12-16-2015

Event-Related Potentials in Episodic and Semantic Memory: Distinguishing the N400 from the fN400

Stephanie Ross

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ABSTRACT

In the present study, we conducted an event-related potentials (ERP) study to examine episodic and semantic memory. We focused on two well-known patterns: the semantic N400 and the old/new fN400. Some researchers have argued that they reflect the same neuropsychological response (Voss & Federmeier, 2011). Others have suggested that they have distinct spatial-temporal signatures and reflect different psychological processes (Bridger, Bader, Kriukova, Unger, & Mecklinger, 2012). In the present study, we analyzed data using the basic N400/fN400 paradigm. We expect to find similar results to Bridger et al. (2012) in that the N400 and fN400 to be reliably different in topography and function.

INDEX WORDS: N400, fN400, Episodic Memory, Semantic Memory, ERP, Electroencephalography

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DISTINGUISHING THE N400 FROM THE fN400 ONLY

by

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of

Honors Bachelor of Science: Neuroscience

College of Arts and Sciences

Georgia State University

2015

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December 2015

ACKNOWLEDGEMENTS

I would like to express the deepest appreciation to Dr. Gwen Frishkoff, who introduced me to this study of Linguistics, and whose enthusiasm for the neural basis of language has conveyed much excitement in me in regard to this research. Without her invaluable guidance, encouragement, and persistent help, this honor would not be possible.

I would like to express thanks to Benjamin Rickles, my graduate student mentor, for invaluable effort and dedication in teaching me the techniques necessary for data processing and spending countless hours manipulating the NEMO pipeline.

I am thankful to the several numerous scientists and universities, the NEMO Team, involved in this study. Without their research and support, this experiment would not be possible.

I am thankful for the funding provided for this project by the National Institute of Health. Without the help of the NIH, this project would not have been possible.

I would also like to express gratitude to one and all who, directly and indirectly, have lent their help in completing this project.

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INTRODUCTION

The present study investigates neurolinguistic processes underlying semantic and episodic memory. According to some researchers, conceptual-semantic processing and familiarity-based memory for past events are associated with distinct neurophysiological patterns, which can be detected using event-related potentials (ERPs). Semantic processing has been most reliably linked to the N400 effect, which is an increased scalp negativity over centroparietal electrodes at around 300-500 ms. (Kutas & Federmeier, 2000). By contrast, familiarity-based memory has been linked to the so-called "frontal" N400 (or fN400) effect, which is an increased negativity over frontocentral electrodes at around 300-500 ms. (Rugg & Curran, 2007). The question is whether the fN400 is indeed a separate electrophysiological pattern, or whether it simply reflects activation of concepts during memory retrieval. This question has significance for many cognitive and neuroscientific domains. For example, if the N400 and fN400 are truly distinct, this could benefit work on vocabulary acquisition, by allowing us to pinpoint the contributions of conceptual-semantic processing — i.e., prior knowledge of words and what they mean— and episodic memory, which reflects domain-general processes that are engaged during learning (Frishkoff, Perfetti, & Westbury, 2009; Frishkoff, Perfetti, & Collins-Thompson, 2010).

In the present paper, we attempted to determine if the N400 and fN400 effects are indeed distinct functional patterns. To address this question, we examine these two ERP patterns within the same experimental paradigm. Two previous studies (Voss & Federmeier, 2011; Bridger, et al., 2012) attempted to measure the N400 and fN400 within the same experimental context. However, they found conflicting results. Voss and Federmeier (2011) found that the two ERP patterns were indistinguishable in timing and spatial (scalp) distribution. By contrast, Bridger and colleagues (2012) found that the N400 effects were substantially more posterior than the frontal fN400 familiarity effects and are therefore likely to reflect distinct cognitive and neural processes. Here, we examine differences in N400 and fN400 effects for words that have concrete meanings (e.g., *boat*, *house*) versus words that have abstract meanings (e.g., *love*, *remorse*). We expect to see **concreteness effects** — i.e., different patterns of activation — reflected in both the N400 and fN400 potentials. However, we also expect to see differences in the spatial distribution of concreteness effects for semantic processing and episodic memory. This finding would strengthen the conclusions of Bridger et al (2012) that the N400 and fN400 are distinct patterns, reflecting activation of distinct cognitive and neural systems. On the other hand, if the two functional contrasts yield electrophysiological patterns that are the same or similar in spatial distribution, this would support Voss & Federmeier (2011), who claimed that the N400 and fN400 effects represent activation of the same cognitive and neural systems.

1.1. Dual-Process Model of Memory

According to Bridger and colleagues (2012), the distinction between N400 semantic effects and fN400 memory effects is compatible with the dual-process model of memory (Hintzman & Curran 1994). The dual-process model posits two distinct processes that support episodic memory: familiarity and recognition. Familiarity-based memory is the feeling of having encountered something before, even if the original context cannot be consciously recalled (Ecker et al, 2007). According to Curran (Curran & Hancock, 2007; Rugg & Curran, 2007; Curran, 2000), familiarity-based memory is associated with the fN400 effect. The most compelling evidence for the specificity of the fN400 is comparison of ERP responses to hits (correctly recognized items that were presented earlier) versus false alarms (incorrect endorsement of new items) and correct rejections (items correctly identified as "new" or never presented). The typical finding is that the fN400 potential is reduced (less negative) for both hits and false alarms (Rugg & Curran, 2007). In other words, the fN400 is affected by any item that is pre-activated or primed, either because it was presented earlier or because it is related to a previously presented item. This pattern can be contrasted with the P600, as described below. Importantly, fN400 effects have been described for form- as well as meaning-based familiarity. For example, in studies that investigated differences in familiarity and recollection based responses using images rather than words, and participants were asked to judge images as old/new and asked to recall specific details that had been associated with the images, a distinct mid-frontal fN400 familiarity effect was seen (Curran & Hancock, 2007; Curran, 2000). These findings suggest that the fN400 memory effect reflects familiarity-based memory and cannot be reduced to conceptual semantic processing. If this is correct, then it makes sense to regard the fN400 as a cognitive biomarker that is functionally, as well as electrophysiologically, distinct from the semantic N400.

Recognition-based memory relies on conscious recollection of an object that has been previously presented, including specific details about the original context (Curran & Hanncock, 2006.) ERP studies of episodic memory have described a parietal P600 (positivity, peaking between 500 and 800 ms). Unlike the fN400, the P600 is enhanced for hits versus false alarms and correct rejections. In other words, the P600 appears to reflect recollection-based memory, which is associated with correctly recognized old items, but not false alarms. For example, Curran and Hancock (2007) presented participants with 360 faces associated with 240 occupations. In the study phase, the participants were shown 24 unique face/occupation pairings. Thirty seconds after the end of the study phase, participants were asked to make an old/new recognition based judgment of a mix of previously presented faces and 12 new ones. If an "old" response was detected, the fixation cross was replaced by a 600 ms delay and the participant was asked, "Do you (1) Remember the person's occupation (2) Remember specific details about the person (other specific details) (3) Not remember any specific details?" The pattern of fN400 responses was consistent with the hypothesis that this component is related to familiarity: occupation hits were equal to familiar hits and greater than misses and correct rejections. In other words, the fN400 findings were consistent with a familiarity-based process. By contrast, P600 responses were significantly greater when participants reported that they could recall specific details about the person or occupation.

Studies of patients with selective damage to the hippocampus have also shed some light on the distinct neural correlates of familiarity and recollection. Studies of patients with selective damage to the hippocampus able to distinguish objects as familiar to them though they were unable to recall any details about the context of the familiarity (Aggelton & Brown, 1999). Studies using event-related potentials have found correlates of recognition-based and familiarity-based as distinct ERP signatures, differing in spatial distribution and timing (Curran & Hancock, 2007; Rugg & Curran, 2007; Debruille, Pineda, & Renault, 1996; Bridger et al, 2012). Studies of pharmacological dissociation between familiarity and recollection effects provided further evidence for the distinction (Curran, DeBuse, Woroch, and Hirsham, 2006). Curran et al. (2006) investigated the pharmacological dissociation of familiarity and recollection effects using midazolam, a benzodiazepine thought to impair recollection more than familiarity, and found that administration of the drug greatly impaired the ability of participants to recognize items from a studied list of words. The parietal old/new recollection N400 effect was eliminated where-as the mid-frontal familiarity fN400 effect remained intact (Curran et al, 2006). This supported the dual process of memory as the effects were found to be associated with distinct topographies and functional qualities. Furthermore, in studies of amnesic patient, “Jon”, with medial temporal lobe damage isolated at the hippocampal formation, and not the parahippocampal formation, the patient suffered impaired recollection-based memory, but familiarity-based memory remained intact (Düzel, Vargha-Khadem, Heinze, Mishkin, 2001). These results supported the dual process of memory theory as selective damage the hippocampal region affected episodic memory and not semantic memory, suggesting that the memory effects are related to distinct functions and networks.

1.2 Are the N400 and fN400 Separate Components?

The distinction between the N400 and fN400 has been questioned by Voss & Federmeier (2011). They conducted an interesting variation on the standard episodic memory paradigm in which they elicited semantic and old/new judgments on each trial. First each word was presented for 500 ms and the subject was asked to make a pleasant/unpleasant judgment. Then there was a short (2500 ms) delay, and subjects were asked to make a graded old/new judgment (remember old, know old, guess old, new). Unbeknownst to subjects, there were sequences of semantically related (and unrelated) pairs of words embedded in the ongoing stimulus sequence. By contrasting ERP responses to related and unrelated words, they showed that semantic relatedness elicited N400 effects. Interestingly, when their N400 effects were maximal at frontal, rather than posterior, electrodes, and the topography of the semantic relatedness effect did not differ from the old/new ERP effects. Thus, Voss & Federmeier (2011) concluded that the N400 and FN400 reflect activation of the same conceptual-semantic networks.

Bridger et al. (2012) concluded that the N400 and fN400 are two functionally and electrophysiologically distinct ERP effects. Essentially, the experiment was an attempt to revisit the conclusions by Voss & Federmeier (2011) that concluded that the N400 and fN400 were not separate effects. Instead of the continuous stream used in the Voss & Federmeier (2011) design, Bridger et al. (2012) set the experiment into three phases: practice, study (priming), and test (recognition). As participants were shown intermixed related and unrelated words, they were asked to make a binary pleasant/unpleasant judgment. Then the participants were given an auditory oddball task to distract them before completing a test phase, during which the participants were shown words from the priming/study phase along with some unprimed/new words and asked to make a new/old (previously seen/not previously seen) judgment. The priming phase was used to elicit N400 effects, and the tests phase was used to elicit the fN400 effects. Based on the changes in ERP activity between these elicited effects, Bridget et al. (2012) concluded that the N400 was associated with priming and distributed as a posterior, parietal effect in the posterior region, and the fN400 was an anterior, fronto-central effect associated with recognition.

There were a number of differences between the two studies that may have contributed to the difference in findings. One important difference was the use of separate study and test phases in Bridger, et al. (2012). Voss & Federmeier (2011) used a continuous recognition paradigm, in which participants made both episodic and semantic judgments in response to every word. This interleaving of tasks may have prompted participants to engage semantic processes and strategies during the old/new judgment, introducing an issue in design as these N400 and fN400 may overlap in time course. This could explain why they found no difference in the timing or distribution of N400 effects for episodic versus semantic contrasts, whereas Bridger et al. (2012) found a more frontal distribution for the episodic contrast, which is typical of fN400 familiarity effects seen in prior work (Curran & Hancock, 2007; Rugg & Curran ,2007; Debruille, Pineda, & Renault, 1996).

1.3 Concreteness Effects in Semantic and Episodic Memory

The present study aims to address this conflicting evidence by replicating the Bridger et al (2012) study and add another experimental factor: stimulus concreteness. In prior work, researchers have reported that concrete words elicit more frontal N400 semantic effects than abstract words (e.g., Kounios & Holcomb, 1994; Holcomb, Kounios, Anderson, & West., 1999). Some authors have dual-coding theory, the use of concrete words invokes both a verbal "linguistic" semantic evaluation and a nonverbal "imaginistic" semantic evaluation, shifting the topographic distribution to a maximal over mid-frontal sites rather than the typical parietal sites (Kounios & Holcomb, 1994; Holcomb et al., 1999; Stròźak, Bird, Korby, Frishkoff, & Curran (*In review*)).

Previous studies have shown that concrete words elicit N400 responses that are more anterior than the typical parietal regions of the scalp (Kounios & Holcomb, 1994; Holcomb et al., 1999; Stròźak et al., *in review*). This topographic difference has been discussed with respect to the dual-coding theory, which posits that concrete words are associated both a "linguistic" (verbal/symbolic) code and an "imag-istic" (visuospatial) code. By contrast, abstract words are coded only in a verbal or symbolic form (Hol-comb et al., 1999). In support of this theory, it has been shown that people judge concrete words more quickly and with higher accuracy than abstract words (Kounios & Holcomb, 1994; Holcomb et al., 1999).

For instance, Kounios and Holcomb (1994) through a two block word judgment tasks of concrete and abstract words and pseudowords. In each block, participants were shown a strings of 160 words: 40 concrete words, 40 pseduowords derived from concrete words, 40 abstract words, and 40 pseudowords derived from abstract words, and participants were asked to judge the words as real English words or false words. When words and pseudowords were compared separately, it was found that participants respond more quickly to concrete words than abstract words and pseudowords. Furthermore, though the participants were equally accurate in their judgments of pseudowords and real words, but participants were more accurate at classifying concrete words than abstract words, and there was no corresponding difference for pseudowords. The ERP responses at 300 -500 ms and 500 – 800 ms to concrete real words were more negative going than abstract real words, and this difference was larger at more anterior locations. However, these differences disappeared with repetition, so Kounios and Holcomb (1994) did a second experiment, asking the participants to explicitly judge words as concrete or abstract, but removing pseudowords from the paradigm. Not only did they reveal significantly faster responses to repeated items, but participants also reacted significantly more quickly to concrete words than abstract words. There was also a trend towards higher accuracy for abstract words than concrete words. Again, concrete words produced more negative-going ERP responses than abstract words, with repetition the magnitude of this concreteness effect decreased. Moreover, the repetition effect for concrete words was larger over right hemisphere sites; whereas, the repetition effect for abstract words was larger over left hemisphere sites. The consistent differences in the ERP and behavioral responses for concrete versus abstract words in both experiments supported the dual-coding theory as there was a different lateralized pattern for concrete and abstract words, and different processes may be involved in comprehending the two different word types.

In a more recent study, Stròźak et al (*In Review*) investigated differences in fN400 and N400 concreteness effects. The study consisted of 12 study-test blocks, 72 words each. During the study phase, the participants were asked to study each word and memorize the color of the word. During test phase, the words were presented again with some new words, and participants were asked to judge whether the word was old or new. During this test phase, the words' colors changed from orange to blue or blue to orange, an effect of familiarity was expected. There was a contrast between familiar words and episodically new words as fN400 effects were elicited for both concrete and abstract words, but the effect was more pronounced at left anterior electrode sites for concrete versus abstract nouns. These two effects also had distinct topographies, adding evidence to the dual-process model of memory as well as the dual coding model.

1.4 Overview of Present Study

The present study was motivated by inconsistent results from previous research (Voss & Federmeier, 2011; Bridger et al, 2012). Our goal is analyze cross-lab data from ERP studies of episodic and semantic memory to settle the debate of whether or not the fN400 and N400 are reliably different in time course, topography, and cognitive function. This study has two aims:

This study aims to determine if the N400 and fN400 are or are not distinct in topography. We will observe increased negativity, peaking at 400-450 ms with a max effect across the centroparietal electrodes in response to semantically unrelated versus related prime-target pairs, and we will also observe increased negativity, peaking at 350-400 ms with a max effect over mid-frontal electrodes in response to new (unfamiliar) versus old (previously presented) words.

The second aim of this study is to determine whether these two components show similar effects of concreteness. In particular, we ask whether the magnitude and topography of the N400 and fN400 effects are the same or different for concrete versus abstract words. Based on previous work (Curran & Hancock, 2007; Rugg & Curran ,2007; Debruille, Pineda, & Renault, 1996; Bridger et al., 2012), we expect to find that concrete words elicit greater and more frontally distributed N400 semantic effects. We also expect that the fN400 memory effect will be stronger for concrete versus abstract words (Kounios & Holcomb, 1994; Holcomb et al., 1999; Stròźak et al. (*In Review*).)

METHODS

2.1 Participants

All participants were native English speaking, healthy, college students between the ages of 18-35 recruited from Georgia State University Psychology courses via the SONA system. As compensation, participants were given course credit.

2.2 Stimuli

The study phase consisted of 160 word pairs, half weakly associated (related) and half unassociated (unrelated). The word pairs were 80 abstract-abstract and 80 concrete-concrete, and there were mixed or blocked. The test phase was comprised of 160 words as well: half old, half new.

Table 1. Mean and standard deviation attributes

		Frequency	Length	Concreteness	Associative Strength
Encoding	prime words	69	4.92	449	0.10
	target words	89	4.92	454	0.10
Recognition	old words	83	4.78	446	*NA*
	new words	79	4.85	448	*NA*

Table 2. Mean and standard deviation attributes for prime words used in Encoding phase

	Frequency	Length	Concreteness	Associative Strength
abstract_abstract_related	87	5.15	326	0.20
abstract_abstract_unrelated	78	5.08	338	0.00
concrete_concrete_related	48	4.73	573	0.21
concrete_concrete_unrelated	58	4.90	557	0.00

2.3 Study Design

Participants completed a single session consisting of three parts (study/encoding, delay, and test/retrieval.) During the study blocks, participants viewed a continuous series of familiar words, presented one at a time in the middle of a computer screen. After each word, they judged the meaning of the word. In some versions of the experiment (table 1), the word meaning was positively or negatively valenced (i.e., "pleasant" or "unpleasant"), and asked to respond as quickly as possible. In some versions, embedded in the study sequence were prime-target word pairs that were weakly semantically related or semantically unrelated. Participants were typically not aware of these embedded patterns. By comparing the brain's response to unrelated and related targets, we hoped to elicit a posterior N400 semantic effect, as well as behavioral (response-time) effects. Between each study phase and retrieval task, there was a 5-minute delay phase, in which participants were given a short break while the experimenters checked the EEG net for impedances, but that is not analyzed here. During the retrieval task, participants were tested on their retention of words from the study blocks. Only worlds that appeared as unrelated targets during study phase were used as ‘old’ words during test blocks. As in the study blocks, words were presented continuously, one at a time, in the center of a screen. Participants were asked to make speeded judgments about whether each word was "old" (presented in the previous block) or "new" (not presented in the previous block). By comparing the brain's response to new versus old targets, we hoped to elicit a frontal fN400 (familiarity-based recognition) effect, as well as differences in response time.

We made several modifications and extensions to the design used by Bridger et al. (2012) while keeping several factors common to both studies. Bridger et al. (2012) gave 20-30 minutes between study and test blocks. We used the 10-minute auditory oddball delay task instead. Bridger et al (2012) used a similar 1,800ms stimulus onset asynchrony, and we used a 2,000ms stimulus onset asynchrony for semantic and episodic phases of the study. Bridger et al. (2012) used concrete words throughout the experiment. We utilized four types of prime-target pairs (abstract-abstract, concrete-abstract, concrete-concrete, abstract-concrete.) Finally, Bridger et al (2012) used 165 German words while we used 120 English words.

Our study included two additional analyses to extend previous work in this area. First, we examined N400 and fN400 effects for abstract and concrete words. Previous studies have found that concrete words elicit more frontal N400 semantic effects. Thus, we expected to find topographic differences between N400 effects for concrete versus abstract words. We further expected to find better memory — and therefore more robust fN400 effects — for concrete versus abstract words, for the comparison of correct hits ("old" judgments) versus correct rejections ("new" judgments"). The increased number of errors for abstract words further afforded the opportunity to compare false alarms (incorrect "old" judgments) with correct rejections. According to the dual-model of memory, which posits distinct cognitive and brain processes underlying familiarity- and recognition-based memory, this comparison also yielded a frontal fN400 effect. If so, it can provide additional evidence that familiarity-based memory, rather than conceptual-semantic priming, is responsible for the fN400 effect. This will strengthen the argument that the fN400 and N400 effects are cognitively and neurally distinct.

2.3 Data Collection

Data was processed and analyzed using NetStation software (NetStation 4, Electrical Geodesics Inc, Eugene, OR). Continuous EEG was filtered using a digital low-pass filter (30 Hz) and digital high-pass filter (0.1 Hz). Epochs were created beginning at 500 ms prior to stimulus onset and ending 1000 ms after. All data was processed for artifacts, including eye blinks, forehead tension, and head movement. All trials containing more than 20 bad channels were discarded. Artifact free trials were averaged. Average reference was corrected for polar average reference effects, and all ERPs were baseline corrected compared to the 500 ms stimulus interval.

2.4 Data Analysis

Behavioral Data Analysis. For study phase analysis, we compared the mean proportion of correct valence judgments semantically related/unrelated words and concrete/abstract word. Study phase data was entered into two-way repeated-measures of variance (ANOVA) with condition (related/unrelated) and concreteness (concrete/abstract) as the repeated measures. For test phase analysis, we compared the mean proportion of correct rejection of new words, correct recognition of old words, and false recognition of new words. Test phase data was entered into ANOVA with condition (correct rejection/ false recognition) and concreteness (concrete/abstract) as the repeated measures. Greenhouse-Geisser *p*-values are reported where appropriate.

ERP Data Analysis. In line with Stróźak et al. (*In Review*), we analyzed data from four scalp regions: LAS (left anterior superior, F3 as central electrode), RAS (right anterior superior, F4 as central electrode), LPS (left posterior superior, as P3 central electrode), and RPS (right posterior superior, P4 as central electrode). Mean amplitude values were computed across all 5 electrodes within each region in the N400/fN400 (250-450ms) and P600 (500-800ms) windows.

For the study phase, we conducted four-way ANOVA for four factors: concreteness (concrete/abstract), laterality (left/right), caudality (posterior/ anterior), and relatedness (unrelated/ related). For test phase, we conducted four way repeated measures ANOVA for concreteness (concrete/abstract), laterality (left/right), caudality (posterior/ anterior), and condition (old/new). Again, Greenhouse-Geisser *p*-values are reported where appropriate.

RESULTS

3.1 Behavioral Results

Study Phase. Mean proportions and standard errors of the means for valence judgments are summarized in Figure 1. Analysis of mean accuracy during study phase valence judgments revealed a main effect of Concreteness as participants were more accurate in their judgments for concrete versus abstract words (F=26.0, p<.001). A Relatedness X Concreteness interaction revealed a larger effect of relatedness for abstract than for concrete judgments in study phase (F=7.8, p=.01). Analysis of mean reaction times also revealed a concreteness effect such that concrete words were responded to more quickly than abstract words (F=5.2, p=.03). There was an effect of relatedness during study phase as well such that primed words were responded to more quickly than unprimed words (F=6.8, p=.02). Post Hoc t-tests revealed an Interaction of Concreteness for related (p=0.000, t=-4.826) and unrelated words (p=0.000, t=-5.191) in study phase accuracy. This interaction remained consistent in study phase reaction time for unrelated words (p=0.027, t=-2.392) and related words (p=0.023, t=-2.469). There was also a Main Effect of Relatedness for abstract words in accuracy (p=0.031, t=2.337) and reaction time (p=0.028, t=2.384) during study phase.

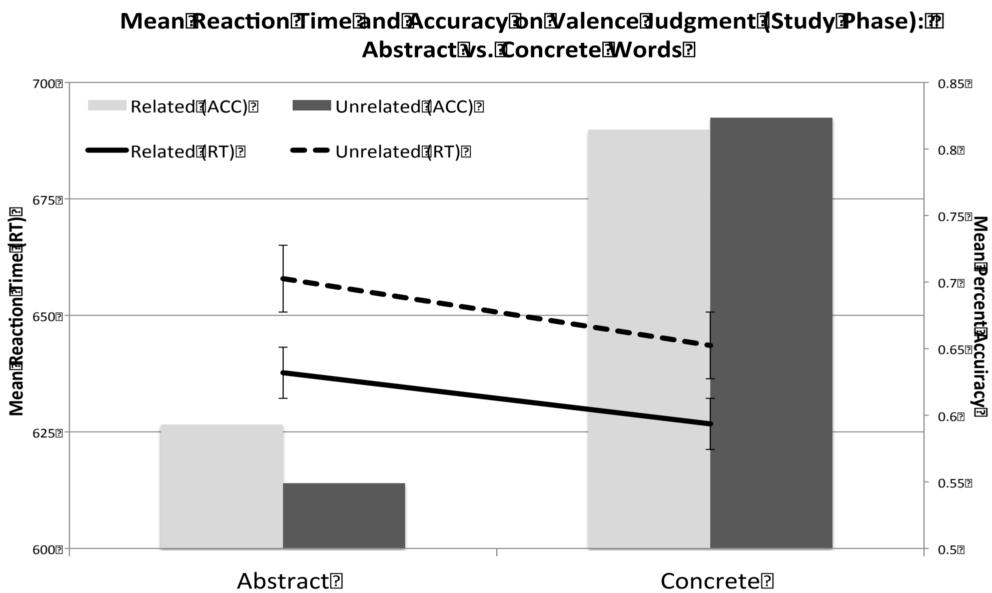

Figure 1. During the study phase, participants were asked to judge words as pleasant or unpleasant. The words were concrete or abstract and presented and related or unrelated to the previous word In the series. Grey bars represent test accuracy. Line graphs represent reaction time.

Test Phase. Mean proportions and standard errors of the means for test phase old/new judgments are summarized in Figure 2. Analysis of mean accuracy revealed a main effect of Old/ New as participants were more accurate for old than new items (*F*=5.0, *p*=.05). A Concreteness X Old/New interaction revealed that this Old/New effect was larger for abstract than for concrete items (*F*=5.6, *p*=.05). Test phase reaction times revealed an Old/New effect such that old words were responded to more quickly than new words (*F*=7.8, *p*=.01). Post Hoc t-tests revealed a Concreteness Effect for new words for both accuracy (*p*=0.016, t=2.658) and reaction time (*p*=0.094, t=1.762) in test phase. Post Hoc t-test also revealed an Old/ New Effect for abstract words in test phase accuracy (*p*=0.016, t=3.023). Old/New Effects were seen for both concrete words (*p*=0.085, t=2.53699) and abstract words (*p*=0.029, t=-2.354) in test phase reaction times.

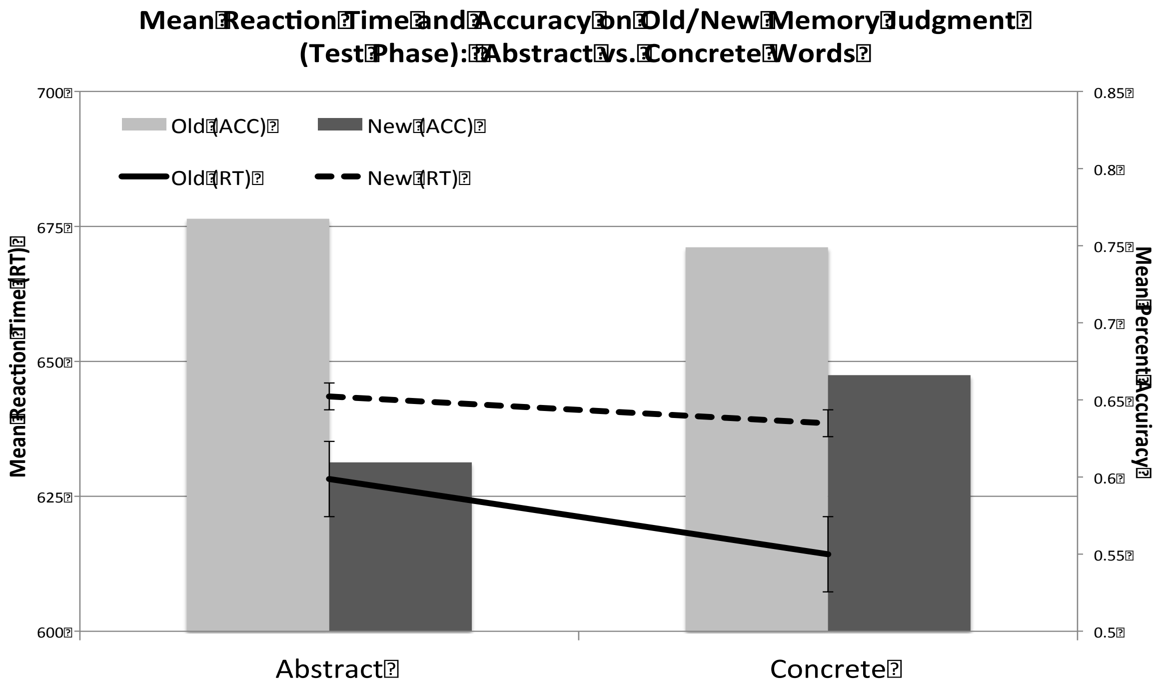

Figure 2. During the test phase, participants were asked to judge words as old (previously seen in study phase) or new (not previously seen in study phase.) Words were concrete or abstract, just as in study phase. Gray bars represent accuracy. Line bar represent reaction time.

3.2 ERP Results: Statistical Analysis

Relatedness Effect (Study Phase). Grand-averaged ERPs elicited by concrete and abstract words during the study phase as shown in Figures 3. During the study phase, there was a main effect of relatedness as related words as N400 effects seen for less negative than effects seen for unrelated words (F=9.3, p=.006). An interaction of Concreteness X Relatedness revealed no significant effect of relatedness for concrete items (F=9.6, p=.338). There was also a trend toward an interaction of Relatedness X Caudality X Laterality (F=2.7, p=.117). ERP responses also showed an Interaction: *the semantic N400 effect for abstract words showed a broader distribution than the N400 for concrete words*. In particular, abstract words showed a larger difference over the left frontal region (Figure 4). This result was also seen in the interaction of Concreteness X Caudality (F=5.0, p=.04). There was also a four way effect of Concreteness X Relatedness X Caudality X Laterality (F=4.5, p=.048). Post hoc analysis revealed no significant interactions of relatedness for concrete or abstract words, though there were trends toward significance in left parietal sites for abstract words (t=1.860, p=.078) and right parietal sites for abstract words (t=1.639, p=.118).

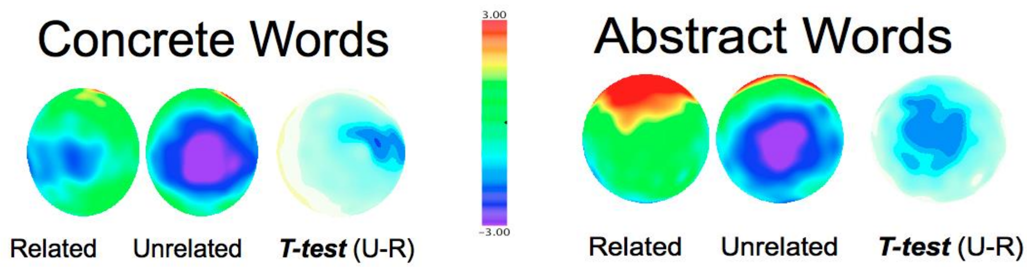

Figure 3. Topographic maps (~380ms) showing study phase (ERP semantic relatedness) effects for abstract words (bottom) and concrete words (top). Notice that the semantic relatedness effect is more widespread for abstract words. *Note: "t-test" maps represent T-test comparisons between related and unrelated words at each electrode.*

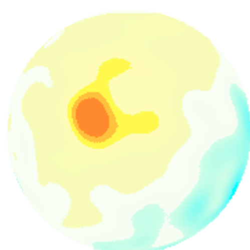

Figure 4. ERP "ttest" map showing interaction effect during study phase at ˜380 ms.

Old/New Memory Effects (Test Phase). To examine old/new memory effects, we compared ERP responses to words that were correctly recognized as old (previously seen) and correctly rejected as new (not previously seen). Figure 5 shows grand-averaged ERPs elicited during test phase for each condition: old, new, abstract, and concrete. There was a main effect of condition as responses to old words were less negative than responses to new words (F=20.4, p=.00). There was also a four way effect of Concreteness X Relatedness X Caudality X Laterality (F=4.9, p=.038). ERP responses also showed an Interaction: *the old/new fN400 memory effect was similar to the interaction effect for the semantic N400*. In particular, abstract words showed a larger difference over the left frontal region (Figure 6). Post Hoc analysis revealed that new abstract words showed a trend towards more negativity than old words at left frontal sites (p=0.057, t=2.030) and showed significantly more negativity at left parietal sites (*p*=0.036, t=2.258). There was also a trend towards more negativity of abstract new words than abstract old words at right parietal sites. (*p*=0.057, t=2.024). Concrete new words showed more negativity at left parietal sites than concrete old words (*p*=0.047, t=2.129). Concrete new words elicited higher negativity over right parietal sites than concrete old words (*p*=0.016, t=2.649). Concrete old words also showed more negativity than abstract old words at left frontal sites (*p*=0.017, t=2.608).

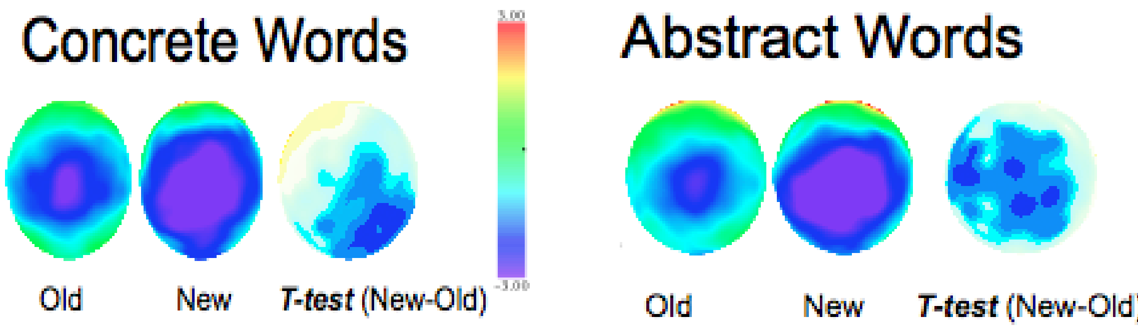

Figure **5.** Topographic maps showing old-new ERP effects during the test phase at ~380ms after word onset. <u>*Note*</u>*: T-test comparisons between old and new words at each electrode.*

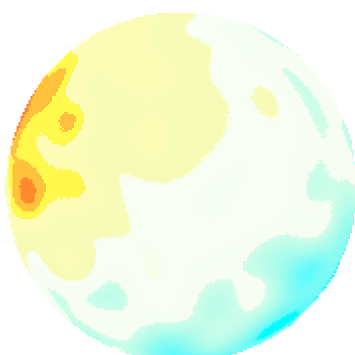

Figure **6.** ERP "ttest" map showing interaction effect during test phase at ˜430ms

3.3 Differences in N400 and fN400 ERP Effects

Repeated measures ANOVA that compared test and study phase memory differences revealed a trend towards a main effect of concreteness (*F*=2.8, *p*=.110), but this was not significant. There was a trend toward a three-way interaction of Experimental Phase X Caudality X Laterality (*F*=0.012, *p*=.052) and a significant four way interaction of Concreteness X Experimental Phase X Caudality X Laterality (*F*=9.0, *p*=.007)Post-hoc analysis revealed concreteness effects were showed a greater negativity at left frontal sites than left parietal for old words (t=-2.285, *p*=0.034). The concreteness effect showed greater negativity at left frontal sites than left parietal sites for unrelated words (t=-2.169, *p*=0.043). There was a trend towards greater negativity over right frontal sites than right parietal sites for related words (t=1.816, *p*=0.078). In Post Hoc comparison of frontal versus parietal memory effects, there was an interaction of left frontal and left parietal sites for concrete words in respect to differences in memory effect (t=2.394, *p*=.027). This resulted from a greater negativity in the left parietal than the left frontal sites.

DISCUSSION

This study had two aims. *The first aim was to determine whether the topography of the N400 and fN400 effects are the same or different for concrete versus abstract words.* Similar to Stròźak et al (*In Review*), we found that the fN400 familiarity effect and the N400 concreteness effect were associated with distinct topographies. However, contrary to Stròźak et al. (*In Review*), we found that abstract words engaged a larger network of brain regions as indexed by semantic N400 and episodic fN400 effects than concrete words. In particular, there were fN400 and N400 effects over left frontal electrodes for abstract, but not concrete words. This pattern of findings is the exact opposite of the patterns reported in Stròźak et al. Below we discuss some possible reasons.

Our second goal was to determine whether or not the N400 and fN400 effects have the same spatial distribution. Analysis of semantic N400 and familiarity based fN400 components revealed that there were trends towards differences in the fN400 and N400 effects, but these differences in caudality and experimental phase did not reach significance. However, if these effects were significant, the findings would not be consistent with Bridger et al (2012) because the fN400 episodic memory effect was centered over centro-parietal sites, and the N400 semantic effect was centered over fronto-central sites. These results also reject the null hypothesis that we would not find differences between the two effects, consistent with Voss and Federmeier (2011), as there was a trend towards a difference, though the topographic and functional distinctions were inconsistent with predictions.

4.1 Concreteness effects in episodic and semantic memory

In the present study, behavioral analyses revealed that the participants more accurately and more quickly judged concrete words than abstract words in study phase. In test phase, the participants responded to old words more quickly, but there was no significant difference how quickly participants judged abstract or concrete words as old/new. The concreteness effect was left lateralized and more negative for old, repeated words than new in study phases. The N400 effect was more negative more left frontal than left parietal for unrelated words than related words. The effects of concreteness were greater for N400 than fN400, as seen in comparisons of experimental phase and the Concreteness X Experimental Phase X Laterality X Caudality interaction. Based on this interaction, the concrete and abstract words engaged separate networks for episodic and semantic memory effect between test and study phase tasks, indicating differences in function and topography between the N400 and fN400 effects.

ERP analysis revealed that abstract words engaged a larger network of brain regions as indexed by semantic N400 and episodic fN400 effects than concrete words. In particular, there were fN400 and N400 effects over left frontal electrodes for abstract, but not concrete words. This pattern of findings is the exact opposite of the patterns reported in Stròźak et al. These distinctions may be accounted for by task related differences. Stròźak et al. (*In Review*) that did not require a semantic word judgment in the study phase as participants were asked to memorize the words and the color of each word. However, the present study required participants to make valence (pleasant/unpleasant) judgments while memorizing each word, and all words were presented in the same color. The use of changing colors by Stròźak et al. (*In Review*) drew the attention of the participants towards nonsemantic parameters, and without the use of a semantic judgment, it cannot be said how much influence the change in color of the visual stimuli may have had in the task. By engaging the participants to also make a valence judgment while viewing the words in study phase, the present study requires that participants focus only on semantic parameters of the word and word meaning. Furthermore, with this task difference, we required deeper levels of processing than one would without the requirement of a semantic judgment (Rugg & Curran, 2007). Not only was the judgment of pleasantness an abstract idea in itself, engaging abstract thought for every word, regardless of condition, it encouraged the participant to carefully evaluate the meaning of each word before the next appeared. However, in study phase of Stròźak et al. (*In Review*) participants were asked to make an 'imagistic' evaluation of the word's color, thus requiring the participants to think of each word as an object in a concrete parameter. Unlike previous studies, the present study also included aspects of semantic relatedness in priming. Because of the inclusion of this aspect in the task, the present study found that there was relatedness effect for abstract words greatest over left parietal sites and not right parietal sites. The differences in lateralization of the N400 effects of this study may have been indexed by the use of related/unrelated priming.

Differences in N400 effects for concrete and abstract words have varied across many previous studies as well (Adornio & Proverbio, 2001; Nittono, Suehiro, Hori, 2002; Kanske & Kots, 2007). For instance, Nittono et al (2002) found that the N400 effect was larger for concrete words, but with vector scaling, the effects appeared similar. Though concrete words were also memorized better than abstract words (Nittono et al, 2002), but there was no significant effect or trend towards this effect was seen in the present study. Though the concrete words were recalled with more accuracy in the present study, we did not find that this difference was significant. The lack of reaction time difference was; however, consistent with Adornio and Proverbio (2001), who also found that no differences in reaction time between concrete and abstract words. Also consistent with Adornio and Poverbio (2001), but not Stròźak et al. (*In Review*), the ERP responses to abstract words was larger over frontal sites, and concrete words were larger over occipital sites and not over left anterior electrode sites. Kanske and Kots (2007) also found differences in N400 responses to concrete and abstract words, but these differences were attributed to task effects, when participants are asked to make a valence judgment versus a lexical priming judgment, the amplitude of ERP response in response to negative words differs, though the participants consistently react more quickly to concrete words than abstract words, concrete words elicited more negative N400 responses in both tasks, and the effects were not lateralized.

4.2 The neurocognitive basis of episodic and semantic memory

Participants responded to old, familiar words more quickly than new words in the test phase, and there was a trend towards N400 distribution differences, as shown by the Concreteness X Experimental Phase X Caudality X Laterality when comparing N400 in study and test phases. Though the topographic differences in episodic and semantic memory effects were not significant, the trend was consistent with Bridger et al (2012) in that two effects were functionally and spatially distinct, but the results was also inconsistent because the fN400 episodic memory effect was centered over centro-parietal sites, and the N400 semantic effect was centered over fronto-central sites, compared to the reverse seen by Bridger and collegues (2012). It is important to note, as indicated by the Concreteness X Experimental Phase X Caudality X Laterality effect, the N400 effect was more negative more left frontal than left parietal for unrelated words than related words in study phase, indicating differences that the differences in N400 distribution is indexed by semantic differences in priming condition.

Thiese findings support the dual process of memory, as different networks were engaged for episodic and semantic memory as semantic priming differences in test and study phases were found to index two distinction topographic and functional memory effects. Though the areas of distribution were not consistent with previous studies (Curran & Hancock, 2007; Rugg & Curran, 2007; Debruille, Pineda, & Renault, 1996; Bridger et al, 2012; Stròźak et al, *In Review*), there is indication that the implication of familiairty-based episodic memory fN400 effects differed from the semantic-based N400 effects.

With the engagement of these separate networks in memory effects, there is indication for the support of dual processes of memory as well. As noted in previous research (Paller, Lucas, Voss, 2012; Voss, Lucas, Paller, 2012), the distinction between episodic and semantic memory effects may have been attributed to an entanglement of implicit and explicit memory processes. Explicit memory is the expression that an item was presented earlier, and implicit memory is an expression where the participant does not realize that their behavior is influenced by the previous experience with an item (Rosburg, Mecklinger, Frings, 2011; Paller et al, 2012; Voss et al, 2012). When the items were presented in the study phase of the present study, the participants were asked to memorize the words before being shown the words again in the test phase, ensuring that explicit memory would be engaged, as the participants were aware that their behavior was being influenced by the familiarity of the item. However, in the study phase, the recollection of semantic meanings in related/unrelated priming was done to engage implicit memory processes. In the present study, the engagement of these processes was selectivity engaged by the strategic task varaition between test and study phases, allowing the differences in the effects elicited to be presented as evidence for the the dual process of memory.

4.3 Limitations and Future Directions

Moving forward, it is necessary to perform better data cleaning of the current data set, increase signal-to-noise ratio, and to preform vector scaling. The present study was also limited in that only the regions of interest, parietal and frontal, were address, while other sites were ignored. Analysis of other sites may reveal that there are topographic differences outside of the selected region of interest. Future studies will aim also to preform meta-analyses of similar studies using similar paradigms to further the distinction of these two effects of episodic and semantic memory.

CONCLUSION

In the present study, we conducted an event-related potentials (ERP) study to examine episodic and semantic memory. We focused on two well-known patterns: the semantic N400 and the old/new fN400. Some researchers have argued that they reflect the same neuropsychological response (Voss & Federmeier, 2011). Others have suggested that they have distinct spatial-temporal signatures and reflect different psychological processes (Bridger et al, 2012). In the present study, we analyzed data using the basic N400/fN400 paradigm with concrete and abstracts words, and we expected to find similar results to Bridger et al. (2012) in that the N400 and fN400 to be reliably different in topography and function. We also expected to replicate the results of Stròźak et al. (*In Review*). However, we found that (1) the N400 semantic memory effect and fN400 familiarity effect elicited centroparietal effects. (2) We also found that abstract words engaged a larger network of brain regions as indexed by semantic N400 and episodic fN400 effects than concrete words. In particular, there were fN400 and N400 effects over left frontal electrodes for abstract, but not concrete words. This pattern of findings is the exact opposite of the patterns reported in Stròźak and collegues (*In Review*) and Bridger and collegues (2012).

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