.68
Anteriority	4,272	11173.04	2793.26	90.91****
Laterality	4,272	903.66	225.91	30.05****
Relation X Anteriority	12,816	18.89	1.57	.83
Relation X Laterality	12,816	6.94	.57	.56
Anteriority X Laterality	16,1088	354.60	22.16	6.97****
Relation X Anteriority X Laterality	48,3264	12.45	.26	.75

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 7. *Percentage of completion types for each of the Relations following a definite article (Experiment 2).*

Type of Completion	Relation			
	Match	Mismatch	Category	Indeterminate
Coreferential with Relevant Antecedent	97.9%	31.7%	82.7%	-
Coreferential with Different Antecedent	1.6%	7.0%	4.0%	3.6%
Same Event, New Discourse Token	-	47.7%	7.2%	87.3%
Different Event, New Discourse Token	0.5%	13.6%	6.1%	9.1%

Table 8. *Completion ANOVA Results of Relation following a definite article (Experiment 2).*

Completion Type	df	Sum Sq	Mean Sq	*F*
Coreferential with Relevant Antecedent	2,224	28.87	14.44	1574.26****
Coreferential with Different Antecedent	3,336	.18	.06	23.94****
Same Event, New Discourse Token	2,224	38.56	19.28	2132.44****
Different Event, New Discourse Token	3,336	1.09	.36	62.94****

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Appendix B

Table 9. *Mean Amplitudes (μV) of Relation following an indefinite article (Experiment 3) for each time region of interest.*

Time Region	Condition			
	Match	Mismatch	Category	Indeterminate
200-300 ms (P2)	5.75	5.86	5.82	5.73
300-500 ms (N400)	3.06	2.01	1.90	1.25
500-650 ms (extended N400)	4.03	3.87	1.90	3.16
750-1000 ms (LPC)	4.21	4.82	4.74	4.12

Table 10. *ERP P2 (200-300 ms) ANOVA results following an indefinite article (Experiment 3).*

Effect	df	Sum Sq	Mean Sq	*F*
Condition	3,168	11.89	3.96	.98
Anteriority	4,224	6782.76	1695.69	86.74****
Laterality	4,224	123.73	30.93	8.93****
Condition X Anteriority	12,672	29.61	2.47	1.84
Condition X Laterality	12,672	4.95	.41	1.37
Anteriority X Laterality	16,896	71.42	4.64	2.37*
Condition X Anteriority X Laterality	48,2688	5.64	.12	.96

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 11. *ERP N400 (300-500 ms) ANOVA results following an indefinite article (Experiment 3).*

Effect	df	Sum Sq	Mean Sq	*F*
Condition	3,168	2483.99	823.00	13.57****
Anteriority	4,224	4839.63	1209.91	91.04****
Laterality	4,224	85.31	21.33	12.55****
Condition X Anteriority	12,672	28.42	2.37	1.69
Condition X Laterality	12,672	6.36	.53	1.78
Anteriority X Laterality	16,896	81.51	5.10	4.32****
Condition X Anteriority X Laterality	48,2688	7.67	.16	1.06

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 12. *ERP Extended N400 (500-650 ms) ANOVA results following an indefinite article (Experiment 3).*

Effect	df	Sum Sq	Mean Sq	*F*
Condition	3,168	4211.91	1403.97	15.76****
Anteriority	4,224	5080.80	1270.2	73.78****
Laterality	4,224	143.82	35.95	17.30****
Condition X Anteriority	12,672	58.26	4.86	2.51*
Condition X Laterality	12,672	17.32	1.44	3.55***
Anteriority X Laterality	16,896	103.65	6.48	4.51****
Condition X Anteriority X Laterality	48,2688	13.27	.28	1.31

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 13. *ERP Late Positive Component/LPC (750-1000 ms) ANOVA results following an indefinite article (Experiment 3).*

Effect	df	Sum Sq	Mean Sq	*F*
Condition	3,168	560.87	186.96	1.67
Anteriority	4,224	10499.39	2624.85	72.80****
Laterality	4,224	170.45	42.61	11.09****
Condition X Anteriority	12,672	39.09	3.26	1.37
Condition X Laterality	12,672	5.63	.47	1.22
Anteriority X Laterality	16,896	136.46	8.53	3.13***
Condition X Anteriority X Laterality	48,2688	16.68	.35	1.18

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 14. *Percentage of completion types for each of the Relations following an indefinite article (Experiment 4).*

Type of Completion	Relation			
	Match	Mismatch	Category	Indeterminate
Coreferential with Relevant Antecedent	79.9%	27.1%	60.1%	-
Coreferential with Different Antecedent	3.8%	6.7%	3.9%	2.1%
Same Event, New Discourse Token	-	49.2%	19.9%	82.2%
Different Event, New Discourse Token	16.3%	17.1%	16.1%	15.7%

Table 15. *Completion ANOVA Results of Relation following an indefinite article (Experiment 4).*

Completion Type	df	Sum Sq	Mean Sq	*F*
Coreferential with Relevant Antecedent	2,224	17.08	8.54	588.01****
Coreferential with Different Antecedent	3,336	.13	.04	16.17****
Same Event, New Discourse Token	2,224	23.32	11.66	668.04****
Different Event, New Discourse Token	3,336	.01	.004	.47

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 16. *ERP P2 (200-300 ms) ANOVA results comparing definite (Experiment 1) and indefinite (Experiment 3) articles.*

Effect	df	Sum Sq	Mean Sq	*F*
Article	1,124	13268.53	13268.53	17.56****
Condition	3,372	296.60	98.87	1.81
Anteriority	4,496	14653.10	3663.28	158.48****
Laterality	4,496	620.47	155.12	29.33****
Article X Condition	3,372	314.77	104.92	1.92
Article X Anteriority	4,496	166.51	41.63	1.80
Article X Laterality	4,496	105.72	26.43	5.00**
Condition X Anteriority	12,1488	33.52	2.79	2.45*
Condition X Laterality	12,1488	1.19	.10	.27
Anteriority X Laterality	16,1984	230.16	14.39	6.09****
Article X Condition X Anteriority	12,1488	8.65	.72	.63
Article X Condition X Laterality	12,1488	8.88	.74	2.00†
Article X Anteriority X Laterality	16,1984	170.87	10.68	4.52****
Condition X Anteriority X Laterality	48,5952	3.78	.08	.59
Article X Condition X Anteriority X Laterality	48,5952	6.65	.14	1.04

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 17. *ERP N400 (300-500 ms) ANOVA results comparing definite (Experiment 1) and indefinite (Experiment 3) articles.*

Effect	df	Sum Sq	Mean Sq	*F*
Article	1,124	3409.31	3409.31	6.40*
Condition	3,372	6507.63	2169.21	39.51****
Anteriority	4,496	8444.85	2111.21	150.35****
Laterality	4,496	395.61	98.90	32.54****
Article X Condition	3,372	305.38	101.79	1.85
Article X Anteriority	4,496	194.91	48.73	3.47*
Article X Laterality	4,496	41.38	10.34	3.40*
Condition X Anteriority	12,1488	28.82	2.40	1.81
Condition X Laterality	12,1488	7.82	.65	1.49
Anteriority X Laterality	16,1984	108.39	6.78	4.93****
Article X Condition X Anteriority	12,1488	23.82	1.99	1.50
Article X Condition X Laterality	12,1488	5.65	.47	1.08
Article X Anteriority X Laterality	16,1984	101.57	6.35	4.62****
Condition X Anteriority X Laterality	48,5952	11.23	.23	1.40
Article X Condition X Anteriority X Laterality	48,5952	6.41	.13	.8

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 18. *ERP Extended N400 (500-650 ms) ANOVA results comparing definite (Experiment 1) and indefinite (Experiment 3) articles.*

Effect	df	Sum Sq	Mean Sq	*F*
Article	1,124	1748.72	1748.72	3.29†
Relation	3,372	2845.87	948.62	11.52****
Anteriority	4,496	10485.29	2621.32	137.76****
Laterality	4,496	793.89	198.47	56.67****
Article X Relation	3,372	2966.26	988.75	12.01****
Article X Anteriority	4,496	78.52	19.63	1.03
Article X Laterality	4,496	109.41	27.49	7.85****
Relation X Anteriority	12,1488	33.88	2.82	1.50
Relation X Laterality	12,1488	6.20	.52	.79
Anteriority X Laterality	16,1984	172.55	10.78	6.32****
Article X Relation X Anteriority	12,1488	55.26	4.61	2.44†
Article X Relation X Laterality	12,1488	23.69	1.97	3.03**
Article X Anteriority X Laterality	16,1984	165.10	10.32	6.05****
Relation X Anteriority X Laterality	48,5952	11.58	.24	1.00
Article X Relation X Anteriority X Laterality	48,5952	10.85	.23	.94

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 19. *ERP Late Positive Component/LPC (750-1000 ms) ANOVA results comparing definite (Experiment 1) and indefinite (Experiment 3) articles.*

Effect	df	Sum Sq	Mean Sq	*F*
Article	1,124	5709.50	5709.50	7.14**
Relation	3,372	525.29	175.10	1.59
Anteriority	4,496	2148.1	5370.28	162.08****
Laterality	4,496	888.09	222.02	37.90****
Article X Relation	3,372	288.14	96.05	.87
Article X Anteriority	4,496	129.34	32.34	.98
Article X Laterality	4,496	188.55	29.64	5.06**
Relation X Anteriority	12,1488	18.67	1.56	.74
Relation X Laterality	12,1488	2.95	.25	.33
Anteriority X Laterality	16,1984	240.37	15.02	5.05****
Article X Relation X Anteriority	12,1488	41.17	3.43	1.62†
Article X Relation X Laterality	12,1488	9.41	.78	1.07
Article X Anteriority X Laterality	16,1984	230.62	14.41	4.85****
Relation X Anteriority X Laterality	48,5952	15.32	.32	.99
Article X Relation X Anteriority X Laterality	48,5952	14.20	.30	.91

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 20. *Completion ANOVA results of Relation comparing definite (Experiment 2) and indefinite (Experiment 4) articles.*

Completion Type	df	Sum Sq	Mean Sq	*F*
Coreferential with Relevant Antecedent	1,231	3.97	3.97	109.04****
Coreferential with Different Antecedent	1,231	<.001	<.001	.05
Same Event, New Discourse Token	1,231	.08	.08	.1.89
Different Event, New Discourse Token	1,231	2.05	2.05	28.32****

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 21. *Completion ANOVA results of Relation X Article comparing definite (Experiment 2) and indefinite (Experiment 4) articles.*

Completion Type	df	Sum Sq	Mean Sq	*F*
Coreferential with Relevant Antecedent	2,462	.92	.46	38.02****
Coreferential with Different Antecedent	3,693	.04	.01	5.16***
Same Event, New Discourse Token	2,462	.81	.40	28.65****
Different Event, New Discourse Token	3,693	.45	.15	19.96****

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Appendix C

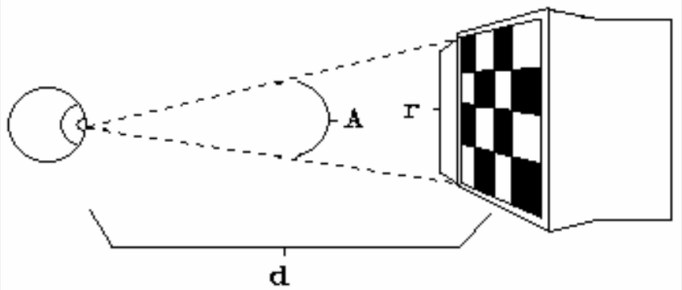
Computing the Visual Angle

The most often used method to describe the size of a visual stimulus is the visual angle. The visual angle is computed from the size of the image and the distance of the image from the observer. Below is a method to compute the visual angle.

The formula,

$$A = (360/2\pi) \times (r/d) = 57.3 \times (r/d),$$

where A is the visual angle, pi is approximately 3.14159, r is the size of the stimulus on the screen, and d is the distance of the observer from the screen, allows you to compute the visual angle.



To compute the visual angle for a task, follow these steps:

Step 1 - Measure the size in centimeters of the stimulus on the screen (r). To compute the visual angle of a single check, divide r by the value in Number of checks displayed.

Step 2 - Measure the distance in centimeters from the observer's eye to the center of the stimulus (d).

Step 3 - Divide r by d and multiply the quotient by 57.3. The resulting visual angle will be in units of degrees.

Appendix D

Calculations for creating a 2-degree visual angle per each target term in the VHF experiment.

$A = (360/2\pi) \times (r/d) = 57.3 \times (r/d)$

where A is the visual angle, pi is approximately 3.14159, r is the size of the stimulus on the screen, and d is the distance of the observer from the screen, allows you to compute the visual angle.

- Need to move the inside edge of the stimuli, so it is 2 degrees left or right of the center

- Distance from monitor = 80cm
- Screen width = 40.64cm
    - Stim2 x-axis = -500,500 (total 1000, 0 is center)
- Each letter of stimulus = 1cm width (size 40 font)

Example:

5 letter word stimulus

A = 57.3 x (r/d)
2 = 57.3 x (r/80)
r = 57.3 x (2/80)
r = 2.79cm

- Stim2 x-axis moved from center of stimulus

5cm/2 = 2.5cm

2.5 + 2.79 = 5.29cm (how far to move stimulus L/R)

5.29 = 13.02% of 40.64 (cm, screen width)

130 on the 1000 scale, x-axis (for input into Stim2)

Appendix E

Table 23. *Mean Amplitudes (μV) of Relation X Hemisphere following a definite article (Experiment 5) for each time region of interest.*

Time Region	Relation / Hemisphere							
	Match		Mismatch		Category		Indeterminate	
	LH	RH	LH	RH	LH	RH	LH	RH
100-200 ms (N1)	-.72	-.76	-.99	-1.20	-.48	-.75	-1.13	-.91
200-300 ms (P2)	3.32	2.55	2.52	1.58	3.24	2.20	2.53	2.04
300-500 ms (N400)	2.29	2.19	.82	.17	1.20	.69	.03	.26
500-650 ms (extended N400)	3.36	3.28	2.52	1.88	2.44	1.90	1.88	1.68
750-1000 ms (LPC)	2.80	2.26	2.70	2.07	2.94	2.22	2.48	1.79

Table 24. *ERP N1 (100-200 ms) ANOVA results following a definite article across hemispheres (Experiment 5).*

Effect	df	Sum Sq	Mean Sq	*F*
Visual Field	1,78	4.33	4.33	.03
Relation	3,234	10.48	3.49	.03
Anteriority	4,312	104.4	26.1	1.31
Laterality	4,312	14.35	3.59	2.13
Visual Field X Relation	3,234	103.49	34.50	.36
Visual Field X Anteriority	4,312	6.55	1.64	.63
Visual Field X Laterality	4,312	83.90	20.98	20.88****
Relation X Anteriority	12,936	8.49	.71	.42
Relation X Laterality	12,936	4.53	.38	.96
Anteriority X Laterality	16,1248	42.93	2.68	2.92***
Visual Field X Relation X Anteriority	12,936	4.39	.37	.22
Visual Field X Relation X Laterality	12,936	3.32	.28	.78
Visual Field X Anteriority X Laterality	16,1248	8.09	.51	2.01†
Relation X Anteriority X Laterality	48,3744	5.69	.12	.93
Visual Field X Relation X Anteriority X Laterality	48,3744	6.20	.13	.98

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 25. *ERP P2 (200-300 ms) ANOVA results following a definite article across hemispheres (Experiment 5).*

Effect	df	Sum Sq	Mean Sq	*F*
Visual Field	1,78	383.65	383.65	2.41
Relation	3,234	505.96	168.65	1.7
Anteriority	4,312	307.62	76.91	2.51
Laterality	4,312	102.32	25.58	5.06*
Visual Field X Relation	3,234	122.94	40.98	.36
Visual Field X Anteriority	4,312	65.04	16.26	4.13*
Visual Field X Laterality	4,312	17.92	4.48	2.52
Relation X Anteriority	12,936	27.62	2.30	.97
Relation X Laterality	12,936	2.31	.19	.36
Anteriority X Laterality	16,1248	80.20	5.01	2.40*
Visual Field X Relation X Anteriority	12,936	11.11	.93	.41
Visual Field X Relation X Laterality	12,936	1.70	.14	.28
Visual Field X Anteriority X Laterality	16,1248	14.57	.91	2.09†
Relation X Anteriority X Laterality	48,3744	9.06	.19	1.14
Visual Field X Relation X Anteriority X Laterality	48,3744	13.27	.28	1.43

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 26. *ERP N400 (300-500 ms) ANOVA results following a definite article across hemispheres (Experiment 5).*

Effect	df	Sum Sq	Mean Sq	*F*
Visual Field	1,78	107.72	107.72	.68
Relation	3,234	2203.88	734.63	5.96****
Anteriority	4,312	81.15	20.29	.67
Laterality	4,312	35.19	8.80	3.81*
Visual Field X Relation	3,234	70.12	23.37	.19
Visual Field X Anteriority	4,312	30.88	7.72	2.31
Visual Field X Laterality	4,312	29.11	7.28	5.39*
Relation X Anteriority	12,936	77.31	6.44	2.67*
Relation X Laterality	12,936	7.72	.64	1.23
Anteriority X Laterality	16,1248	47.65	2.98	2.15*
Visual Field X Relation X Anteriority	12,936	17.19	1.43	.56
Visual Field X Relation X Laterality	12,936	1.85	.15	.29
Visual Field X Anteriority X Laterality	16,1248	10.07	.63	1.68
Relation X Anteriority X Laterality	48,3744	10.66	.22	1.00
Visual Field X Relation X Anteriority X Laterality	48,3744	17.48	.36	1.52†

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 27. *ERP N400 (300-500 ms) ANOVA results following a definite article in the RVF/LH (Experiment 5).*

Effect	df	Sum Sq	Mean Sq	*F*
Relation	3,216	5302.37	1767.46	15.02****
Anteriority	4,288	54.04	13.51	.80
Laterality	4,288	18.40	4.60	2.00
Relation X Anteriority	12,864	89.34	7.45	2.79*
Relation X Laterality	12,864	3.01	.25	.44
Anteriority X Laterality	16,1152	43.33	2.71	2.69**
Relation X Anteriority X Laterality	48,3456	18.63	.39	1.56*

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 28. *ERP N400 (300-500 ms) ANOVA results following a definite article in the LVF/RH (Experiment 5).*

Effect	df	Sum Sq	Mean Sq	*F*
Relation	3,216	5250.07	1750.02	13.54****
Anteriority	4,288	66.49	16.62	1.00
Laterality	4,288	89.02	22.25	17.90****
Relation X Anteriority	12,864	20.57	1.71	.74
Relation X Laterality	12,864	12.64	1.05	2.13*
Anteriority X Laterality	16,1152	45.02	2.81	3.65****
Relation X Anteriority X Laterality	48,3456	15.53	.32	1.52†

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 29. *ERP Extended N400 (500-650 ms) ANOVA results following a definite article across hemispheres (Experiment 5).*

Effect	df	Sum Sq	Mean Sq	*F*
Visual Field	1,78	50.08	50.08	.21
Relation	3,234	1701.50	567.17	3.66*
Anteriority	4,312	26.16	6.54	.19
Laterality	4,312	178.15	44.54	8.57****
Visual Field X Relation	3,234	392.00	130,67	.70
Visual Field X Anteriority	4,312	29.30	7.33	1.76
Visual Field X Laterality	4,312	37.29	9.32	9.71****
Relation X Anteriority	12,936	60.96	5.08	1.54
Relation X Laterality	12,936	21.62	1.80	2.56*
Anteriority X Laterality	16,1248	90.42	5.65	3.17***
Visual Field X Relation X Anteriority	12,936	7.45	.62	.18
Visual Field X Relation X Laterality	12,936	10.57	.88	1.46
Visual Field X Anteriority X Laterality	16,1248	9.12	.57	1.58
Relation X Anteriority X Laterality	48,3744	14.91	.31	1.01
Visual Field X Relation X Anteriority X Laterality	48,3744	17.67	.37	1.09

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10

Table 30. *ERP Late Positive Component/LPC (750-1000 ms) ANOVA results following a definite article across hemispheres (Experiment 5).*

Effect	df	Sum Sq	Mean Sq	*F*
Visual Field	1,78	43.73	43.73	.21
Relation	3,234	550.14	183.38	1.07
Anteriority	4,312	718.06	179.51	4.43*
Laterality	4,312	145.72	36.43	8.10****
Visual Field X Relation	3,234	456.94	152.32	.70
Visual Field X Anteriority	4,312	10.45	2.61	.57
Visual Field X Laterality	4,312	80.89	20.22	21.37****
Relation X Anteriority	12,936	52.61	4.38	1.01
Relation X Laterality	12,936	14.13	1.18	1.22
Anteriority X Laterality	16,1248	57.33	3.58	1.60
Visual Field X Relation X Anteriority	12,936	13.53	1.13	.25
Visual Field X Relation X Laterality	12,936	7.28	.61	.78
Visual Field X Anteriority X Laterality	16,1248	11.92	.75	1.75†
Relation X Anteriority X Laterality	48,3744	22.53	.47	1.0
Visual Field X Relation X Anteriority X Laterality	48,3744	19.45	.41	.78

*p< .05, **p<.01, ***p<.005, ****p<.001, †.05<p>.10