# Anticipation during language processing: Investigating the use of sentence context during reading in young adults

Alison Johns, Kristy Wilson

Dr. Esther Kim, Dr. Jacqueline Cummine

Sentence Context Use During Reading

SENTENCE CONTEXT USE DURING READING

**ABSTRACT**

The N400 is an event-related potential (ERP) component that has been suggested to be associated with the processing of semantic information. Specifically, researchers have found that the N400 effect is prominent when words are incongruent in a given sentence context. Furthermore, the size of the N400 effect can be modulated by the degree to which the incongruent word is semantically related to the expected word (i.e., the word that would most plausibly complete the sentence). The present study investigates the use of sentence context in young healthy adult readers as they read sentences containing either expected or unexpected words. Unexpected words consisted of words that were considered within-category violations (i.e., were in the same semantic category as the expected word) or between-category violations (i.e., were in a different semantic category than the expected word). We did not find a significant difference in the N400 effect between the different sentence conditions. We did find a significant difference between the mean amplitude in the congruent and the incongruent between-category sentence conditions between 600-900 ms that may resemble a post-N400 positivity, also known as a frontal PNP. Implications for our understanding of the neural mechanisms underlying online language processing and the use of context are discussed.

*Keywords*: N400, frontal PNP, EEG, language processing, sentence context, reading

**INTRODUCTION**

Humans use sounds and letters to represent concepts in the world to communicate with one another. In order for a listener to understand what a speaker is referring to, the listener must have prior experience with the words and their corresponding referents (Archibald & O'Grady, 2009). All of these words and concepts are stored in our brain in vast semantic networks of concepts called the *lexicon* (Archibald & O'Grady, 2009). The study of how meaning is represented and interpreted in language is called *semantics* (Archibald & O'Grady, 2009). Similarly, language comprehension requires "the recruitment and integration of world knowledge stored in long-term memory" (Federmeier & Kutas, 1999, p. 469). Listeners, or readers, not only have to decipher a phonetic code to understand language; they often have to use contextual clues in order to correctly interpret the intended meaning of a word or sentence (Archibald & O'Grady, 2009).

The current study aims to examine the use of semantic context during language processing in young healthy adults. Over the past few decades, researchers have been investigating the use of context during language processing in various populations and in different experimental paradigms (Ehrlich, 1981; Federmeier & Kutas, 1999; Federmeier, McLennan, De Ochoa, & Kutas, 2002; Federmeier, 2007). A set of terminology has emerged from this literature to describe the different neurocognitive processes involved in context use and language processing. Although closely related, these terms have important distinctions, and a firm understanding of their operational definitions is required in order to compare and contrast subtle differences that take place during language processing. For example, a distinction must be made between prediction (i.e., when a specific lexical item is anticipated) and expectation (i.e., when a general semantic concept is anticipated in a given context), as well as between constraint (i.e., the degree to which a context limits the possible semantic concepts that can plausibly complete the sentence) and cloze probability (i.e., the probability of a specific target word completing a particular sentence frame). For the purposes of this paper, we have operationally defined a selection of these terms, which can be found in Table 1 below.

| **Term** | **Definition** |
|---|---|
| ***Predicted*** | When a specific lexical item is anticipated (e.g., *sugar*); related to cloze probability |
| ***Expected*** | When a general semantic concept is anticipated (*e.g., white powdered food item*) in a given context; related to constraint |
| ***Plausible*** | Similar to *expected,* a word that logically fits in a given context; related to constraint |
| ***Semantically Related*** | Words that belong to the same semantic category (e.g., *sugar* and *flour*) |
| ***Semantically Unrelated*** | Words that belong to a different semantic category (e.g., *sugar* and *dog)* |
| ***Constraint*** | The degree to which a context limits the possible semantic concepts that can plausibly complete the sentence; related to plausibility and expectations.<br><br>***High-constraint*** e.g., *She really wanted some ice cream, so she walked into the kitchen and opened the* _____ [freezer/fridge/refrigerator]<br>***Low-constraint*** e.g., *I found her by the* ____ [large number of semantic concepts that could plausibly complete the sentence] |
| ***Cloze Probability*** | The probability of a specific target word completing a particular sentence frame; related to prediction.<br><br>***High Cloze Probability*** e.g., *The opposite of the colour black is* ____[the probability of predicting the word *white* is high given the preceding sentence frame]<br>***Low Cloze Probability*** e.g., *My favourite colour is* _____ [large number of lexical items (i.e., colours) that can complete the sentence frame] |

***Table 1***. Operational definitions of pertinent concepts.

To provide further clarity regarding these terms, consider the following examples of three distinct sentence conditions. First, the sentence, "I take coffee with cream and *sugar*" illustrates a condition where the final word is expected and can be predicted from the context. Second, the sentence, "I take coffee with cream and *flour*" illustrates a condition where the final word violates the context, but at the same time bears a semantic relation to a word that may be expected (i.e., sugar). Finally, the sentence, "I take coffee with cream and *dog*" illustrates a condition where the final word violates the context, and bears no semantic resemblance to the expected word. From these sentences, it is clear that context use during language processing is a complicated, subtle phenomenon wherein the slightest change in a word can have a ripple effect on the rest of the sentence. The current study attempts to investigate the electrophysiological mechanisms associated with expectations and/or predictions, hereafter referred to as sentence context, during processing of sentences with high cloze probabilities in young adults. This study represents the first step in a research project that will examine reading comprehension processes in younger adults, older adults, and adults with aphasia. Results from this study will provide the framework from which performance of individuals with aphasia can be compared, in an effort to learn more about how sentence context can be used to facilitate reading in individuals with reading impairments secondary to aphasia.

***Sentence Context Effects on Language Comprehension***

Sentence context plays an important role in terms of facilitating our language comprehension. For example, consider the word *'light'* in the following two sentences:

1. "Can you turn the *light* on?"
2. He picked up his bicycle and was astonished at how *light* it felt.

In the first sentence, the word *light* refers to a lamp or fixture that illuminates a room. However, in the second sentence, the word *light* means 'not heavy'. Not only does the context of the sentence change the meaning of the word; our world knowledge impacts the way we perceive and communicate lexical concepts (Nieuwland & Van Berkem, 2006). Support for the use of sentence context in language comprehension comes from eye-tracking research (Ehrlich, 1981). Researchers have used eye-tracking techniques such as measuring fixation durations (i.e., how long a person spends looking at an item) to examine the effect of context on language processing. Fixation duration is thought to index moment-to-moment language processing; specifically, longer fixation durations indicate increased processing difficulty when reading sentences (Rayner, 1998; Ehrlich, 1981). Ehrlich and colleagues (1981) measured fixation times on particular target words as subjects read passages that differed in the extent to which they constrained or predicted the target words. They found that subjects were less likely to fixate on the target words in high-constraint passages (i.e., passages in which the context strongly predicted the target word) than low-constraint passages, and that fixation times were shorter when the target words were predictable than when they were unpredictable (Ehrlich, 1981). These data indicate that highly constrained sentences allow the reader to anticipate, or predict, a concept or lexical item, which in turn facilitates speed of language processing. Conversely, when expectations are violated, processing speed is negatively impacted. Taken together, these eye-tracking data suggest that language processing is influenced by context-related expectations. These behavioural data are supported by results from neuroimaging studies, which indicate the presence of a neural marker, namely the N400, for context violation during language processing (Kutas & Hillyard, 1980a).

***The N400 as a Marker for Semantic Processing During Language Processing***

In order to help understand what is going on inside the human brain, researchers use neuroimaging techniques. One such method is electroencephalography (EEG), which measures the electrical activity in our brains (Coles & Rugg, 1995). From EEG, we can isolate *event-related potentials* (ERPs), which are electrophysiological responses that represent brain activity that is time-locked to a particular stimulus event. As such, EEG has high temporal resolution and is therefore a useful tool for investigating online processing, such as language comprehension during reading where researchers aim to examine participants' neural activity in response to a particular stimulus, for example, reading a word (Coles & Rugg, 1995).

The N400 is the most widely studied language-related ERP component, and has been suggested to be important in the processing of semantic information (Kutas & Hillyard, 1980a; Kutas & Federmeier, 2011). For example, Kutas and Hillyard (1980a) conducted three different experiments in which participants read a series of sentences containing either expected or anomalous words, and recorded their brain activity using EEG. The researchers observed a late negative wave in response to the semantically incongruent words that was distinct from the late positive P300 response that typically occurs in response to unexpected or surprising stimuli. Given this distinction, Kutas and Hillyard speculated that the N400 component was not associated with just any type of meaningful stimuli, but rather, likely reflected a disruption of language processing caused by a semantically inappropriate word. The hypothesis that the N400 response was specific to interpretation of meaning was supported; the N400 response did not occur in response to non-semantic manipulations of context (e.g. physical attributes of the word; Kutas & Hillyard 1980b), to grammatical or morphological violations (Kutas & Hillyard 1980a), or to deviations in nonlinguistic stimuli (e.g. anomalous notes in melodies; Beson & Macar, 1987).

In more recent work, Federmeier and Kutas (1999) speculated that the organization of semantic memory plays an integral role in determining how information in a sentence context will affect word processing. In their study, Federmeier and Kutas (1999) investigated the relationship between sentence context and semantic memory structure during online sentence processing using EEG. In order to do this, Federmeier and Kutas (1999) used pairs of sentences that served to 1) establish context (i.e., the first sentence) and 2) varied in their expectancy (i.e., congruent vs. incongruent trials). More specifically, the second sentence contained a word from one of the following three conditions: (1) a congruent word (e.g., *sugar*), (2) a word from the same semantic category (i.e., within-category) that violated the expectations set up by the context (e.g., *flour*), or (3) a word from a different semantic category (i.e., between-category) that violated the expectations set up by the context (e.g., *dog*). Examples of these conditions can be found in Table 2.

| Condition | Definition | Example |
|---|---|---|
| Congruent | A word that is semantically related and expected in the given context. | I take coffee with cream and *sugar.* |
| Within-category violations | A word that is semantically related, but unexpected in the given context. | I take coffee with cream and *flour.* |
| Between-category violations | A word that is semantically unrelated, and unexpected in the given context. | I take coffee with cream and *dog.* |

***Table 2.*** Sentence context conditions used in Federmeier & Kutas (1999) as well as the present study.

The researchers also manipulated the contextual constraint (i.e., degree to which the context sentence created an expectation for a particular word). For example, the sentence, "She really wanted some ice cream, so she walked into the kitchen and opened the ____", is strongly constraining because it generates a high expectancy for the semantic concept of a *freezer, fridge,* or *refrigerator.* Conversely, a weakly constraining sentence, such as, "I found her by the ____", has a large number of possibilities that could plausibly complete the sentence.

Federmeier & Kutas (1999) found that all of the unexpected words elicited an N400 response, reflecting a disruption of on-line language processing. However, they also found that contextual information was not the only contributing factor to the magnitude of the N400 response. The unexpected words that belonged to the same semantic category as the expected words elicited a reduced N400 response compared to words that were both unexpected and semantically unrelated. Federmeier and Kutas suggested that this reduced N400 reflects the neural organization of our semantic memory. They suggested that processing words that are semantically related to the expected word is not *as* disruptive as processing completely unrelated and unexpected words. This is due to the fact that "the processing of a sentence context results in the activation of a set of semantic features associated with the word or words that are likely to come next" (p. 490), thus increasing the activation level of semantically related words, and facilitating their processing (Federmeier & Kutas, 1999). Thus, the structural organization of our semantic memory influences language comprehension processes as well as context. This then leads to the question of how exactly our semantic memory is structured, and how the structure itself, or the means by which we recruit information, may change across our lifespan.

### *Sentence Context Effects and Aging*

Behavioural research has shown that adults show age-related declines in cognition beginning in early-adulthood (Salthouse, 2010). However, despite declines in measures of efficiency or effectiveness of online processing, measures of verbal knowledge abilities often show increases with age, at least until people are in their 60s (Park, 2002; Salthouse, 2010). The research has demonstrated that older adults, like younger adults, show evidence of context use in on-line sentence processing (Hopkins, Kellas, & Paul, 1995), and that older adults are able to rely on sentence context to support language processing in challenging listening conditions (Pichora-Fuller, 2008). Although this research suggests that both older and younger adults use context during language processing, neurophysiological research suggests that older adults may not use it in the same way as their younger counterparts (Federmeier & Kutas, 2005).

Federmeier et al. (2002) examined the sentence context use in younger and older adults in order to investigate changes in semantic memory organization and language processing as a function of age. They used a similar paradigm to their 1999 study, this time having subjects listen to pairs of sentences, in order to investigate age-related changes in language processing and, specifically, the use of long-term semantic memory during online language processing. They expected that both younger and older adults would use context predictively, which would be evidenced by a larger N400 effect for words that were both unexpected and semantically unrelated, especially in highly constraining contexts. Interestingly, the results indicate that older adults do, in fact, use context to facilitate language processing, but the pattern of results differed for older adults compared to younger adults. For older adults, within-category violations elicited smaller N400 effects than between category violations only in low constraint contexts, while within-category and between-category violations did not differ in high constraint contexts. This is the opposite effect that was seen in the younger participants. In the younger participants, they found that N400 responses were smaller for within-category violations in high constraint contexts as opposed to low constraint contexts. In other words, processing of within-category violations was facilitated in highly constraining contexts for younger adults. Together, these findings suggest that older adults and younger adults use context differently during language processing.

***Purpose of the Current Study***

The goal of the present research is to examine the use of sentence context in young healthy adults using electroencephalography (EEG). We predict that young adults will demonstrate N400 effects when reading sentences containing semantic anomalies, and these effects will be modulated by the degree of the semantic context anomalies. This study is study 1 in a series of studies investigating the neural mechanisms of reading in young healthy adults

(Study 1), older healthy adults (Study 2), and people with aphasia (Study 3). Ultimately, this research will contribute to a better understanding of the nature of reading impairments, and also help to support the development of evidence-based treatments for people with aphasia and alexia.

## METHODS

### ***Participants***

Forty-one young adults were recruited from the population of the University of Alberta graduate and undergraduate student bodies. Of the forty-one, ten participants were excluded from the analysis due to the following reasons: non-native English speakers, being left handed or ambidextrous according to the Edinburgh assessment and analysis of handedness (Oldfield, 1971), technical errors during the recording of the EEG, or too much noise in the EEG signal. The remaining thirty-one participants (4M; 27F) had a mean age of 23.7 years. All thirty-one of the participants included were right-handed according to the Edinburgh assessment and analysis of handedness (Oldfield, 1971). All participants included in the analysis spoke and read English as a first language. Participants had no history or stroke or other brain injury or disease, and no history of reading or learning disabilities. Participants were compensated with a $10 gift card for taking part in the study. This study was approved by the Human Research Ethics Board (HREB) at the University of Alberta. All participants consented to participate in the study; a copy of the consent form can be found in Appendix A.

***Materials***

Stimulus materials consisted of 120 pairs of sentences; 40 of the sentences were from Federmeier and Kutas (1999), and 80 were developed for the purpose of this study based on the methods outlined by Federmeier and Kutas (1999) (Donnelly & Kinsman, 2014). Forty pairs of target words were chosen with an average Thorndike-Lorge (1944) written frequency of 655.56 (range 12 - 5 786), average concreteness rating of 577.16 (range 381 - 640), and average imageability rating of 588.22 (range 402 - 642) (Donnelly & Kinsman, 2014). These pairs of words represented 40 different categories (i.e. medical professionals, law professionals). Each category was grouped with another related category to create an overarching category (i.e. medical + law professionals → professionals). The expected and semantically related (within-category) word was chosen from the category (i.e. medical professionals), and the semantically unrelated (between-category) word came from the overarching category (i.e. professionals).

The first sentence in each pair set up the context (e.g., *"Checkmate," Rosaline announced with glee*). The second neutral sentence (e.g., *She was getting to be very good at playing* _______) contained a final word target from one of three conditions: congruent (e.g., *chess*), anomalous-semantically related (e.g. *monopoly*), or anomalous-semantically unrelated (e.g., *football*). The expected exemplars had cloze probabilities (i.e., the probability of the target word completing a particular sentence) ranging from 0.5 to 1.0, with a mean of 0.86, to "constrain the amount of variability in the degree of facilitation provided by the context sentence" (Donnelly & Kinsman, 2014, p. 12).

The stimulus sentences were normed on 89 individuals (19M; 66W) with a mean age of 26 years (Donnelly & Kinsman, 2014) to ensure that the words used in the stimuli were indeed congruent or anomalous based on the context. A survey was sent to 90 individuals containing the stimuli sentences with the target words missing (e.g., I take coffee with cream and _____), and participants were instructed to finish the sentence with first word that came to mind. Cloze probabilities were calculated from the responses, and only words which resulted with cloze probabilities of 0.5 or greater were included in the congruent condition (Donnelly & Kinsman, 2014). Cloze probability for within-category violations ranged from 0 to 0.24 (M =0.014), and ranged from 0 and 0.041 (M= 0.0016) for between-category violations (Donnelly & Kinsman, 2014). Additionally, forty pairs of control sentences were randomly dispersed among the stimulus sentences to act as fillers, such that there was an equal number of sentences containing expected and unexpected sentence-final words (Donnelly & Kinsman, 2014). Sentences were presented using EPrime Software (Psychology Software Tools, Inc.) on a desktop PC computer. Participants were fitted with a 64 channel Geodesic Sensor Net (Electrical Geodesics Inc., Eugene, OR) and electroencephalograms (EEGs) were recorded onto a desktop Mac computer.

***Procedure***

Participants completed the study in one experimental session. At the beginning of each session, participants were informed about the study procedure and provided consent. Participants also completed the Edinburgh assessment and analysis of handedness (Oldfield, 1971). This questionnaire assesses the laterality of the participant’s hand in everyday activities or the dominance of their right or left hand. For the experiment, participants were seated in front of a computer in a sound-reduced, dark room to limit extraneous sensory input, and were instructed to passively read the sentences. Each set of sentence pairs was preceded by the presentation of a 500 ms fixation cross. The first sentence in each stimulus pair was presented in its entirety and participants read it at a comfortable pace. Participants then used a button press to proceed to the next sentence. A 250 ms fixation cross separated the first and second sentence. Words in the second sentence of each stimulus-pair were presented one word at a time with a 500 ms word to word onset time, and target words were flagged on the corresponding EEG output in Net Station. Figure 1 depicts how the stimuli were presented during the experiment. Participants were given the opportunity to take a short break mid-way through the study if needed.

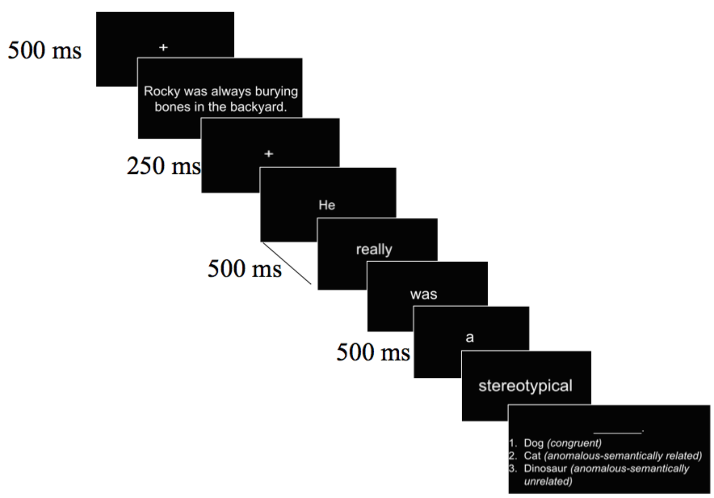


Figure 1. Stimulus presentation and timing as it appeared on EPrime during the experiment. Participants read the first sentence at their own pace, and used a button press to proceed to the next sentence. Following a 250 ms fixation cross, the second sentence was presented one word at a time; each word was presented for 250 ms.

## DATA ANALYSIS

### *ERP Analysis*

Incoming data was sampled at a rate of 1000 Hz and ERPs were computed for epochs extending from 100ms before (baseline) the stimulus onset and 1000ms after the stimulus onset using the EEGLab toolbox in MATLAB. Electrode impedance was kept below 50 kΩ during recording. Data collected from the experiment was analyzed using EEGLAB toolbox (Delorme & Makeig, 2004) in MATLAB along with custom script in the program. Preprocessing of the EEG data included the signal from EEG recordings being band-pass filtered between 0.1 to 30 Hz. Then, the bad channel components were detected and removed before the signal was average re-referenced to the central electrode, Cz. The artifacts in the data were corrected in the EEGLAB toolbox in MATLAB, by independent component analysis (Delorme & Makeig, 2004). Blinks and eye movements were detected by the electrodes around the eye muscles (electrode 62 and 63). The electrodes of interest included the central electrode, Cz, frontal electrode, Fz, and parietal electrode, Pz. Our focus for analysis of the N400 ERP component was the 300-500 ms post-stimulus time window. This was chosen based on evidence presented from previous studies indicating that is the range in which we would expect to see an N400 effect (Federmeier & Kutas, 1999; Federmeier, McLennan, De Ochoa, & Kutas, 2002; Federmeier & Kutas, 2005).

### *Statistical Analysis*

A one-way repeated measures ANOVA was conducted for each dependent variable of interest: mean amplitude and peak latency of the ERP of interest; and at each electrode of interest: Fz, Cz, and Pz. The independent variable was target type (i.e., congruent, within-category violation, and between category violation). A selection of time windows spanning 300 -- 900 ms post-stimulus onset were analyzed. During the 300 - 500 ms post-stimulus time window, we hypothesized that we would see significant differences between sentence conditions. Planned a priori pairwise comparisons were then conducted on any other significant results to examine the effect of sentence condition on mean amplitude and peak latency within the group of young adults.

## RESULTS

### *Mean Amplitude*

***Mean amplitude 300-500 ms.*** Mauchly's test indicated that the assumption of sphericity was assumed at Cz, Pz, and Fz. There was no main effect of sentence condition at: Cz, $F(2, 60)= 1.240$, $p= 0.29$; Pz, $F(2, 60)=0.378$, $p=0.687$; or Fz, $F(2, 60)=1.495$, $p=0.232$

***Mean amplitude 600-900 ms.*** Mauchly's test indicated that the assumption of sphericity was not violated at Pz and Fz. There was no main effect of sentence condition at Pz, $F(2, 60)=2.635$, $p=0.08$. However, there was a main effect of sentence condition at Fz, $F(2, 60)=3.725$, $p=0.030$. Post hoc paired *t* tests indicated that there was a significant difference ($p=0.019$) between mean amplitude in the congruent condition (M = .26, SD = 1.64) and mean amplitude in the incongruent between-category condition (M = -.28, SD = 1.57). See Figure 2 below.

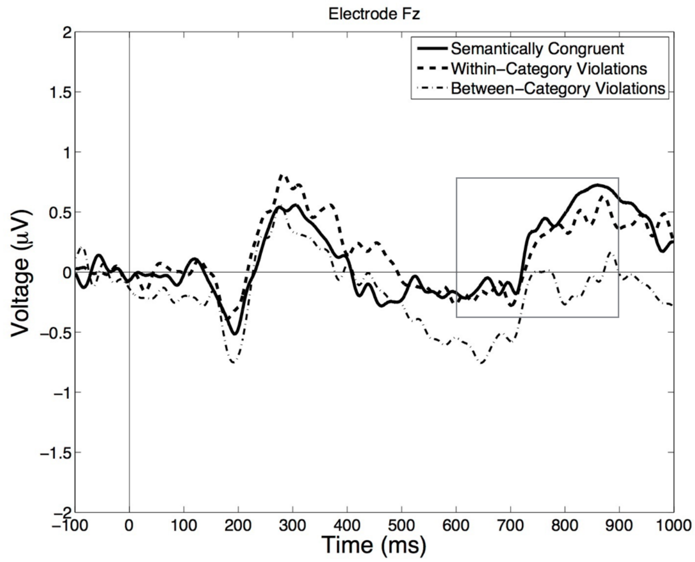


Figure 2. Grand average ERPs (N=31 young adults) shown at the frontal electrode site (Fz). Between category violations had a significantly greater mean amplitude (M = -.28, SD = 1.57) than words in the semantically congruent condition (M = .26, SD = 1.64) between 600-900 ms.

There were no further significant results in any of the other time windows.

***Peak Latency***

***Peak Latency 300 - 500 ms.*** Mauchly's test indicated that the assumption of sphericity was not violated at Cz, and Fz. There was no main effect of sentence condition at Cz, F(2, 28)=0.489, $p$=0.615 or Fz, F(2, 28)=0.014, $p$=0.986. Mauchly's test indicated that the assumption of sphericity was violated at Pz, therefore degrees of freedom were corrected using the Greenhouse-Geisser estimates of sphericity. There was no main effect of sentence condition at Pz, F(1.662, 49.851)= 0.610, $p$=0.518.

There were no significant results in any of the other time windows.

## DISCUSSION

### *Purpose of the Current Study*

This study used electroencephalography (EEG) to investigate top-down facilitation during reading as young adults read sentences containing semantically incongruous words. We predicted that young adults would demonstrate N400 effects when reading sentences with semantic anomalies, and that these effects would be modulated by the degree of the semantic context anomalies (i.e., within-category versus between-category violations). We did not find a significant difference in mean amplitudes of the N400 response for the different sentence conditions. However, a significant difference was found between the mean amplitude in the congruent and the incongruent between-category sentence conditions in the 600-900ms time window for the frontal electrode, measured at Fz. Below, we discuss these findings in relation to those of Federmeier and Kutas' study of context use in young adults (Federmeier & Kutas, 1999). Then, we discuss possible variables that may have impacted the present results, and discuss the overall implications for models of typical and impaired language processing.

### *The N400 as a Marker for Semantic Processing During Language Processing*

We hypothesized to find an N400 effect as a function of sentence condition. We failed to reject the null hypothesis; the amplitude and latency of the N400 did not change significantly as a function of sentence condition. These results conflict with those of Federmeier and Kutas (1999). A methodological difference between the present study and that of Federmeier and Kutas (1999) may contribute to the disagreement between results. The present study collected electroencephalography (EEG) from participants while they passively read the sentence stimuli.

Conversely, in the Federmeier and Kutas (1999) experiment, participants completed a recognition memory test after reading the sentence stimuli. Thus, it could be argued that the participants may have been less engaged while reading the stimuli during the present study compared to the Federmeier and Kutas (1999) study. This lack of engagement may have contributed to the difference in results, as the passively reading participants may have exhibited a diminished response to unexpected stimuli if they were paying less attention to the sentence context overall. This could possibly explain why we did not find significant differences in N400 amplitude between all three sentence conditions, resulting in a disagreement of results between the present study and the Federmeier and Kutas (1999) study.

Assuming the differences are not arising from methodological differences between the studies, we provide several possible explanations. First, the present study controlled for cloze probability, but not constraint (Donnelly & Kinsman, 2014). It is possible that the uncontrolled effects of constraint could have influenced the results, considering that Federmeier and Kutas found differences in the mean amplitude and peak latency of the N400 for sentences with high versus low constraint (Federmeier and Kutas, 1999). While we anticipated that focusing on high cloze probability sentences would mitigate the effects of constraint, it is possible that context use during language processing is a much more subtle phenomenon than we suspected. Future research that aims to tease apart the effects of constraint, cloze probability, as well as the difference between prediction (i.e., prediction for specific lexical-items) versus expectation (i.e., expectation for a general semantic concept that may be expressed using various lexical items) are necessary. Likewise, further work that compares the facilitative effects of constraint and cloze probabilities in both younger and older adults is needed to fully appreciate the complicated nature of sentence processing.

Another possible explanation for the differences between our work and previous work relates to Federmeier and Kutas' (1999) claim that context-independent long-term memory structure has patterned effects on language processing. More specifically, they suggest that structural and functional similarities between real-world objects (i.e., category structure) impact neural organization and consequently language comprehension (Federmeier & Kutas, 1999). As such, the richness of connectivity of one's semantic network, or the strength of connections between semantically related words, may impact that individual's language processing. In line with this notion, it is important to consider individual variability in life experience, and consequently, individual variations in semantic connectivity. For example, in Federmeier and Kutas' (2002) study of context use in older adults, they found a subset of older adults whose N400 results patterned similarly to the younger participants. Interestingly, this subset of older adults demonstrated larger vocabularies and higher verbal fluency than the other older participants (Federmeier & Kutas, 2002). One could infer from these results that possessing a large vocabulary and a high verbal fluency could possibly correlate with possessing a richly connected semantic network, such that strong connections exist between semantically related words. Thus, the possibility also exists that there are subsets of younger adults who have stronger or weaker connected semantic networks, relatively, and that this would affect the magnitude of the N400 effect, especially for within-category violations.

Consider the hypothesis that the strength of connectivity of an individual's semantic network impacts their online interpretation of the sentence. It could be conceivable that one individual has a stronger semantic network than the other. When they both process the same sentence containing a within-category violation, it may be possible that the processing of the within-category violation would be facilitated for the individual with the stronger network because they are able to draw on those strong semantic connections. However, the individual with the weaker connection does not have the same advantage. Now suppose both readers were participants in the current ERP study. The individual with the stronger semantic network might show a decreased N400 response for within-category violations (compared to between-category violations), while the individual with the weaker semantic network may not. Research has shown that a typically aging individual's world knowledge and vocabulary increases at least up until 60 years of age (Salthouse, 2010). As general information gained from relevant experiences and vocabulary increase as a function of one's age (eventually peaking by a certain age, followed by decline), it could be argued that an individual's semantic network becomes stronger with age and experience (Salthouse, 2010). In the present study, the sample of young adults may have been skewed towards individuals with relatively weaker semantic networks. This could have contributed to our finding of no significant difference between the within-category violations and the between-category violations. Ultimately, much research is needed to explore the relationship between the strength and structure of semantic memory and N400 effects. Such individual variables could have an important impact on our understanding of language processing in both healthy and clinical populations.

Another relationship to consider is the possible effects of working memory on language processing. Working memory is responsible for the rapid trapping and processing of new and previously stored information (Gordon, Hendrick, Johnson, & Lee, 2006). In terms of language processing, working memory allows individuals to make moment-to-moment interpretations and conclusions based on the information presented and real-world knowledge (Bartek, Lewis, Vasishth, & Smith, 2011). It is important to examine the influence that working memory has on language comprehension and the possibility of differences between the capacity of individuals' working memory. It could be conceivable that one individual has a weaker working memory capacity than another. When they both read and interpret a sentence containing a within-category violation, it may be possible that the processing of the within-category violation would be facilitated for the individual with the superior working memory capacity. This is due to the individual's ability to hold the information in their mind long enough to make associations and interpretations about the text using their world knowledge. The individual with the weaker working memory may not have the same opportunity. Now suppose both individuals were participants in the current ERP study. The individual with the stronger working memory may show a decreased N400 response to the within-category violation (compared to between-category violations) while the individuals with the weaker working memory may not. We know from behavioural research that adults demonstrate age-related declines in cognition beginning in early-adulthood, including in efficiency and effectiveness of the ability to manipulate material online, or in short, working memory (Salthouse, 2010). Thus, given that our sample consisted of young adults, it is possible that our sample was not representative of the entire working memory continuum, but rather consisted primarily of individuals with relatively stronger working memory capacity. This could possibly explain why we did not find a significant difference between the congruent and the within-category violations in our sample.

Like the strength of an individual's semantic network, working memory capacity is another individual variable that complicates theories of online language processing. We suggest the possibility that the effects of sentence context on language comprehension are not all or none, and likely do not have clear-cut boundaries. There are likely complex and overlapping relationships between language processing and other cognitive processes. Further work is needed to explore the interrelationships among sentence comprehension, language processing and other cognitive domains, such as long term memory and working memory. These inquiries draw attention to the complex nature of language processing and the interrelated areas that can affect this process.

Interestingly, we did find a significant difference between the mean amplitude in the congruent and the incongruent between-category sentence conditions between 600-900 ms in the frontal electrodes. This change in amplitude is not consistent with results typically seen for an N400 response (Kutas & Hillyard, 1980b; Federmeier & Kutas, 1999). However this finding may be reminiscent of a post-N400 positivity, referred to as a frontal PNP, a neutral term suggested in a review by Van Petten and Luka (2012) to refer to "any enhanced positivity that is evident immediately after a larger N400 in a comparison between two conditions" (p. 183). Van Petten and Luka suggest that a frontal PNP effect may be attributed to the presentation of unexpected lexical items, rather than the presentation of unexpected general concepts that may be expressed by alternate words. As mentioned in Table 1, this sort of lexical-item specific prediction is more closely related to sentences with high cloze-probabilities, whereas facilitation of general concepts is more closely related to sentence constraint (Van Petten & Luka, 2012). With this in mind, the appearance of a frontal PNP is consistent with the fact that the stimuli for the present study were created using high cloze probabilities (i.e., greater than 0.5), but constraint was neither manipulated nor measured as a distinct variable. Future research is necessary to untangle the various ERP components that are elicited by different manipulations in sentence context, such as the distinction between constraint and cloze probability. Finally, more research is needed to investigate the conditions that elicit post-N400 positivities, and to attempt to understand the cognitive implications of this relatively new ERP component.

***Implications for sentence context effects in other populations***

Federmeier (2007) suggested that older and younger adults rely on different approaches to language comprehension. They suggest that older adults use a “bottom-up”, or integrative approach to language processing, to assess the overall coherence of the context and the plausibility that a word will fit that context. Conversely, younger adults use a predictive approach to processing, where the context is used to actively anticipate and prepare for the upcoming words. Not only did Federmeier (2007) suggest that younger and older adults use qualitatively different strategies, it was also suggested that these strategies might be lateralized to different hemispheres. This lateralization of strategies could have important implications for understanding context use in populations with acquired brain injury (e.g., stroke) to one or both hemispheres. Further research is necessary to better understand the role of lateralization and its interaction with various anticipatory strategies such as prediction and expectation. Gaining a better understanding of how healthy adults use context to facilitate language processing has important implications for understanding language processing in individuals with acquired language impairments, such as aphasia. Reports of improved reading in individuals with aphasia have been reported following text-reading treatments, however, the mechanisms of these improvements remain unclear (Kim & Bolger, 2012). It is thought that the "semantic and/or syntactic constraints imposed while reading a text facilitates single word identification in people with aphasia" (Beeson & Insalaco, 1998, p.168). Eye-tracking techniques have been used to study online processing of sentence context in PWA. In 2012, Kim and Bolger used eye fixation time and eye movement patterns while participants read both high and low-constraining context sentences. The researchers observed that eye-movements of PWA were more efficient while reading high-context sentences compared to low-context sentences (Kim & Bolger, 2012). These results suggest that high-context sentences support word processing in PWA. The results are comparable to those of the older adults in Federmeier et al.'s (2002) study that examined the use of sentence context in older and younger adults, where it was observed that older adults' language processing during a reading task was facilitated by highly constraining contexts, as well as earlier eye-tracking studies of sentence reading with contextually constraining sentences (Ehrlich, 1981). One could hypothesize that people with aphasia would demonstrate decreased N400 responses compared to healthy individuals in all conditions due to the fact that their semantic networks have been disrupted and may be less connected as a result of their injury. Furthermore, if highly constraining contexts help to facilitate language processing for people with aphasia, one might hypothesize that they would exhibit an increased N400 response in highly constraining contexts compared to low-context sentences if they are able to use context in the same way as healthy older adults. Further research is needed to examine the effects of context on language processing in healthy aging as well as clinical populations.

**SUMMARY AND IMPLICATIONS**

ERP and behavioural data support the theory that incremental processing of context leads to general expectations about upcoming semantic content (Van Petten & Luka, 2012). However, it is clear that context effects are not black and white, but rather, subtle differences in how context is presented, as well as individual variability in cognitive and language abilities, can have significant implications on the way in which we process language. This study highlights this notion, and encourages further research on the neurological underpinnings of language processing in order to better understand typical cognitive processes, and the implications those might have on the development of treatments for clinical populations.

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**CONSENT FORM**

**Part 1 (to be completed by the Principal Investigator):**

Title of Project: Neurophysiological mechanisms of reading in aphasia: Context effects and response to treatment

Principal Investigator: Dr. Esther Kim Phone Number(s): 780-248-1542

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**Part 2 (to be completed by the research subject):**

| | Yes | No |
|---|---|---|
| Do you understand that you have been asked to be in a research study? | ☐ | ☐ |
| Have you read and received a copy of the attached Information Sheet? | ☐ | ☐ |
| Do you understand the benefits and risks involved in taking part in this research study? | ☐ | ☐ |
| Have you had an opportunity to ask questions and discuss this study? | ☐ | ☐ |
| Do you understand that you are free to withdraw from the study at any time, without having to give a reason? | ☐ | ☐ |
| Has the issue of confidentiality been explained to you? | ☐ | ☐ |
| Do you understand who will have access to the information you provide? | ☐ | ☐ |

Who explained this study to you? ___________________________________________________
I agree to take part in this study: YES ☐ NO ☐

Signature of Research Subject ___________________________________________________

(Printed Name) ___________________________________________ Date: _______________

Signature of Witness ____________________________________________________________

I believe that the person signing this form understands what is involved in the study and voluntarily agrees to participate.

Signature of Investigator or Designee______________________________ Date __________

**THE INFORMATION SHEET MUST BE ATTACHED TO THIS CONSENT FORM AND A COPY GIVEN TO THE RESEARCH SUBJECT**