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Contextual effects on conceptual blending in metaphors: An event-related potential study

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ABSTRACT

Blending theory proposes that metaphor involves mappings between elements in two distinct domains and integration of information from these two domains. Previous event-related potential (ERP) studies have suggested that literal mapping occurs during metaphor comprehension. However, it has remained unclear whether accessing literal meanings affects metaphor comprehension and the contextual factors affecting blending remain poorly understood. The present study used a two stimulus word-to-sentence matching paradigm to study the effects of literal mapping and semantic congruity on metaphor comprehension using probe words from different domains. ERPs were recorded when 18 participants read short novel metaphors (e.g., *The girl is a lemon*) or literal control sentences (e.g., *The fruit is a lemon*) preceded by either a relevant or irrelevant word. Five conditions were measured: congruent target metaphor, congruent source metaphor, congruent literal, incongruent metaphor, and incongruent literal conditions. The analysis of the late positive components (LPC) revealed a significant difference in the P600 amplitudes between incongruent and congruent conditions. We also demonstrated that mapping across remote domains evoked larger P600 amplitudes than mapping across close domains or performing no mapping. The results suggest that the demands of conceptual reanalysis are associated with conceptual mapping and incongruity in both literal and metaphorical language, which supports the position of blending theory that there is a shared

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mechanism for both metaphoric and literal language comprehension. Amplitude differences suggest that integration difficulty is modulated by mapping degree rather than the timing of lexical access in the present study. Our results do not provide evidence that directly supports earlier models that propose literal meanings are accessed before or in parallel with metaphoric meanings.

1. Introduction

A metaphor is a figure of speech that establishes an analogical relationship between two things or concepts. The relationship is based on the mapping of similar features across two domains: the source domain and the target domain. For example, in *Beth is a peach*, the sweet feature of a peach (source domain) is mapped to the pleasant personal quality of Beth (target domain). As comprehension of metaphors depends on successful analogical mapping, metaphors demand more effort in semantic processing than literal sentences. The non-obvious semantic relationships between the agent (e.g., *Beth* in *Beth is a peach*) and theme (e.g., *peach* in *Beth is a peach*) in metaphors are also expected to cause semantic processing difficulty. Based on these reasons, ERP research on metaphors has predominantly focused on semantic integration difficulty, typically associated with the N400, though research has observed the P600 usually occurs along with N400 in metaphor comprehension (Coulson & Van Petten, 2002; Pynte, Besson, Robichon, & Poli, 1996; Sotillo et al., 2005; Teuscher, McQuire, Collins, & Coulson, 2008). A few studies have focused on hemispheric lateralization, which has also been considered to indicate processing difficulty in non-literal language comprehension (Arzouan, Goldstein, & Faust, 2007; Coulson & Van Petten, 2002, 2007; Sotillo et al., 2005). However, it still remains unclear how conceptual mapping and contextual congruity affect metaphor comprehension. The present study aims to address these questions by varying degrees of mapping and semantic congruity of probe words presented prior to metaphorical and non-metaphorical statements.

1.1. Conceptual blending theory and metaphor processing

The Conceptual Blending Theory (CBT) proposes that both literal and metaphoric expressions involve the construction of multiple cognitive models and establishment of mappings between the conceptual components in both target and source domains (Coulson & Van Petten, 2002; Fauconnier & Turner, 1998; Teuscher et al., 2008). For instance, in order to understand the sentence "That stone we saw in the natural history museum is a gem", a mapping must be established between a gem and the stone we saw in the natural history museum. In a metaphor such as "He knows power is an intoxicant", the semantic attribute of power in the target domain must be mapped onto the attribute of intoxicant in the source domain. ERP studies have focused on better specifying the timing of access to literal and metaphoric meanings.

In order to test how the demand of conceptual integration affected difficulty of both literal and metaphoric language, Coulson and Van Petten (2002) created a midway 'literal mapping' condition (e.g., He used cough syrup as an intoxicant). They found that the metaphor condition (e.g., He knows power is an intoxicant) elicited the largest N400 amplitude, the literal mapping condition the second largest, and the literal condition the smallest. The graded amplitude suggested that degrees of mapping varied according to domains of the described target and that the remotely related domains demanded the most effort in conceptual integration. Their results support the CBT by showing that literal, literal mapping and metaphorical sentences all involve mapping at varying degrees and that the mapping degree primarily associates with the N400 amplitude with co-occurrence of P600.

Before the CBT was proposed, there were several previous models for metaphor comprehension and these vary with regard to the timing of access for metaphorical and literal meanings. They differ from the CBT in that earlier theories are more concerned about whether literal and metaphorical meanings are accessed differently whereas the CBT focuses on how mapping in both literal and metaphorical

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language affects integration difficulty. For instance, the standard pragmatic model has suggested that a literal meaning is accessed before a metaphoric meaning (Grice, 1975; Searle, 1979). To our knowledge, to date there has not been any ERP research that supported the pragmatic view. On the other hand, the direct access model posited that metaphors and literal sentences involve the same mechanism and are processed in parallel (Gibbs, 1984; Glucksberg, 2003). There has been some support for the direct access model as metaphoric meanings are suggested to be directly accessed when contextual relevant information is provided (Pynte et al., 1996).

1.2. Components related with metaphor processing

1.2.1. Negative component N400 and congruity

ERP research has generally reported that metaphors elicited larger N400 amplitudes than literal sentences. Several different paradigms have been used for ERP research on metaphors. Earlier research often used the sentence-final word paradigm to study the difference in metaphors (e.g., The fighters are lions) from literal sentences (e.g., The animals are lions). Pynte et al. (1996) reported that metaphors in the sentence-ending position showed larger N400 amplitudes than words with only literal interpretations. Since the N400 has been observed to be associated with semantic incongruity in literal sentence comprehension, Pynte and colleagues proposed that metaphoric meanings are incongruent meanings in contrast to common literal meanings. Since then, ERP studies on metaphors have compared metaphors with incongruent conditions and found that incongruent stimuli elicited greater N400 amplitudes than metaphors (Arzouan et al., 2007; Tartter, Gomes, Dubrovsky, Molholm, & Stewart, 2002). The other commonly used paradigm for metaphor comprehension is Stimulus1-Stimulus2 (S1-S2), a sentence to word matching paradigm. Based on the incongruity-assumption, this paradigm usually presents a metaphor (S1) followed by a congruent or incongruent word (S2). For example, Sotillo et al. (2005), used a metaphor sentence (e.g., The green lung of the city) followed by a relevant word (e.g., park) or an irrelevant word (e.g., semaphore). Their analyses revealed that metaphorically-related S2 target words elicited larger N400 amplitudes than unrelated S2 words. However, anomalous sentences triggered even larger amplitudes than metaphors. They proposed that N400 responses caused by metaphors show an anomaly (expectancy) effect rather than an incongruity effect. Similarly, A recent study, Arzouan et al. (2007) used word pairs as stimuli for a relatedness judgment task, where the second word in the pair varied along a continuity of a literal word, conventional metaphor, novel metaphor and unrelated word (Arzouan et al., 2007). The analyses revealed that unrelated words showed the largest N400 amplitudes, the novel metaphor the second largest, the conventional the third, and the literal word the smallest. The above studies all share the hypothesis that metaphorical meanings are incongruent or anomalous.

1.2.2. Late positive component P600 and reanalysis

The P600 has traditionally been considered to be a component associated with syntactic processing (Friederici, 1995, 2002; Hagoort, Brown, & Groothusen, 1993). A number of studies found that the P600 was sensitive to syntactic violations, complexity, and reanalysis (see van Herten, Kolk, & Chwilla, 2005 for review). While semantic violations and semantically incongruent words have reliably elicited the N400, recent ERP studies have reported P600 effects in semantic reversal anomalies (van Herten et al., 2005; Kolk, Chwilla, van Herten, & Oor, 2003) and thematic role animacy violations (Kuperberg, Sitnikova, Caplan, & Holcomb, 2003). Kuperberg et al. (2003) proposed that thematic role animacy violation (e.g., For breakfast the eggs would only eat toast and jam) triggered an evaluation process to determine if the thematic role assigned to the nouns in a sentence was appropriate for the lexico-semantic rules of words in the sentence. This suggests that the P600 is involved in self-monitoring, which also received support from Kolk et al.'s (2003) and van Herten et al.'s (2005) studies. Their research showed that semantic reversal anomalies (e.g., The cat that fled from the mice ran across the room) elicited P600 instead of N400. Since these semantically anomalous sentences were syntactically unambiguous, the P600 effect could not be attributed to syntactic difficulty. They suggested that the P600 was sensitive to any anomaly that violated an expectation. Importantly, they proposed that reanalysis should be a general process used to check the verdicality of initial sentence processing rather than specifically serving an ambiguity resolution function (Friederici, 1995, 2002), overcoming

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grammatical violations (Hagoort et al., 1993), or overcoming syntactic complexity (Kaan, Harris, Gibson, & Holcomb, 2000).

Interestingly, previous metaphor research that reported N400 also reported the presence of a P600 but did not discuss the role of P600 in detail. A recent study on nominal metaphor comprehension reported that metaphoric sentences revealed significantly larger P600 than literal sentences (De Grauwe, Swain, Holcomb, Ditman, & Kuperberg, 2010). They suggested that the P600 reflected additional analysis to resolve a conflict between the literal interpretation and the match between the metaphorical meaning, the context and information within semantic memory. In addition, van Herten et al. (2005), in support of the self-monitoring account proposed by Kolk et al. (2003), expanded the definition of reanalysis to include reprocessing after encountering any unexpected stimuli whether syntactic or semantic, the role of the P600 in metaphor comprehension could be either rechecking or reanalysis process.

In motivating the present study, we considered incongruity and metaphoricity to be two separate factors that affect semantic processing. The incongruity factor is manipulated with the congruity of probes and sentences. The metaphoricity factor is controlled with literal and metaphoric sentences. In line with the blending approach, the present study also focuses on the relationship between degrees of mapping and integration difficulty. Interpretation of a metaphor is based on mapping of an attribute from a source domain (e.g., "metal" is the source domain of *iron* in *The words are iron*) to a target domain (e.g., "language" is the target domain of *words* in *The words are iron*). The level of mapping varies at different degrees when the attribute in consideration refers to the property of the source domain (e.g., "hard" is referred to considering the source domain of *iron* in the example *The words are iron*) or quality of the target domain (e.g., "powerful" is referred to considering the target domain of *words* in the example *The words are iron*). We hypothesized that the remote connection of the referred attribute to the target domain may lead to more integration difficulty. That is, remote connections between concepts in two domains suggested by the probe word and the target sentence have a lower degree of conceptual mapping, which in turn leads to higher integration difficulty. For instance, the pair of *hard-the words are iron* would cause more integration difficulty than the pair of *powerful-the words are iron* because the mapping degree of the former is lower than the latter. The relationship of integration difficulty and degree of mapping is illustrated in Fig. 1.

To investigate how these factors might affect semantic processing in metaphors, we used an S1(probe word)-S2(sentence) paradigm, where the probe word may or may not match the sentence semantically. There are five conditions of interest: congruent target metaphor condition (e.g., sarcastic-The girl is a lemon), congruent source metaphor condition (e.g., sour-The girl is a lemon), congruent literal condition (e.g., sour – The fruit is a lemon), incongruent metaphor condition (e.g., wavy – The girl is a lemon) and incongruent literal condition (e.g., intelligent – The fruit is a lemon). Unlike metaphors that have probes for source and target domains, the literal sentences do not have a target domain for mapping. Therefore, we only have 5 conditions. Examples of the conditions and the factors manipulated in the present study, such as congruity, metaphoricity, degree of mapping and integration difficulty, are shown in the Table 1. Although the congruent target metaphor and congruent literal conditions both have high degrees of mapping, the metaphor condition is more abstract than the literal condition. Therefore, we consider the integration difficulty for the congruent target metaphor condition to be intermediate and that for the congruent literal condition to be low.

Though some ERP studies on metaphors have suggested the functional relatedness of P600 and N400 in metaphor comprehension (Coulson & Van Petten, 2002), few have focused on the depth of P600 in metaphor processing and sentence comprehension. In accordance with the view that the P600 effect is sensitive to any unexpected linguistic stimuli and reflects self-monitoring of initial sentence processing, it is likely that the P600 will be sensitive to incongruity, to closeness of mapping, and to metaphoricity.

We predict that graded degrees of mapping will result in a correspondingly graded level of reanalysis difficulty, which will be reflected by the P600. We also anticipate that metaphoricity will cause more integration difficulty in metaphors than literal sentences, which may be reflected by the N400. More specifically, incongruent conditions are expected to trigger larger P600 responses due to unexpected occurrences of the sentence following the probe word. Metaphors are anticipated to demonstrate larger N400 and P600 amplitudes than literal sentences because metaphors require more

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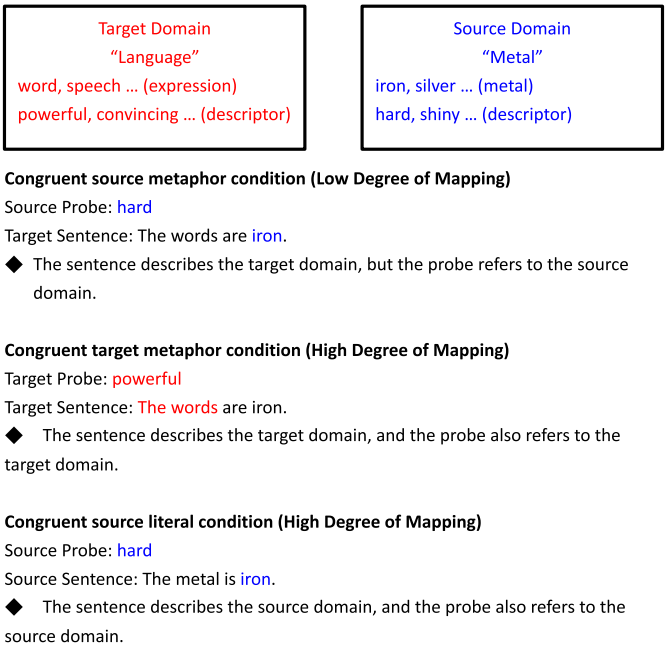

Fig. 1. Illustration of degrees of mapping for congruent Conditions. For the three exemplary sentences, the target domain is the language domain and the source domain is the physical domain (metal). Objects and attributes that belong to the target domain are presented in red while those belonging to the source domain are shown in blue. For the pair "hard-the words are iron", the sentence describes the target domain, but the probe refers to the source domain. Therefore, the pair has a low degree of mapping. For the pair "powerful-the words are iron", both the sentence and the probe describe the target domain. Thus, the pair has a high degree of mapping. For the pair "hard-the metal is iron", both the sentence and the probe describe the source domain resulting in a high degree of mapping. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

integration effort (Coulson & Van Petten, 2002) and more effortful self-monitoring of sentence processing. Lastly, the congruent target metaphor condition (e.g., sarcastic-the girl is a lemon) is predicted to exhibit larger N400 and P600 amplitudes than the source metaphor condition (e.g., sour-the girl is a lemon) because the former condition demands more effort in integrating the semantic attribute of

Table 1
Examples of the experimental sentences.

Condition	Probe (stim 1)	Sentence (stim 2)	Congruency	Metaphoricity	Degree of mapping	Intergration difficulty
Incongruent metaphor	Idiotic	The girl is a lemon	Incongruent	Yes	No	High
Congruent target metaphor	Sarcastic	The girl is a lemon	Congruent	Yes	High	Low
Congruent source metaphor	Sour	The girl is a lemon	Congruent	Yes	Low	Intermediate
Incongruent literal	Idiotic	The fruit is a lemon	Incongruent	No	No	High
Congruent literal	Sour	The fruit is a lemon	Congruent	No	High	No
Incongruent metaphor	Silly	The words are iron	Incongruent	Yes	No	High
Congruent target metaphor	Powerful	The words are iron	Congruent	Yes	High	Low
Congruent source metaphor	Hard	The words are iron	Congruent	Yes	Low	Intermediate
Incongruent literal	Silly	The metal is iron	Incongruent	No	No	High
Congruent literal	Hard	The metal is iron	Congruent	No	High	No
Incongruent metaphor	Loud	The lady is cinnamon	Incongruent	Yes	No	High
Congruent target metaphor	Sexy	The lady is cinnamon	Congruent	Yes	High	Low
Congruent source metaphor	Spicy	The lady is cinnamon	Congruent	Yes	Low	Intermediate
Incongruent literal	Loud	The spice is cinnamon	Incongruent	No	No	High
Congruent literal	Spicy	The spice is cinnamon	Congruent	No	High	No

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the target domain (e.g., sarcastic) with the semantic property of the sentence-final word (e.g., lemon). Unlike the study by Coulson and Van Petten (2002), we present the attribute for mapping in the preceding context rather than requiring that it be inferred from the sentences as it was in their prior study. The presence of the probe word may direct the participant to focus on the meaning of the referred attribute in the source (concrete) or target (abstract) domain. The current design will allow us to investigate the context-guided conceptual mapping and control parameters such as degrees of mapping, metaphoricity and contextual congruity.

The present study adopts the proposal of CBT that both metaphorical and literal language involve mapping and that the degree of mapping affects integration difficulty. Our predictions are based on this view. Alternatively, the standard pragmatic view that proposes literal meaning is accessed before the metaphor meaning, would predict that, for congruent conditions, the congruent literal condition (e.g., *hard-the metal iron*) would cause the least integration difficulty, the source metaphor condition (e.g., *hard-the words are iron*) the intermediate integration difficulty, and the congruent target metaphor condition (e.g., *powerful-the words are iron*) the highest integration difficulty. The integration difficulty would be reflected by amplitudes of the N400 or P600. The contrary direct access model would yield different predictions. The direct access theory proposes literal meaning is in parallel with the metaphor meaning. This view would predict that, for congruent conditions, the congruent literal condition (e.g., *hard-the metal iron*) and the congruent target metaphor condition (e.g., *powerful-the words are iron*) would have equally low levels of integration difficulty. The congruent source metaphor condition (e.g., *hard-the words are iron*) would be predicted to cause the highest integration difficulty level because the context (probe word) is inconsistent with the target sentence. For both models, the incongruent conditions would predict relatively larger amplitudes than the congruent conditions as the inconsistent contexts may cause greater difficulty in semantic integration than consistent context.

2. Methods

2.1. Participants

Eighteen (10 male, 8 female) healthy young adults that aged 19–36 years old participated in the study. All the participants were right handed and native English speakers. All subjects had at least one year of college education.

2.2. Materials

The experiment used a stimulus 1-stimulus 2, word to sentence matching paradigm. In order to control the possible confounding factors affecting semantic processing of the words and sentences, two experimenters generated a list of 225 word-sentence sequences using The University of South Florida Word Association Norms (http://www.cyber.acomp.usf.edu/FreeAssociation/Intro.html) and Extensions of the Paivio, Yuille, and Madigan norms (Paivio, Yuille, & Madigan, 1968). The sentences were controlled to be in the format of 'X is a (n) Y' to avoid any effect of syntactic difficulty. Using the reported statistics of the normalized words in the above-mentioned two databases, two separate raters calculated the word number of sentences and imageabilty, frequency and syllable length of the sentence-final words and the probe words. Imageability ratings of probe words (mean = 3.96, SD = 0.66) and the sentence final words for the metaphors (mean = 4.56, SD = 0.72) and for the literal sentences (mean = 3.62, SD = 0.91) were very similar. Word frequency of probe words (mean = 6.255, SD = 0.57) and the sentence final words for the metaphors (mean = 6.08, SD = 0.51)) and for the literal sentences (mean = 5.78, SD = 0.83)) were highly comparable as well. Mean word lengths for metaphor sentence-final word (mean = 4.11, SD = 0.87), literal sentence final word (mean = 6.55, SD = 2.45), and probe word (mean = 6.58, SD = 2.06) were not significantly different. Before the ERP study, a group of 23 subjects were asked to rate the degree of metaphoricity of the sentences used in the study with 1 being the least metaphorical and 7 the most metaphorical. Metaphors were rated significantly higher than literal sentences (metaphor mean = 6.8, SD = 0.32, literal mean = 2.3, SD = 0.11, $p < 0.001$).

Among the 225 sentences, 135 were metaphors (90 congruent, 45 incongruent) and 90 were literal sentences (45 congruent and 45 incongruent). The metaphors were divided into three subsets. Forty-five

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metaphors were preceded by a probe word that represented the semantic attribute of the source domain and the condition. Forty-five metaphors were preceded by a probe word that suggested the attribute from the target domain. The remaining forty-five metaphors were preceded by words with meanings that were irrelevant to the metaphoric or literal meanings. The 90 literal sentences were divided into two subsets 45 each. The first subset of literal sentences was preceded by words that were semantically related to the sentences and the second subset of the sentences was preceded by irrelevant words. Because we do not intend to study literal mapping in the current study, we do not have the congruent target literal condition and therefore we had five conditions (e.g., congruent literal, incongruent literal, congruent source metaphor, congruent target metaphor and incongruent metaphor.

We use the stimulus 1-stimulus 2 (S1-S2) paradigm, where S1 is a probe word related or unrelated to S2. S2 was either a literal sentence or a novel metaphor. Each stimulus pair included a word followed by a sentence. ERPs were analyzed only in response to S2, the last word in the sentence. S1 preceding a literal sentence was a related or unrelated word. In addition to unrelated words, S1 preceding a metaphor was able to be related to metaphors in a target domain (e.g., sarcastic-the girl is a lemon) or a source domain (e.g., sour-the girl is a lemon). This word represented the type of relationships that occurred between the items. For example, 'sarcastic' in the trial set 'sarcastic-the girl is a lemon' suggests that lemon is used metaphorically to describe the girl's personality.

2.3. Procedure

Participants were told to read sentences during the experiment. They did not have to make any behavioral responses during the trials. During the experiment, the words of the sentences were shown one at a time in black text against a white background on a computer screen. First, the probe word was presented for 3000 ms in the middle of the screen. The sentence was then shown one word at a time for 500 ms followed by a fixation cross "+" for 1000 ms. A total of 225 sentences were shown in a randomized order, sectioned into 56-57 sentences per block for four blocks. At the end of each block, there was a break and participants rested for 2 min. We gave each participant a questionnaire in which he or she had to answer multiple-choice questions (with three options) about the most appropriate meanings of the novel metaphors that were presented during the experiment. Mean agreement was above 80% for participants preferred meanings of the novel metaphors used in the study.

2.4. Data acquisition and preprocessing

Continuous EEG was recorded from a 64-electrode NeuroscanQuickcap using a Neuroscan Syn-Amps2 amplifier and Scan 4.3.2 software sampled at 1 kHz with impedances typically below 10 kΩ. The data were processed to remove ocular and muscle artifacts. The continuous EEG data were band-pass filtered from 0.15 Hz to 30 Hz for analysis. The EEG data were segmented offline into 2-s epochs spanning 500 ms before to 1500 ms after the presentation of the visual stimuli.

The data were recorded with a reference electrode located near the vertex, resulting in small amplitudes over the top of the head. In order to eliminate this effect, the data were re-referenced to the average potential over the entire head, which approximates the voltages relative to infinity. This removes undesirable reference effects, wherein channels near the reference appear to have artificially small amplitudes, and provides a more accurate representation of the brain activity under each electrode. The technique is valid provided the electrode cap has at least 64 electrodes and artifacts have been excluded. In order to minimize a small bias in the electrode-based average reference (Junghofer, Elbert, Tucker, & Braun, 1999), a spline-based estimate of the average scalp potential (Ferree, Luu, Russell, & Tucker, 2001) was computed using spherical splines. Placing the electrode cap on a realistic phantom head, the electrode coordinates were digitized (Polhemus, Inc.), and these coordinates were used to fit the splines for each subject. In subjects with a small number of bad electrodes, the splines were used to interpolate those electrodes, to yield a total of 62 data channels in every subject.

3. Results

We initially probed the data for an N400 effect, as this was predicted to reflect greater integration difficulty in metaphors over literal sentences. The electrophysical data of all conditions did not reveal

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the N400 effect, which often spans the latency window of 300–700 ms. We did not observe an increase in amplitudes in the specified time window in comparison with other time windows. We considered the latency window of 600 ms–1200 ms to be a measure of the P600. We did not observe significant latency differences among conditions using unpaired 2-sample *t*-test (congruent literal vs. congruent target metaphor $p = 0.08$, congruent literal vs. congruent source metaphor $p = 0.78$, incongruent literal vs. congruent literal $p = 0.15$, incongruent metaphor vs. congruent target metaphor $p = 0.26$, incongruent metaphor vs. congruent source metaphor $p = 0.39$). The scalp distribution maps of the ERPs for all conditions are presented in Fig. 2. As indicated in Fig. 2, anterior (i.e., frontal and temporal) and posterior (i.e., parietal and occipital) regions exhibited amplitude differences for both literal conditions and the congruent target metaphor condition.

All electrodes of each quadrant were averaged separately for the 600–1200 ms post-stimulus time window. We conducted a multi-factorial ANOVA (metaphoricity × congruity × hemisphere) of the mean amplitudes within the time window in each quadrant. Analysis of the 600–1200 ms post-stimulus time window revealed a reliable effect of congruity. The effect was equally strong in all four respective quadrants: the left ($F(1,17) = 11.040$, $p = 0.004$), the right ($F(1,17) = 10.618$, $p = 0.005$), the anterior ($F(1,17) = 13.116$, $p = 0.002$) and the posterior ($F(1,17) = 10.039$, $p = 0.006$). At the post-stimulus interval of 700 ms, we observed a main effect of metaphoricity in the right hemisphere ($F(1,17) = 4.462$, $p = 0.050$) and at the anterior electrodes ($F(1,17) = 5.655$, $p = 0.029$). There was an interaction of congruity and metaphoricity in the right hemisphere ($F(1,17) = 5.360$, $p = 0.033$) at the time window of 1200 ms. Congruity interacted with metaphoricity in the posterior electrodes ($F(1,17) = 6.079$, $p = 0.025$).

In accordance with our predictions, we observed hemispheric differences in processing literal sentences and metaphors. There was also a significant congruity by hemisphere interaction ($F(1,17) = 6.568$, $p = 0.020$). We also observed hemispheric difference for both literal and metaphoric conditions. A comparison of left and right hemisphere ($F(1,17) = 4.678$, $p = 0.045$) showed significance for all conditions with the left larger than the right-hemisphere in amplitudes.

In general, incongruent conditions evoked larger amplitudes than congruent conditions, and metaphor conditions evoked larger amplitudes than literal conditions. The incongruent metaphor

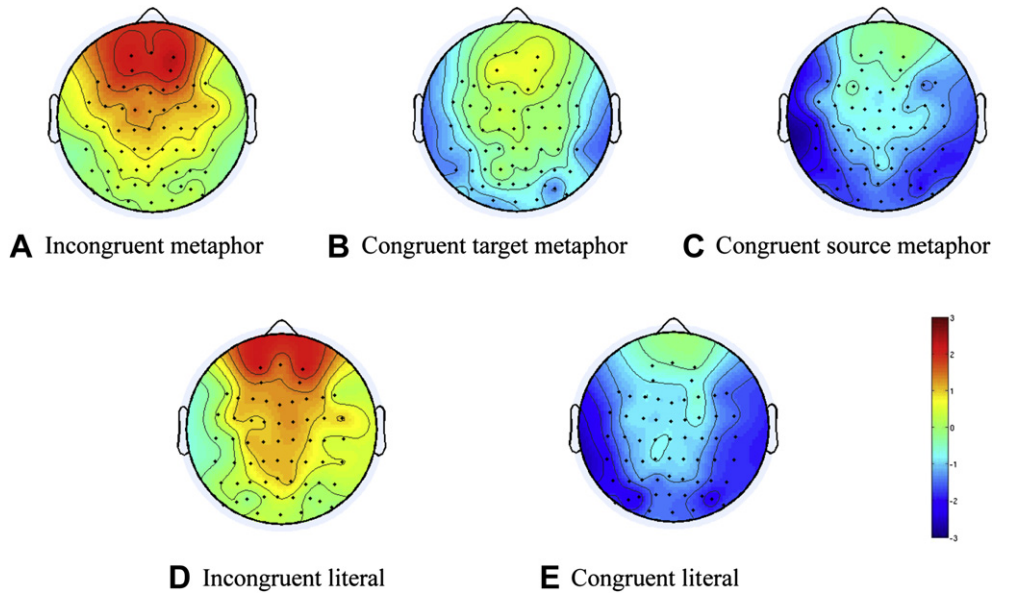

Fig. 2. Scalp Distribution over the 600–1200 ms time window for all conditions, (A) Incongruent metaphor, (B) Congruent target metaphor, (C) Congruent source metaphor, (D) Incongruent literal, (E) Congruent literal.

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condition evoked larger P600 amplitudes than all other conditions as predicted. The source metaphor condition showed the smallest P600 amplitudes. The three middle conditions, in descending order were the incongruent literal condition, the congruent target metaphor condition and the congruent literal condition respectively. The congruent target metaphor condition showed larger amplitudes than the congruent literal condition (Fig. 3) but the difference did not reach significance.

Two sample *t*-tests revealed that incongruent metaphors evoked significantly larger amplitudes than congruent source metaphors in the anterior and posterior regions ($p = 0.031$). The incongruent metaphor condition elicited an insignificantly larger amplitude than the congruent target metaphor ($p = 0.398$). The congruent target metaphor condition elicits an insignificantly larger amplitude than the congruent source metaphor condition ($p = 0.774$). The incongruent literal sentences elicited larger amplitudes than the congruent literal sentences as in Fig. 4. In this comparison, we observed significance in amplitudes at the time window of 800–1200 ms in the anterior and posterior regions ($p = 0.002$). We did not perform corrections for multiple comparisons for these analyses. For EEG analysis, the problem of multiple comparisons can be solved by restricting the search-space prior to inference. As a result, there is only one test per repeated measure. (Kilner & Friston, 2010). Following this rationale, we averaged the data over pre-specified sensors in each quadrant and time-windows of interest.

4. Discussion

We investigated the neurophysiological correlates of semantic processing of sentences preceded by words that provided contextual information. We have examined two types of semantic properties that may cause processing difficulty: incongruity and metaphoricity. While the majority of previous ERP studies of metaphor have focused on the N400, the present study did not find N400 in response to metaphors or literal sentences. It is possible that the unexpected content of the metaphor elicited P600 effect as previous research reported that unexpected semantic anomaly elicited P600 instead of N400 (Kuperberg et al., 2003).

The P600 observed in the present study is consistent with a reanalysis process in sentence comprehension, which is a common process that checks the veridicality of sentence processing regardless of sentence types. We also included varying degrees of conceptual mapping in the experimental paradigm and our analysis revealed an amplitude difference that might arise from different degrees of mapping. Therefore, the results also offer evidence in support of the conceptual blending theory (Coulson & Van Petten, 2002; Fauconnier & Turner, 1998; Teuscher et al., 2008). The results support the theory by showing that literal and metaphorical sentences both involve mapping and that the mapping degree associates with the P600 amplitude.

4.1. Conceptual mapping in metaphor

A major focus of ERP metaphor research has been isolating an appropriate model of metaphor comprehension. Two prominent theories include the standard pragmatic model and the conceptual blending theory. According to the standard pragmatic model, metaphors are processed with qualitatively different mechanisms from those for literal language (Gibbs, 1984; Glucksberg, 2003). On the other hand, the conceptual blending theory suggests that literal and non-literal language use the same processing mechanisms, known as the continuity claim (Coulson & Van Petten, 2002; Fauconnier & Turner, 1998; Teuscher et al., 2008). According to this theory, metaphor processing only differs from literal sentence comprehension in that metaphor comprehension requires mapping between elements in separate domains, while literal sentence processing involves mapping in the same domain. The mapping of attributes from two distinct domains depends on background information in each domain and only relevant attributes are involved with mapping (Coulson & Van Petten, 2002). Usually mapping occurs from the literal domain to the abstract (metaphoric) domain. For instance, in the metaphor *Beth is a peach*, the attribute "sweet" of the word "peach" is selected for mapping, whereas other attributes such as "pink" and "fruit" are inhibited. The property "sweet" was then applied to the domain of a human.

Despite existence of neural models for metaphor comprehension, little research has been conducted to study how mapping in same or across different domains affects semantic processing. A

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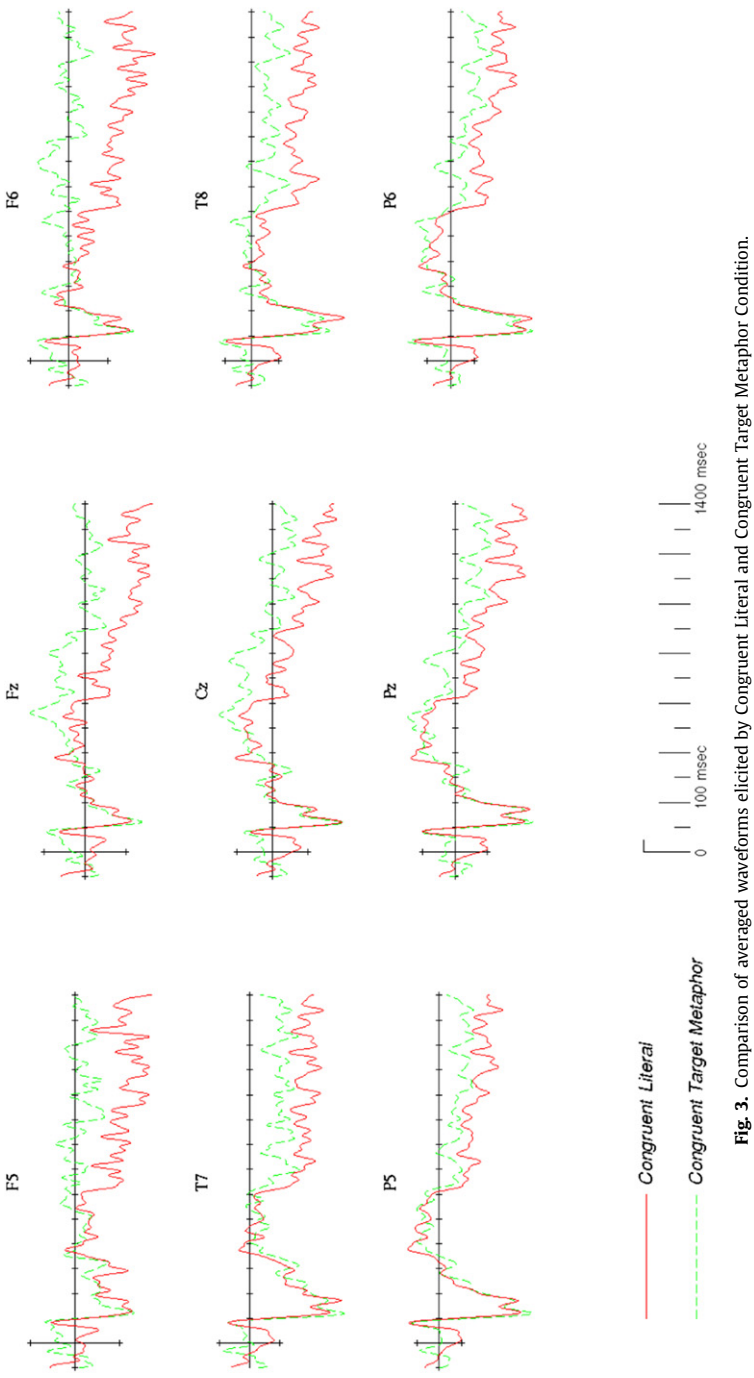

Fig. 3. Comparison of averaged waveforms elicited by Congruent Literal and Congruent Target Metaphor Condition.

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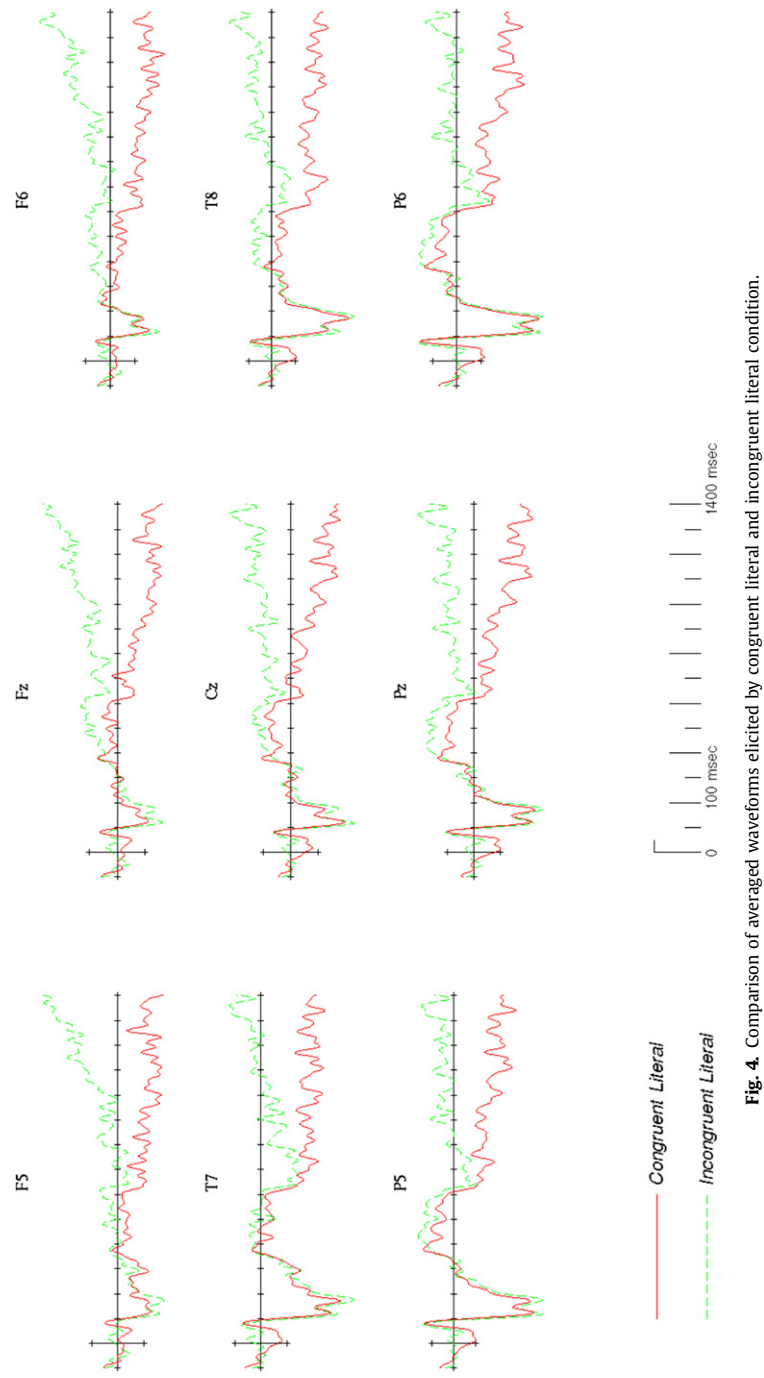

Fig. 4. Comparison of averaged waveforms elicited by congruent literal and incongruent literal condition.

recent attempt to verify the conceptual blending theory indirectly shows that semantic features of the literal domain inferred from the sentences are easier to integrate than the features of the metaphoric domain (Coulson & Van Petten, 2002). In their study, they used a literal mapping condition (e.g., He has used cough syrup as an intoxicant) in addition to the metaphor (e.g., He knows that power is a strong intoxicant) and literal condition (e.g., He knows that whisky is a strong intoxicant). Graded N400 amplitudes were reported among these conditions with metaphors being the largest and literal sentences the smallest, suggesting that sentences that required mapping across remotely related domains (e.g., power and intoxicant) called for more effort in conceptual integration as reflected by larger N400 amplitudes. The late positive component also exhibited the same pattern. The present research is similar in that we also included stimuli that represented the attributes of the source and target domains in the design. However, the current research differs from their study by placing an overt semantic feature of source or target domain before a metaphor to directly observe the priming effect on metaphor comprehension. While we did not observe N400 effects, we did find graded P600 amplitudes among the literal condition, source metaphor condition, and congruent target condition. The congruent target metaphor condition elicited the largest amplitude and the source metaphor condition the smallest, with the literal condition in the middle. This pattern indicates that integration of contextual information of the target domain with metaphor comprehension required the most effortful reanalysis.

Coulson and Van Petten (2002) also observed a larger P600 amplitude for metaphors. Based on studies that reported larger P600 amplitudes in recognition of low-frequency words (Coulson & Van Petten, 2002; Van Petten, 1993; Van Petten, Kutas, Kluender, Mitchiner, & Mcisaac, 1991), they proposed that the larger P600 in novel metaphor comprehension might reflect retrieval of additional conceptual structure from semantic memory. In our study, it was likely that the word representing the target attribute was involved with conceptual mapping across two distinct domains and that the stronger late positivity reflected the active retrieval of information and integration of the target attribute. However, Coulson and Van Petten (2002) found that the midway literal mapping condition demonstrated intermediate amplitude, while our results showed that source metaphor elicited the smallest amplitude. It was possible that the attribute of the source domain did not evoke sufficient conceptual structures used in facilitating mapping across domains, and therefore did not result in significant integration effort. Our findings support the mapping hypothesis in that sentences that involved mapping across remotely-related domains demanded the greatest degree of reanalysis or integration effort. Semantic attributes that were not mapped to the target domain did not affect the reanalysis process and therefore the source literal condition elicited the smallest amplitude.

4.2. Functions of P600 in metaphor comprehension

Earlier ERP studies have generally maintained that the P600 reflects the effort to reanalyze syntactic structures with the presence of grammatical errors or syntactic complexity (Friederici, 1995, 2002; Hagoort et al., 1993; Kaan et al., 2000). On the other hand, recent research using experimental designs with thematic role mismatches, which might trigger semantic rather than syntactic processing difficulty, reported P600 effects but not N400 effects (van Herten et al., 2005; Kolk et al., 2003; Kuperberg et al., 2003). For instance, Kuperberg et al. (2003) evaluated how conceptual relationships between noun-phrases and verbs affect processing of written language using simple, unambiguous sentences. They compared non-violated sentences such as “For dinner the girls would only eat steak and bread”, thematic role animacy violations such as “For dinner the meat would only eat steak and bread”, and non-thematic role pragmatic violations such as “For dinner the girls would only fight steak and bread”. Kuperberg et al. (2003) found that only the thematic role animacy violations elicited a large P600 effect. The violation occurred because an inanimate object, which was more likely to be the theme, appeared in the role of agent (actor of the event). Kuperberg et al. (2003) discussed three possible explanations for the large P600 amplitude in animacy violation. The first account was that the P600 indicated a self-monitoring, or checking process (Kolk et al., 2003). The second possibility was that the P600 indexed syntactic integration (Gibson, 1998; Kaan et al., 2000). The third explanation was that in the thematic role animacy violations, reanalysis occurred in order to reassign the thematic role of *meat* in the example from the agent performing an action to the theme in order to make sense of the sentence. The

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P600 amplitude scaled up with difficultly level for reassigning the roles to repair the structure. This suggests that reanalysis elicits a P600 effect and is not restricted to syntactic mismatches.

The role of the P600 in metaphor comprehension can be either rechecking or reanalysis process. The P600 may reflect a checking process during an encounter of unexpected stimuli in the present study, as the incongruent literal and metaphor sequences both elicited significantly larger amplitudes than the congruent sequences. This pattern is not surprising because incongruent sequences were unexpected and would likely trigger self-checking. Comparing the incongruent conditions, the incongruent metaphor sequence triggered larger amplitude than the incongruent literal sequence. This suggests that incongruent contextual information poses a greater challenge to processing of metaphors than literal sentences. Metaphors demand greater effort in self-monitoring or re-checking because participants have to consider whether the probe word is an attribute related to the unconventional metaphoric meaning.

The general reanalysis process proposed by van Herten et al. (2005) can also account for the results in the current research. For instance, the source metaphor condition (*spicy-the girl is cinnamon*) displayed the smallest amplitude. *Spicy* was only related with the concrete meaning of the word "cinnamon" but not related to the metaphoric meaning (i.e., *The girl is sexy*) and thus did not prompt reanalysis of the comprehension of the metaphoric meaning. In contrast, the target congruent metaphor condition (*sexy-the girl is cinnamon*) triggered larger amplitudes because the probe word *sexy* directed participants to think about the metaphorical interpretation of the sentence, which involves reanalysis of the semantic features of the word in the metaphor. Somewhat similar to this reanalysis account is a recent explanation proposed by De Grauwe and colleagues who studied nominal metaphor comprehension (2010). They suggested that P600 reflected additional analysis to resolve a conflict between the implausibility of the literal interpretation and the match between the metaphorical meaning of the critical word, the context and information within semantic memory. In our research, the additional analysis is also required to resolve the conflict between the interpretation of sentences and the match between the sentences and probe words. Therefore, our results also support De Grauwe and colleagues' proposal.

4.3. Hemispheric lateralization

Several neuropsychological studies have established that patients with right hemisphere damage show impaired metaphor comprehension compared to patients only with focal lesions in the left hemisphere, suggesting an asymmetrical contribution of the right hemisphere in metaphor processing (Van Lancker & Kempler, 1987). This observation has motivated the proposal of the right hemisphere metaphor theory. Previous ERP research has not provided consistent findings in support of this proposal. According to Sotillo et al.'s (2005) results, source localization of the N400 component showed that the right middle/superior temporal gyrus was more activated when S2 stimuli were related to the S1 metaphor stimuli as opposed to unrelated. They concluded that comprehension of metaphoricity instead of incongruity increased right but not left hemispheric activity.

Coulson and Van Petten (2002) hypothesized that ERPs would provide an accurate measure of the contribution of the two cerebral hemispheres to figurative language processing. They hypothesized that if the right hemisphere contributed more to metaphor processing, it would support the claim of the standard pragmatic model that figurative language uses qualitatively different processing mechanisms than literal language (Coulson & Van Petten, 2002). Coulson and Van Petten (2002) found that there was no overall significant relationship between sentence type and hemisphere; however, they did find that frontal positivity was slightly larger on the right in a comparison of literal sentence with literal-mapping sentences, suggesting a three-way interaction between sentence type, anterior/posterior, and left/right hemisphere for these two conditions (Coulson & Van Petten, 2002).

In the present study, we observed a similar anterior-posterior difference as Coulson and Van Petten (2002). The anterior-posterior positivity interacts with metaphoricity at the interval of 1000 ms–1400 ms. However, we did not observe consistent left-right hemispheric differences across conditions throughout the post-stimulus interval. We only observed the main effect of metaphoricity in the right hemisphere at the 700 post-stimulus interval. The results suggested that there was no right-hemisphere advantage in metaphor processing. Our findings differ from findings of lateralization in

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previous metaphor ERP research that reported right lateralization of metaphor comprehension throughout the whole time windows of the N400 and the P600 (Arzouan et al., 2007; Sotillo et al., 2005). The current results support the position of the conceptual blending theory that literal sentence and metaphor comprehension share the same processing mechanism in a left-lateralized manner because our analysis revealed that the P600 was significantly larger in the left than the right hemisphere for all conditions. Lastly, the results support our hypothesis that congruity was a separate factor from metaphoricity. There was a main effect of congruity in both hemispheres at all intervals whereas there was no reliable effect of metaphoricity in a particular hemisphere at several intervals.

5. Conclusion

The present study demonstrated that the congruent target metaphor condition that involved mapping across remote domains evoked larger P600 amplitudes than the congruent literal condition that involved mapping in close domains or the source metaphor condition that involves no mapping. This pattern of results suggests that metaphorical mapping may cause semantic reanalysis of sentences and that remote mapping may require more reanalysis effort than close mapping. We also observed significant differences in P600 amplitudes between congruent and incongruent conditions. This indicates that incongruity is a strong factor to trigger the reanalysis process in both metaphors and literal sentences. We conclude that demands of conceptual reanalysis associate with the processing difficulty in both literal and metaphorical languages, which supports the blending theory that suggests a shared mechanism for both metaphoric and literal language comprehension.

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References

Arzouan, Y., Goldstein, A., & Faust, M. (2007). Brainwaves are stethoscopes: ERP correlates of novel metaphor comprehension. *Brain Research, 1160*(17597591), 69–81.
Coulson, S., & Van Petten, C. (2002). Conceptual integration and metaphor: an event-related potential study. *Memory and Cognition, 30*(6), 958–968.
Coulson, S., & Van Petten, C. (2007). A special role for the right hemisphere in metaphor comprehension? ERP evidence from hemifield presentation. *Brain Research, 1146*, 128–145.
De Grauwe, S., Swain, A., Holcomb, P. J., Ditman, T., & Kuperberg, G. R. (2010). Electrophysiological insights into the processing of nominal metaphors. *Neuropsychologia, 48*(7), 1965–1984.
Fauconnier, G., & Turner, M. (1998). Conceptual integration networks. *Cognitive Science, 22*(2), 133–187.
Ferree, T. C., Luu, P., Russell, G. S., & Tucker, D. M. (2001). Scalp electrode impedance, infection risk, and EEG data quality. *Clin Neurophysiology, 112*(3), 536–544.
Friederici, A. D. (1995). The time course of syntactic activation during language processing: a model based on neuropsychological and neurophysiological data. *Brain and Language, 50*(3), 259–281.
Friederici, A. D. (2002). Towards a neural basis of auditory sentence processing. *Trends in Cognitive Sciences, 6*(2), 78–84.
Gibbs, R. W. (1984). Literal meaning and psychological theory. *Cognitive Science, 8*(3), 275–304.
Gibson, E. (1998). Linguistic complexity: locality of syntactic dependencies. *Cognition, 68*(1), 1–76.
Glucksberg, S. (2003). The psycholinguistics of metaphor. *Trends in Cognitive Sciences, 7*(2), 92–96.
Grice, H. P. (1975). Logic and conversation. In P. Cole, & J. Morgan (Eds.), *Syntax and semantics 3: Speech arts*. Academic Press, 3.
Hagoort, P., Brown, C., & Groothusen, J. (1993). The syntactic positive shift (Sps) as an Erp measure of syntactic processing. *Language and Cognitive Processes, 8*(4), 439–483.
van Herten, M., Kolk, H. H., & Chwilla, D. J. (2005). An ERP study of P600 effects elicited by semantic anomalies. *Brain Research Cognitive Brain Research, 22*(2), 241–255.
Junghofer, M., Elbert, T., Tucker, D. M., & Braun, C. (1999). The polar average reference effect: a bias in estimating the head surface integral in EEG recording. *Clinical Neurophysiology, 110*(6), 1149–1155.
Kaan, E., Harris, A., Gibson, E., & Holcomb, P. (2000). The P600 as an index of syntactic integration difficulty. *Language and Cognitive Processes, 15*(2), 159–201.
Kilner, J. M., & Friston, K. J. (2010). Topological Inference for EEG and MEG. *The Annals of Applied Statistics, 4*(3), 1272–1290.
Kolk, H. H. J., Chwilla, D. J., van Herten, M., & Oor, P. J. W. (2003). Structure and limited capacity in verbal working memory: a study with event-related potentials. *Brain and Language, 85*(1), 1–36.
Kuperberg, G. R., Sitnikova, T., Caplan, D., & Holcomb, P. J. (2003). Electrophysiological distinctions in processing conceptual relationships within simple sentences. *Cognitive Brain Research, 17*(1), 117–129.

Please cite this article in press as: Yang, F.-P. G., et al., Contextual effects on conceptual blending in metaphors: An event-related potential study, *Journal of Neurolinguistics* (2012), http://dx.doi.org/10.1016/j.jneuroling.2012.10.004

Paivio, A., Yuille, J. C., & Madigan, S. A. (1968). *Concreteness, imagery, and meaningfulness: Values for 925 nouns*.
Pynte, J., Besson, M., Robichon, F. H., & Poli, J. (1996). The time-course of metaphor comprehension: an event-related potential study. *Brain and Language, 55*(3), 293–316.
Searle, J. R. (1979). *Expression and meaning: Studies in the theory of speech acts*. Cambridge University.
Sotillo, M., Carretie, L., Hinojosa, J. A., Tapia, M., Mercado, F., Lopez-Martin, S., et al. (2005). Neural activity associated with metaphor comprehension: spatial analysis. *Neuroscience Letters, 373*(1), 5–9.
Tartter, V. C., Gomes, H., Dubrovsky, B., Molholm, S., & Stewart, R. V. (2002). Novel metaphors appear anomalous at least momentarily: evidence from N400. *Brain and Language, 80*(3), 488–509.
Teuscher, U., McQuire, M., Collins, J., & Coulson, S. (2008). Congruity effects in time and space: behavioral and ERP measures. *Cognitive Science, 32*(3), 563–578.
Van Lancker, D. R., & Kempler, D. (1987). Comprehension of familiar phrases by left- but not by right-hemisphere damaged patients. *Brain and Language, 32*(2), 265–277.
Van Petten, C. (1993). A comparison of lexical and sentence-level context effects in event-related potentials. *Language and Cognitive Processes, 8*(4), 485–531.
Van Petten, C., Kutas, M., Kluender, R., Mitchiner, M., & Mcisaac, H. (1991). Fractionating the word repetition effect with event-related potentials. *Journal of Cognitive Neuroscience, 3*(2), 131–150.

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