Hemispheric asymmetry in interpreting novel literal language: An event-related potential study

Tristan Davenport\textsuperscript{a,b,*}, Seana Coulson\textsuperscript{a,b}

\textsuperscript{a} Cognitive Science Department, University of California San Diego, San Diego, CA, USA
\textsuperscript{b} Center for Research in Language, University of California San Diego, San Diego, CA, USA

\textbf{Abstract}

Conceptual mapping, or making connections between conceptual structure in different domains, is a key mechanism of creative language use whose neural underpinnings are not well understood. The present study involved the combination of event-related potentials (ERPs) with the divided visual field presentation technique to explore the relative contributions of the left and right hemispheres (LH and RH) to the construction of novel meanings in fully literal language. Electroencephalogram (EEG) was recorded as healthy adults read sentences that supported either a conventional literal reading of the sentence final word ("His main method of transportation is a boat."), or a novel literal meaning derived from conceptual mapping ("The clever boys used a cardboard box as a boat."). The novel and conventional conditions were matched for cloze probability (a measure of predictability based on the sentence context), lexical association between the sentence frame and the final word (using latent semantic analysis), and other factors known to influence ERPs to language stimuli. To compare effects of novelty to previously reported effects of predictability, a high-cloze conventional condition ("The only way to get around Venice is to navigate the canals in a boat.") was included. ERPs were time-locked to sentence final words ("boat") presented in either the left visual field, to preferentially stimulate the RH (lvf/RH), or in the right visual field, targeting the LH (rvf/LH). The N400 component of the ERP was affected by predictability in both presentation sides, but by novelty only in rvf/LH. Two distinct late frontal positive effects were observed. Word predictability modulated a frontal positivity with a LH focus, but semantic novelty modulated a frontal positivity focused in RH. This is the first demonstration that the frontal positivity may be composed of multiple overlapping components with distinct functional and anatomical characteristics. Extending contemporary accounts of the frontal positivity, we suggest that both frontal positivities reflect learning mechanisms involving prediction based on statistical regularities in language (LH) and world knowledge (RH).

Published by Elsevier Ltd.

\section{Introduction}

Mapping, or making connections between conceptual domains, has been identified as a key mechanism of creativity in language (Fauconnier, 1997; Fauconnier & Turner, 2002; Lakoff & Johnson, 1980; Pinker, 2007). Metaphor, for instance, relies on mappings such as that between love and travel in the sentence, "This relationship isn't going anywhere," in which the word relationship is used as though it refers to a vehicle as well as a real relationship. Since the mid-1990s, the neural basis of creative language has become a topic of increasing interest in cognitive neuroscience (for recent reviews, see Giora, 2007; Coulson & Davenport, 2011). Although early neurological work implicated the right hemisphere (RH) in metaphor processing (Winner & Gardner, 1977), a number of subsequent studies have shown that in terms of both processing difficulty and neural activation sources, a conventional metaphorical expression is processed more easily and with less reliance on RH neural substrates than a novel metaphor (e.g., Ahrens et al., 2007; Faust & Mashal, 2007). This implies that the neural resources recruited for processing depend on whether the expression is novel or conventional, rather than whether it is literal or metaphorical (Giora, 1997).

It is worth noting that the experimental results that led to this theoretical focus on the novel/conventional distinction came entirely from comparisons of novel and conventional metaphors. However, speakers are also able to use novel conceptual mappings in purely literal language (Coulson & Matlock, 2001). In a sentence such as, "The clever boys used a cardboard box as a boat," the word boat must be understood as bearing some of the semantic features of a
cardboard box as well as some semantic features of a boat. Deciding which features of each input domain to activate is computationally difficult, yet such sentences are easily understood. Previous ERP experiments on novel mappings in literal language revealed a late frontal ERP effect distinct from that elicited by novel metaphors (Coulson & Van Petten, 2002), and distinct from that elicited by the manipulation of predictability (Davenport & Coulson, 2011).

However, no study has yet investigated whether novel and conventional literal expressions display hemispheric asymmetry similar to novel and conventional metaphorical language. Accordingly, the present study employs divided visual field presentation to assess differences in hemispheric sensitivity to novel and conventional literal language, using the same materials as Davenport and Coulson (2011). Continuity between literal and metaphorical meanings (Coulson & Van Petten, 2002; Giora, 1997) naturally predicts similar effects of novelty in literal language as in metaphorical language: a left hemisphere (LH) advantage for conventional language and a RH advantage for novel language (Giora, Zaidel, Soroker, Batori, & Kasher, 2000).

1.1. Hemispheric asymmetry in semantic processing

Neuropsychological investigations into the neural basis of creative language typically begin with the dichotomy between the two cerebral hemispheres. It is well established by now that both the left and right hemispheres (LH and RH) perform semantic processing during language comprehension (Chiarello & Beeman, 1998). However, lesion studies and divided visual field experiments have also shown that, at least in right-handed people, LH and RH contribute differently to language comprehension. In particular, LH lesions can impair the “core” language functions as in Broca's aphasia and Wernicke's aphasia, while RH lesions typically lead to impairments in applying social and discourse cues to language use (Brownell, Potter, Bihrl, & Gardner, 1986; Brownell, Carroll, Rehak, & Wingfield, 1992). RH lesion patients have been reported to have difficulties comprehending metaphor (Winner & Gardner, 1977), jokes (Brownell, Michel, Powelson, & Gardner, 1983), verbal irony (Kaplan, Brownell, Jacobs, & Gardner, 1990), indirect requests (Stemmer, Giroux, & Joannette, 1994), anaphor resolution (Brownell et al., 1992), and causal inference (Tompkins, Scharp, Fassbinder, Meigh, & Armstrong, 2008). These results have contributed to a neat, perhaps over-simplified, theoretical picture in which the LH handles the linguistic processes necessary for literal language comprehension, while the pragmatic processing relevant for figurative language resides in the RH.

However, neuroimaging, event-related potential (ERP) and behavioral studies on neurotypical individuals have complicated this neat division (see Coulson & Davenport, 2011 for a review). While an early neuroimaging study supported the prevailing hypothesis that metaphor is the province of the RH (Bottini et al.), later studies that better controlled for the difficulty of the literal and metaphorical stimuli have found more LH activation in the metaphor condition (Rapp, Leube, Erb, Grodd, & Kircher, 2004; 2007; Lee & Dapretto, 2006; Marshal, Faust, Hendler, & Jung-Beeman, 2009). Convergent evidence has come from studies of literal language comprehension that varied task difficulty. As the difficulty of the task increased, so did RH activation (St. George, Kutas, Martinez, & Sereno, 1999; Xu, Kemeny, Park, Frattali, & Braun, 2005), suggesting that difficulty, rather than figurativity per Xu et al., 2005; Mashal et al. 2009).

Researchers using ERP and reaction time methods have exploited the organization of the human visual system to target one hemisphere at a time with visual stimuli. In the divided visual field technique, a visual stimulus such as a printed word is flashed on a computer monitor far enough to the left or right of the fixation point that the word is outside of the participant's fovea. This visual information stimulates only the parts of the retina that are linked to the contra-lateral hemisphere of visual cortex. Consequently, stimuli presented in left visual field are initially processed in the right hemisphere (rvf/RH), and vice-versa for the opposite visual field (lvf/LH). Although information about this stimulus is shared with the contra-lateral hemisphere beginning about 10–20 ms after presentation, the initial targeting of one hemisphere appears to bias processing of the stimulus in that hemisphere's favor (Banich, 2002).

Researchers have also found it fruitful to combine divided visual field presentation with the recording of ERPs (see e.g. Kutas & Federmeier, 2011). A multi-dimensional signal, ERPs allow the investigator to examine how the lateralized presentation affects the brain's real time response to language stimuli. For example, examination of visual potentials in the ERP (e.g. the P1 and N1 components) can provide the investigator with evidence that the VF manipulation effectively stimulated the desired hemisphere. Examination of later components such as the N400, a neural response to meaningful stimuli that is thought to index the difficulty of retrieving semantic information in a particular context (Kutas & Hillyard, 1980, 1984; Kutas & Federmeier, 2011), and late positivities – referred to alternately as the P600 (see e.g., Kuperberg, Sinitnikova, Caplan, & Holcomb, 2003), late positive complex (LPC; see e.g., Wlotko, Federmeier, & Kutas, 2012), or post-N400-positivities (PNP; see e.g. Van Petten & Luka, 2012) – can reveal how increasing the contribution of either the left or the right hemisphere affects the brain's real time response to the linguistic manipulation of interest.

Combination of the DVF techniques with ERPs is particularly valuable for examining the RH contribution to language ERP effects observed under normal processing conditions (Federmeier, Wlotko, & Meyer). For example, Coulson and Williams (2005) found that with rvf/LH presentation, the N400 was larger for the critical word in a joke than a non-joke control (“My mechanic couldn’t fix my brakes, so instead he fixed my HORN/TIRES”); with lvf/RH presentation, the N400 was similar sized for jokes and non-jokes, as if joke-relevant information was more active in the RH. Accordingly, joke relevant probes (“INFIDELITY”) elicited larger N400 priming effects following jokes than non-joke controls (“A replacement player hit a home run with my GIRL/BALL”) with lvf/RH than rvf/LH presentation, suggesting an important RH contribution to the semantic processing of jokes (Coulson & Wu, 2005).

To date, divided visual field experiments have provided mixed evidence for the hypothesis that metaphorical language has a RH basis. An early study using two word phrases such as “stinging bee” and “stinging insult” suggested that metaphorical meanings were initially activated in both hemispheres but decayed more rapidly in LH (Anaki, Faust, & Kavets, 1998). However, attempts to replicate those results failed (Kacinik, 2003). Moreover, studies using sentential primes have shown metaphorical priming in both presentation sides (Kacinik & Chiarello, 2007) and larger metaphor priming effects in rvf/LH (Faust & Weisger, 2000). Coulson and Van Petten (2007) conducted a divided visual field study comparing the processing of sentence final words used either literally or metaphorically. Examining ERPs recorded to the lateralized critical words, they found that critical words in metaphorical sentences elicited larger amplitude N400 than those in cloze-matched literal sentences. However, the size of the N400 effect was similar with rvf/LH and lvf/RH presentation, arguing against a RH advantage for metaphorical language processing.

1.2. Theories of hemispheric asymmetry

To explain hemispheric asymmetries in processing different kinds of creative and figurative language, a number of hypotheses...
have arisen positing different ways of storing and/or activating semantic representations in the two hemispheres. Two prominent accounts are discussed below.

1.2.1. The graded salience hypothesis

The graded salience hypothesis (Giora, 1997) posits two distinct mechanisms of semantic processing. One is a fast, automatic mechanism that retrieves salient meanings—i.e., frequent, conventional, contextually appropriate, or emotionally resonant meanings. The other is a slow, deliberate mechanism that constructs non-salient meanings—i.e., infrequent, unfamiliar, or contextually inappropriate meanings with few emotional associations. The graded salience hypothesis further stipulates that the fast retrieval mechanism is primarily in LH, and the slow meaning construction mechanism is primarily in RH. The hemispheric asymmetry aspect of graded salience arose from neuropsychological findings that RH lesion patients have difficulty with novel language such as sarcasm, but not with conventional metaphors or proverbs, which are highly salient due to their frequency and familiarity (Giora et al., 2000).

Arguing in favor of the graded salience hypothesis, Faust and colleagues have conducted a series of divided visual field priming experiments that compare novel metaphors with conventional ones. In these experiments, participants were asked to make sensicality judgments of 2-word Hebrew phrases of four types: literal (problem solution), conventional metaphor (transparent intention), novel metaphors drawn from published poetry (consciousness storm), and unrelated (wisdom wash). The first word was presented centrally as the prime and the second in lvf/RH or rvf/LH. Faust and Mashal (2007) reported faster reaction times to novel metaphors in lvf/RH at SOAs of both 400 and 1100 ms, but similar reaction times in both presentation sides for other stimulus types. The graded salience hypothesis further predicted that the RH homologues (Pobric, Mashal, Faust, & Lavidor, 2008) supported Faust and Mashal’s (2007) initial conclusion that LH supports literal and conventional metaphorical language processing, while RH supports novel metaphor processing.

1.2.2. The coarse coding hypothesis

Faust and colleagues’ findings have also supported another view of hemispheric asymmetry in semantic processing: Jung-Beeman’s coarse coding hypothesis (for a review, see Jung-Beeman, 2005). The coarse coding hypothesis emerged from experiments using the summation priming technique, in which three words (e.g., foot, glass, and cry) together primed a weakly related target (cut) in lvf/RH but not in rvf/LH (Beeman et al., 1994; but also see Kandhadai & Federmeier, 2008). Beeman and colleagues argued that this result reflected a hemispheric asymmetry in the way semantic knowledge is stored. In LH, semantic knowledge is stored in such a way that when a concept is activated, that activation quickly spreads to its strongest associates. In RH, however, activation spreads more slowly, and includes both weakly and strongly related concepts, allowing RH to fill in tenuous semantic connections such as those required to comprehend novel metaphors.

The hemispheric asymmetry posited by the coarse coding hypothesis applies to three distinct but interacting stages of language processing. In the activation stage, localized to Wernicke’s area and its RH homologue, semantic representations are activated in response to incoming words; because semantic associative relationships are coded more coarsely in RH, more distant associates are activated in that hemisphere. In the integration stage, supported by more anterior regions of temporal cortex in both hemispheres, “the degree of overlap among multiple semantic fields” is computed, supporting message-level interpretation. Importantly, this process is also driven by input and does not seem to involve any rule-based combinatorial processing, nor does it constitute in itself the formation of a message-level interpretation of the input. In the selection stage, localized to Broca’s area and its RH homologue, the activated concepts compete with each other through mutual activation and inhibition, eventually selecting the most strongly activated concepts for action or consciousness (Jung-Beeman, 2005).

1.3. The present study

The graded salience hypothesis and the coarse coding hypothesis have both been influential in guiding investigations of hemispheric asymmetry in semantic processing. Experiments testing these hypotheses have most often compared novel metaphors to conventional ones (Faust & Mashal, 2007; Mashal & Faust, 2008; Pobric et al., 2008), or compared language requiring causal inferences to language comprehensible without those inferences (Beeman, Bowden, & Gernsbacker, 2000; Virtue, Haberman, Clancy, Parrish, & Jung-Beeman, 2006a; Virtue, Van den Broek, & Linderholm, 2006b). Both hypotheses abstract across the literal/figurative divide and treat novelty/conventionality as a more important distinction, in terms of allocating neural resources to processing. Both hypotheses predict that any hemispheric asymmetry observed in comparing novel and conventional language should not depend on whether the stimuli are literal or figurative. In both cases, a RH advantage is expected for novel language and a LH advantage for conventional language. However, novel and conventional literal language have never been compared experimentally using a paradigm that could illuminate hemispheric differences.

Previous comparisons of novel and conventional literal language have suggested that, at least for the first 500 ms, the two are processed in a qualitatively similar way to each other as well as to novel metaphors. Coulson and Van Petten (2002) compared ERPs elicited by the final words of conventional literal sentences (The conductor had no idea the train had been boarded by a villain), novel literal sentences (In the best part of the movie, the hero has to impersonate the villain), and novel metaphorical sentences (Many people in the agency now believe the hero has to impersonate the villain). In addition to having the same critical words, the stimuli were matched for cloze probability – the likelihood of the final word appearing in that context – a variable known to strongly affect the amplitude of the N400 elicited by words in sentential contexts (Kutas & Hillyard, 1984). Despite being cloze-matched, the three sentence categories elicited differently-sized N400s: literal conventional sentences elicited the smallest N400, novel metaphors elicited the largest N400, and novel literal sentences elicited an intermediate N400. Compared to the conventional literal condition, both types of novel sentences elicited larger late positivities. Notably, the scalp topography of these positivities differed between the novel conditions, with an anterior focus for the novel literal effect and a posterior focus for the novel metaphorical effect. This difference suggested that even if these positivities indexed similar processes, such as the construction or revision of novel conceptual mappings, they reflected the activity of at least partially different neural substrates.

A follow-up study by Davenport and Coulson (2011) compared the relatively low-cloze novel literal (LN) materials and the equally low-cloze conventional literal (LC) ones to high-cloze conventional literal (HC) materials, and found that the late frontal effect of novelty was an augmentation of the late frontal positivity frequency elicited by unpredictable words in constraining sentence contexts (Federmeier, Wlotko, De Ochoa-Dewald, & Kutas, 2007). Davenport and Coulson argued that just as the late frontal
positivity reflects the revision of pre-activated lexical-semantic information (Federmeier et al., 2007), the added effect of novelty on this positivity reflects the revision of higher-order semantic expectations that were violated by the novel conceptual mappings found in the LN condition. If this is indeed the case, the relative contribution of the two hemispheres should be similar for processing literal language varying in the predictability of lexical-semantic information as for literal language varying in the predictability of higher-order semantic expectations.

Accordingly, the present study combines the divided visual field technique with the same stimuli used by Davenport and Coulson (2011), in order to examine hemispheric asymmetries in the effects of predictability and novelty on the real-time processing of literal language. Divided visual field presentation will allow us to observe how increasing the contribution of the left versus the right hemisphere impacts ERP effects of predictability and novelty reported by Davenport and Coulson (2011). If the neural substrate of predictability and novelty ERP effects is similar, we might expect divided visual field presentation to similarly impact both effects. Moreover, data from the present study will also enable us to compare hemispheric asymmetries in the processing of conventional and novel literal language to those for metaphoric language (e.g. Coulson & Van Petten, 2007).

As discussed earlier, the graded salience (Giora et al., 2000) and coarse coding (Jung-Beeman, 2005) hypotheses agree that the RH has an advantage over the LH in processing novel language. However, the two theories differ in that the graded salience hypothesis assigns this RH advantage to qualitatively different mechanisms located in the two hemispheres, while the coarse coding hypothesis posits similar mechanisms in each hemisphere that differ in both their rate and the extent of activation spread. Because the graded salience hypothesis posits a fast, memory-based mechanism in LH and a slower, constructive mechanism in RH, it suggests the effect of novelty will make itself known on the N400 component in rvf/LH, reflecting fast-acting processes for activating information in semantic memory (Kutas & Federmeier, 2011). Our manipulation of novelty might be expected to increase the amplitude of the N400 elicited by final words in the LN condition because, relative to the LC condition, they have less salient conceptual relationships to their contexts. By contrast, with lvf/RH presentation, the graded salience hypothesis suggests the effect of novelty might emerge on a late positivity, reflecting more controlled processes of meaning construction.

By contrast, the coarse coding hypothesis proposes that the two hemispheres share the same basic activation, selection and integrative mechanisms, but differ in the range of semantic associates accessible based on a given input. This range is larger in the RH, resulting in activation of more distant semantic associates but slower speeds for activation and selection of related concepts. Because the coarse coding hypothesis posits qualitatively similar processes in each hemisphere, it suggests the effect of novelty will appear on the same ERP component(s) in each presentation side, but predicts differences in either the onset or the duration of those effects. The coarse coding hypothesis predicts a smaller N400 novelty effect with lvf/RH than rvf/LH presentation, and that the duration of this effect should be longer in the lvf/RH. Similarly, the slower RH rise time might be manifested in later onset of the late positivity with lvf/RH presentation.

2. Methods

2.1. Participants

24 UC San Diego undergraduates (16 women) participated in exchange for course credit. Five additional subjects participated, but were excluded from analysis due to excessive artifacts (i.e., > 30% in a critical bin). All subjects were right-handed, with a mean score of + 935 on the Edinburgh Handedness Inventory, and none had left-handed family members. None had a history of head injuries or psychiatric problems. All subjects had normal or corrected-to-normal vision. The mean age of the subjects was 20 years, ranging from 18 to 27.

2.2. Materials

Materials consisted of 240 triplets of sentences, with each member of a triplet ending in the same target word and each belonging to a different one of the three experimental conditions: High-predictability conventional (HC), low-predictability conventional (LC) and low-predictability novel (LN). Each sentence was associated with a true/false question intended to test comprehension and encourage semantic processing of the stimuli. For sample stimuli and comprehension questions, see Table 1.

Experimental sentences were normed for cloze probability by presenting them – missing the final word – to 128 UCSD undergraduates who were instructed to supply a one-word completion. No participants in this norming study took part in the ERP experiment. Mean cloze probabilities were .67 for the HC condition (SD = .26), .59 for the LC condition (SD = .16), and .58 for the LN condition (SD = .13). Sentences including the final word were also normed for concreteness in a separate study: 115 participants were given complete sentence stimuli and asked to rate them for concreteness on a scale of 1–5, with 1 being the most concrete and 5 the most abstract. Concreteness ratings for target words alone were obtained in the same way in yet another norming study (mean = 2.1, SD = 1.3). Because the same final words were used in each condition, word concreteness and other statistics of the final words were identical across conditions. None of the norming studies shared participants, nor did any norming participants take part in the ERP experiments. All norming statistics are summarized in Table 2.

The 240 sentence triplets were split among 6 lists of 240 total sentences each, in a 2 (presentation sides) × 3 (sentence types) Latin square design. Each stimulus list therefore contained 40 unique stimuli in each of the following six conditions: HC-rvf/LH, HC-lvf/RH, LC-rvf/LH, LC-lvf/RH, LN-rvf/LH, LN-lvf/RH. Because the same set of sentence-final words was used in each list, each of the 6 conditions had the same average value for all word-level properties — mean length of final word (M = 6.4, SD = 2.0), mean number of orthographic neighbors of final word (M = 4.2, SD = 2.8), mean overall frequency of final word, per million words (M = 86.1, SD = 8.1), and word concreteness (M = 2.1, SD = 1.3).

2.3. Procedure

All stimuli were presented in white letters on a black background, while subjects sat 40 in. away from the monitor. At all times, a small orange fixation dot was present in the center of the monitor. The beginning of each trial was signaled by a fixation cross in the center of the monitor. Thereafter, a stimulus sentence was presented one word at a time. Each word was presented centrally for 200 ms, with a 300-ms inter-stimulus interval. Each word was presented centrally, except for the sentence-final word, which appeared with its inner edge 2 to the left or right of the center of the monitor, the same degree of lateralization used by Coulson and Van Petten (2007).

One second after the disappearance of the final word, the word READ? was presented in green letters. The participant was instructed to indicate with a button press whether they had successfully read the entire stimulus sentence. After another 1000-ms delay, the comprehension question was presented for 6 s, during which time the subject answered with a button press. To minimize movement artifacts, subjects were instructed to refrain from blinking or eye movements at all times except during the presentation of the comprehension questions, see Table 1.

Table 1 Sample materials and comprehension questions.

<table>
<thead>
<tr>
<th>High-cloze literal</th>
</tr>
</thead>
<tbody>
<tr>
<td>A giant, ornate church like Westminster Abbey is called a cathedral.</td>
</tr>
<tr>
<td>T/F: Cathedrals are places of worship.</td>
</tr>
<tr>
<td>Crops come from a farm, but manufactured goods like cars come from a factory.</td>
</tr>
<tr>
<td>T/F: Crops and machines come from the same place.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Low-cloze literal</th>
</tr>
</thead>
<tbody>
<tr>
<td>It scared him to be alone in the cathedral.</td>
</tr>
<tr>
<td>T/F: He would rather have companions in the cathedral.</td>
</tr>
<tr>
<td>Experts say the main source of taxes in this town is the factory.</td>
</tr>
<tr>
<td>T/F: The factory operates tax-free.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Low-cloze literal mapping</th>
</tr>
</thead>
<tbody>
<tr>
<td>At one time, this movie house was a cathedral.</td>
</tr>
<tr>
<td>T/F: The cinema used to be a cafeteria.</td>
</tr>
<tr>
<td>He had apparently seen the artist’s studio but thought it was a factory.</td>
</tr>
<tr>
<td>T/F: The studio looked very industrial from the outside.</td>
</tr>
</tbody>
</table>
question. After 1000 ms from the comprehension question disappeared, a fixation cross appeared, signaling the start of the next trial. Stimuli were presented in 12 blocks of 20 sentences each, with a short break allowed between each block. At the beginning of the experiment, a practice block was presented to the participant in order to familiarize him or her with the procedure. Total time in the recording booth was 60–70 minutes.

2.4. Electrophysiology

EEG was recorded with 29 tin electrodes in a mesh cap, organized in the International 10–20 configuration. Recordings were taken from eight lateral sites: T5/6, TP 7/8, FT 7/8, FT 7/8; 10 medial sites: P3/4, CP3/4, C3/4, FC 3/4, and F3/4; 5 midline sites: Pz, CPz, Cz, FCz, and Fz; 3 prefrontal sites: FP1/2 and FPz; and 3 occipital sites: O1/2 and Oz. Three additional electrodes were placed at the outer canthi of the eyes and below the left eye, to record eye movements and blinks. At all sites, electrical impedance was reduced below 5 kΩ with gentle abrasion. All EEG recorded was referenced during data collection to a single electrode on the left mastoid. After artifact rejection, the EEG data were re-referenced to an average of the left and right mastoid electrodes. The EEG was amplified using a 5A instrumentation bioelectric amplifier, digitized online at 250 Hz. ERPs were time-locked to the last word of each stimulus sentence. ERPs were examined for artifacts due to movement and channel blockage: overall, 16% of trials were rejected for containing artifacts (M = 13.1%, M = 17.3%, M = 17.3%), there was no effect of sentence type, indicating that rejection rates were similar across sentence type ([F(2,23)] = 0.3, p = 0.73). Subsequent to artifact rejection, ERPs were averaged within conditions.

2.5. Analysis

Only stimuli which participants indicated they were able to read were included in analysis. ERP amplitudes were compared to a 100-ms pre-stimulus baseline. To compensate for the violation of the sphericity assumption, the Greenhouse-Geisser correction (Greenhouse & Geisser, 1959) was applied where appropriate. The original degrees of freedom have been maintained for the sake of clarity. However, all p-values cited are the corrected ones. Finally, in all of the analyses presented below, the Presentation Side factor indexed whether the critical word was presented in the lvf or the rvf, whereas the Hemisphere factor indexes the location of electrodes on the scalp.

2.5.1. Effects of presentation side

Presentation side analyses were intended to assess whether our divided visual field paradigm adequately shifted the balance of processing to the targeted hemisphere. Accordingly, brain responses to all sentence-final words presented to the rvf/LH were averaged together, and compared to those presented to the lvf/RH with repeated measures ANOVAs. In keeping with prior work combining divided visual field presentation with ERP recordings (e.g., Coulson, Federman, Van Petten, & Kutas, 2005), presentation side analyses targeted early visual potentials P1 and N1, as well as the selection negativity (SN) that indexes attentional selection of task-relevant stimuli for further processing (see Hillyard & Arillo-Venuto, 1998 for a review). Measurements were made at lateral posterior electrode sites T5/T6 and T7/T8, chosen first, because early visual potentials (P1 and N1) are often the largest there, and, second, because their lateral location affords easy measurement of the SN. The early visual potentials P1 and N1 were analyzed both for peak latency and for mean amplitude in the 75–125 ms (P1) and 100–200 ms (N1) time windows. Analysis of the SN involved only mean amplitude measurements of ERPs 300–1200 ms because, unlike the visual potentials, this component has no clear peak. Repeated measures ANOVAs involved factors Presentation Side (lvf/rvf), Hemisphere (left, right), and Electrode Site (Temporal, Temporal-Parietal).

Table 2

<table>
<thead>
<tr>
<th>Property</th>
<th>High-predictability conventional (HC)</th>
<th>Low-predictability conventional (LC)</th>
<th>Low-predictability novel (LN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word-level</td>
<td>Concreteness</td>
<td>Frequency per million</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.4 (2.0)</td>
<td>6.4 (2.0)</td>
<td>6.4 (2.0)</td>
</tr>
<tr>
<td></td>
<td>2.1 (1.3)</td>
<td>2.1 (1.3)</td>
<td>2.1 (1.3)</td>
</tr>
<tr>
<td></td>
<td>4.2 (2.8)</td>
<td>4.2 (2.8)</td>
<td>4.2 (2.8)</td>
</tr>
<tr>
<td></td>
<td>86.1 (8.1)</td>
<td>86.1 (8.1)</td>
<td>86.1 (8.1)</td>
</tr>
<tr>
<td>Sentence-level</td>
<td>Latent semantic analysis (Semantic similarity between sentence frame and critical word) 0=orthogonal;1=identical</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>.33 (.15)</td>
<td>.23 (.12)</td>
<td>.23 (.11)</td>
</tr>
<tr>
<td></td>
<td>Concreteness</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.11 (0.31)</td>
<td>2.28 (0.3)</td>
<td>2.43 (0.33)</td>
</tr>
<tr>
<td></td>
<td>Cloze probability</td>
<td>0.67 (0.26)</td>
<td>0.09 (0.16)</td>
</tr>
</tbody>
</table>

2.5.2. Effects of sentence type (HC vs. LC vs. LN)

To assess the impact of our linguistic manipulation we measured three ERP components known to be sensitive to various effects of language processing: the P2, the N400, and the late positivity. As in our previous work with these language materials (Davenport & Coulson, 2011), initial analysis involved mean amplitude measurements of ERPs elicited between 200–300 ms (P2), 300–500 ms (N400), and 600–1200 ms (late positivity). Repeated measures ANOVA included factors Sentence Type (3 levels), Presentation Side (lvf/RH, rvf/LH), and Electrode Site (29 levels).

2.5.3. Effects of predictability (HC vs. LC)

Analysis of predictability effects included planned comparisons of N400 and late positivity elicited by HC and LC in each presentation side. Intended to help characterize the topography of predictability effects, measurements were focused on medial electrode sites Fp1, F3, Fc3, C3, P3, O1, and their RH counterparts Fp2, F4, Fc4, C4, P4, and O2. Repeated measures ANOVAs included the linguistic factor Predictability (HC/LC), and the two scalp site factors Hemisphere (left/right) and Anteriority (seven levels).

2.5.4. Effects of novelty (LC Vs. LN)

Effects of novelty were assessed by conducting mean amplitude measurements of the N400 and late positivities elicited by LC and LN materials. Repeated measures ANOVAs were confined to the medial electrode sites and included factors Novelty (LC/LN), Presentation Side (lvf/rvf), Hemisphere (left/right) and Anteriority (7 levels). Pre-planned comparisons included separate analyses of data from each presentation side.

3. Results

3.1. Comprehension

Following each experimental trial were two checks for comprehension. First, subjects were cued by the word READ? to indicate by button-press whether they had read the preceding stimulus sentence. Subjects reported being able to read fewer words in lvf (76%) than in rvf (88%). An analysis of variance (ANOVA) with sentence type and presentation side as factors revealed a significant tendency to answer “yes” to fewer words presented in the lvf than in the rvf ([F(1,23)] = 30.6, p < 0.0001). The ANOVA also revealed a significant effect of sentence type, reflecting the greater difficulty the subjects had with the low-cloze conditions in both VF’s (rvf/LH: M = 91%, LN = 89%, M = 85%; lvf/RH: M = 85%, LN = 73%, M = 70%), ([F(2,46)] = 8.3, p < 0.001). Separate one-way ANOVAs for each presentation side showed a marginal readability difference between the conditions in rvf/LH ([F(2,22)] = 2.5, p = 0.09) and a significant readability difference in lvf/RH ([F(2,22)] = 6.2, p < 0.01). Both of these differences reflected lower readability scores for the low-predictability conditions.

Participants were also presented with a true/false comprehension question after each trial. Overall, 88% of questions to lvf/LH stimuli were answered correctly, as were 82% of questions to lvf/RH stimuli. An initial ANOVA with presentation side and sentence type as factors indicated that accuracy was higher in lvf/LH than lvf/RH: [F(1,22)] = 13.1%, M = 17.7%, M = 17.3% (marginal readability difference between the conditions in rvf/LH). An analysis of variance (ANOVA) with presentation side and sentence type as factors indicated that accuracy was higher in rvf/LH than lvf/RH: [F(1,22)] = 13.1%, M = 17.7%, M = 17.3% (marginal readability difference between the conditions in rvf/LH).
There was also a main effect of sentence type, reflecting the overall lower accuracy rates for questions to low-cloze stimuli in both VF’s (rvf/LH: $M_{HC} = 88\%$, $M_{LC} = 89\%$, $M_{LN} = 87\%$; lvf/RH: $M_{HC} = 88\%$, $M_{LC} = 79\%$, $M_{LN} = 80\%$) ($F[2,46] = 8.7, p < 0.001$). The interaction between sentence type and presentation side was not significant ($F[2,46] < 1$).

3.2. Event-related potentials

Grand average ERPs are shown in Figs. 1–4. Fig. 1 highlights the impact of the presentation side manipulation on the early visual components, including the P1 (75–125 ms) and N1 (100–200) at posterior sites, as well as the SN (300–1200 ms) that follows. Fig. 1 clearly shows that the N1 and the SN were larger over the hemisphere contra-lateral to presentation side. Fig. 2 shows ERPs to all three conditions in each presentation side. The N400 (300–500 ms) is visible in the comparison of the high predictability conventional condition and the two low predictability conditions. N400 effects were broadly distributed in each presentation side, though largest at central and posterior sites (see Fig. 2). Low predictability conventional (LC) materials elicited larger N400 than novel (LN) with rvf/LH, but not lvf/RH presentation (see Figs. 2 and 3). Late positivity (600–1200 ms) effects are also visible in each presentation side. Fig. 2 shows that relative to the high predictability condition, the low-predictability conditions elicited late positivities over anterior sites and relative negativities over central and posterior sites, although these latter effects may be continuations of the N400. Comparison of the two low predictability conditions in Fig. 3 shows that the novel (LN) materials elicited a larger frontal positivity than conventional materials (LC) with presentation to lvf/RH, but not the rvf/LH. Fig. 4 shows a comparison of the two conventional conditions; low-cloze conventional (LC) materials elicited a focused but prominent frontal positivity compared to high-cloze conventional (HC) materials in rvf/LH only.

3.2.1. Effects of presentation side (rvf/LH Vs. lvf/RH)

In order to assess whether the presentation side manipulated effectively shifted the balance of processing to the targeted...
hemisphere, we examined the P1 component (75–125 ms), the N1 component (100–200 ms), and the selection negativity (300–1200 ms) as outlined in Section 2.5.1. As detailed below, the P1 component peaked earlier over contra-lateral than ipsi-lateral sites, suggesting the stimuli reached visual cortex in the targeted hemisphere 11–15 ms earlier than the non-targeted hemisphere. The mean amplitude of the N1 component was significantly larger over contra-lateral than ipsi-lateral sites, indicating the stimulus received enhanced visual processing in the targeted hemisphere. Presentation side effects are shown in Fig. 1.

3.2.1.1. P1 (75–125 ms). Analysis of P1 amplitudes revealed only a non-significant trend for larger P1s over RH sites, regardless of presentation side (hemisphere F[1,23] = 3.7, p = 0.07). No other effects were found (presentation side F[1,23] < 1; presentation side x hemisphere F[1,23] < 1).

Analysis of P1 peak latency found no main effect of presentation side (F[1,23] < 1), or of hemisphere (F[1,23] < 1), but, rather, a robust presentation side x hemisphere interaction, reflecting earlier P1 peaks elicited by contra-lateral presentation (LH: 92 ms, RH: 95 ms), compared to those elicited by ipsi-lateral presentation (LH: 107 ms, RH: 106 ms) (F[1,23] = 32.8, p < 0.0001).

3.2.1.2. N1 (100–200 ms). As in the analysis of the P1, the mean amplitude and peak latency of the N1 component was subjected to repeated measures ANOVA. The mean amplitude analysis revealed a robust hemisphere X presentation side interaction, reflecting N1s an average of 1.5 μV larger after contra-lateral word presentation, compared to ipsi-lateral presentation (F[1,23] = 43.8, p < 0.0001). The main effect of presentation side was not significant (F[1,23] < 1); nor was hemisphere (F[1,23] = 3.7, p = 0.07), though there was a trend for more negative values over LH electrodes.

A similar analysis of N1 peak latency revealed only a non-significant trend for the presentation side by hemisphere interaction (F[1,23] = 3.9, p = 0.06), reflecting slightly earlier peak latencies over contra-lateral (156 ms) than ipsi-lateral (161 ms) electrode sites.

3.2.1.3. Selection negativity (300–1200 ms). The SN is an extended negativity observed in divided visual field presentation, which is generally more negative over lateral temporal sites in the targeted hemisphere (Coulson et al., 2005). Unlike the visual potentials, there is no clear peak to this component. Consequently, analysis involved only mean amplitude measurements. The SN was more negative over contra-lateral than ipsi-lateral sites, as reflected by the presentation side x hemisphere interaction (F[1,23] = 54.5, p < 0.0001). There were no main effects of presentation side (F[1,23] = 2.3, p = 0.15) or hemisphere (F[1,23] = 3.0, p = 0.1).

3.2.2. Overall Effects of sentence type (HC Vs. LC Vs. LN)

Fig. 2 shows ERPs to all three sentence types, with the left side of the figure showing ERPs to words presented to the rvf/LH, and...
the right side of the figure words presented to the lvf/RH. In order to assess the effects of our linguistic manipulations, we analyzed ERP components that are often modulated by differences in linguistic content, namely the P2, the N400, and the late positivity as outlined in section 2.5.2. Results of these analyses are shown in Table 3. Presentation side modulated sentence type effects observed on the N400 and the late positivity.

3.2.2.1. P2 (200–300 ms). Larger P2 amplitudes have been argued to reflect enhanced visual processing resulting from predictions about upcoming visual word forms (Federmeier and Wotanko, 2007). Analysis of P2 components was intended to assess the related claim that this top-down predictive processing occurs only in the LH. Consistent with the claim that sentence context supports the prediction of visual word forms, the HC condition elicited larger P2 components than the low predictability conditions LC and LN (see Fig. 2 and Table 3). However, the P2 effect did not vary as a function of presentation side, suggesting both hemispheres can benefit from predictions about upcoming visual word forms.

3.2.2.2. N400 (300–500 ms). The N400 is interpreted as reflecting neural activity related to retrieval of information from semantic memory, with amplitude reductions indicating less effortful processing. N400 amplitude was analyzed to reveal how presentation side manipulation affected the fast-acting semantic activation processes engaged by words in the three sentence types. As can be seen in Fig. 2, the less predictable conditions (LC and LN) elicited larger N400s than the HC condition in both presentation sides. Besides the significant main effect of sentence type, analysis also revealed an interaction between sentence type and presentation side, pointing to different N400 patterns in each presentation side (see Table 3). These differences are explored in more detail in our analysis of predictability and novelty effects.

3.2.2.3. Late positivity (600–1200 ms). Finally, analyses of the late positivity revealed that both low-predictability conditions elicited more positive ERPs than the HC condition over anterior sites, and more negative ERPs over central and posterior electrodes (see Fig. 2). Analysis also revealed a significant interaction between presentation side, sentence type and electrode site, suggesting localized voltage differences between conditions as a function of presentation side (see Table 3). These differences are explored in more detail in our analysis of predictability and novelty effects.

3.2.2.4. Summary of sentence type effects. Analyses encompassing both presentation sides and all 3 sentence types revealed different patterns of N400 and late positivity effects in each presentation side. The details of these voltage differences are addressed below in terms of effects of predictability and novelty.

3.2.3. Predictability Effects

Within each presentation side, pre-planned comparisons were made between HC and LC, as outlined in Section 2.5.3. As detailed below, presentation side affected the topography of N400 predictability effects, but not their size. This outcome suggests both hemispheres were able to benefit from sentence context supporting the activation of conventional literal meanings.

Over posterior scalp, both presentation sides showed a larger late positivity for HC than LC. However, a larger frontal positivity for LC was observed only with rvf/LH presentation, suggesting greater LH involvement in the meaning integration and selection processes indexed by the frontal positivity.

3.2.3.1. Predictability effects on the N400 (300–500 ms). Within rvf/LH, LC elicited a larger N400 than HC that was most prominent over central and parietal sites, and this effect was bilaterally symmetric (see Table 4). Within lvf/RH, the HC vs. LC comparison manifested a similar pattern, although the effect was larger over LH sites (see Table 4).

3.2.3.2. Predictability effects on the late positivity (600–1200 ms). In rvf/LH, the LC condition was more positive than the HC condition over anterior sites, but more negative over posterior sites (see Fig. 4 and Table 4). The rvf/LH predictability effect was bilaterally symmetric. In lvf/RH, the LC condition elicited more positive ERPs than the HC condition over the most anterior sites (FPz and FP2), and more negative voltages than the HC condition over central and posterior electrodes, especially over LH scalp (see Fig. 4 and Table 4).

It is possible that the predictability × anteriority interactions observed in each presentation side are driven entirely by voltage differences over posterior electrodes, and that there is no significant, predictability-related frontal positivity in either presentation side. In order to test this possibility, a post-hoc repeated measures ANOVA using the predictability and electrode factors was conducted on a cluster of six frontal electrodes (FPz/F2/F3/F4) in each presentation side. The main effect of predictability revealed that LC voltages were significantly more positive than HC voltages with presentation to the rvf/LH (F(1,23) = 5.4, p = 0.03) but not to lvf/RH (F(1,23) < 1).

3.2.3.3. Summary of predictability effects. Consistent with previous findings, the unexpected words of the LC condition elicited larger N400s in both presentation sides than the more expected words

### Table 3

<table>
<thead>
<tr>
<th>Time window</th>
<th>Relative amplitude</th>
<th>Factors</th>
<th>F-values</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2 (200–300 ms)</td>
<td>HC &gt; LC = LN</td>
<td>Sentence type</td>
<td>F(2,46) = 6.7</td>
<td>0.003**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sentence type × presentation side</td>
<td>F(2,46) &lt; 1</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sentence type × presentation side × electrode</td>
<td>F(56,1288) &lt; 1</td>
<td>n.s.</td>
</tr>
<tr>
<td>N400 (300–500 ms)</td>
<td>LC &gt; LN &gt; HC</td>
<td>Sentence type</td>
<td>F(2,46) = 21.4</td>
<td>&lt;.0001***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sentence type × presentation side</td>
<td>F(2,46) = 4.5</td>
<td>0.02**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sentence type × presentation side × electrode</td>
<td>F(56,1288) = 1.7</td>
<td>0.13</td>
</tr>
<tr>
<td>Late Positivity (600–1200 ms)</td>
<td></td>
<td>Sentence type</td>
<td>F(2,46) &lt; 1</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sentence type × presentation side</td>
<td>F(2,46) = 1.6</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sentence type × presentation side × electrode</td>
<td>F(56,1288) = 7.6</td>
<td>&lt;.0001***</td>
</tr>
</tbody>
</table>

All time windows were measured for mean amplitude over all 29 electrodes. All reported p-values reflect the Greenhouse-Geisser correction. Relative amplitude describes relative positivity for the P2, and relative negativity for the N400.
of the HC condition. In rvf/LH only, the LC condition elicited a larger frontal positivity than the HC condition.

3.2.4. Effects of novelty (LC vs. LN)

To compare the effect of semantic novelty, independent of predictability, ERPs to the two low predictability conditions (LC and LN) were compared as described in Section 2.5.4. Fig. 3 shows grand average ERPs to LC and LN materials presented to the rvf/LH and the lvf/RH. Larger N400 to LC than LN was evident with presentation to the rvf/LH, but not the lvf/RH. A larger anterior positivity for LN was evident with presentation to the lvf/RH, but not the lvf/LH.

3.2.4.1. Novelty effects on the N400 (300–500 ms). Planned comparisons (summarized in Table 5) examined the medial electrodes within presentation side for interactions between novelty, anteriority and hemisphere. In rvf/LH, the LC condition elicited larger N400s than the LN condition (see Table 5). This effect was broadly distributed and somewhat larger over LH sites than RH sites (see Table 5 for details and the lower part of Fig. 3). In lvf/RH, the N400s elicited by the LN and LC conditions did not significantly differ, although there was a non-significant trend for the LN condition to elicit larger N400 over RH posterior electrodes (see Table 5).

3.2.4.2. Novelty effects on the late positivity (600–1200 ms). The rvf/LH comparison revealed no main or interaction effect of novelty (see Table 5). In lvf/RH, however, the LN condition elicited more positive voltage than the LC condition over left anterior sites, as reflected in significant novelty × anteriority and novelty × anteriority × hemisphere interactions (see Table 5 for details and the lower part of Fig. 3 for a topographical plot).

3.2.4.3. Summary of novelty effects. Compelling evidence of hemispheric asymmetry was observed on the N400 and late positivity components. In sum, with rvf/LH presentation, novelty impacted the N400 and late positivity components. In sum, with rvf/LH presentation, novelty impacted the N400 component, as LC elicited larger N400 than LN; with lvf/RH presentation, novelty impacted the late frontal positivity, which was larger for the LN than LC materials.

### Table 4
Predictability effects: Planned comparisons of HC and LC conditions in each presentation side.

<table>
<thead>
<tr>
<th>Time window</th>
<th>Relative amplitude</th>
<th>Presentation side</th>
<th>Factors</th>
<th>F-values</th>
<th>p-Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>300–500 ms (N400)</td>
<td>LC &gt; HC</td>
<td>rvf/LH</td>
<td>Predictability</td>
<td>F[1,23] = 32.7</td>
<td>&lt; 0.0001**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pred. x Ant.</td>
<td>F[6,138] = 11.7</td>
<td>0.0001**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pred. x Hem.</td>
<td>F[1,23] = 2.0</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pred. x Hem. x Ant.</td>
<td>F[6,138] = 1</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>LC &gt; HC</td>
<td>lvf/RH</td>
<td>Predictability</td>
<td>F[1,23] = 13.6</td>
<td>0.001**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pred. x Ant.</td>
<td>F[6,138] = 9.4</td>
<td>0.0005***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pred. x Hem.</td>
<td>F[1,23] = 7.4</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pred. x Hem. x Ant.</td>
<td>F[6,138] = 1</td>
<td>n.s.</td>
</tr>
<tr>
<td>600–1200 ms (Late positivity)</td>
<td>LC &gt; HC (Frontally)</td>
<td>rvf/LH</td>
<td>Predictability</td>
<td>F[1,23] &lt; 1</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pred. x Ant.</td>
<td>F[6,138] = 6.6</td>
<td>0.003*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pred. x Hem.</td>
<td>F[1,23] &lt; 1</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pred. x Hem. x Ant.</td>
<td>F[6,138] = 1</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>LC &gt; HC (Frontally)</td>
<td>lvf/RH</td>
<td>Predictability</td>
<td>F[1,23] &lt; 1</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pred. x Ant.</td>
<td>F[6,138] = 5.2</td>
<td>0.009***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pred. x Hem.</td>
<td>F[1,23] = 5.1</td>
<td>0.03*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pred. x Hem. x Ant.</td>
<td>F[6,138] = 1.7</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

Relative amplitude describes relative negativity for the N400, and relative positivity for the late positivity.

### Table 5
Semantic novelty effects: Planned comparisons of the LC and LN conditions in each presentation side.

<table>
<thead>
<tr>
<th>Time window</th>
<th>Relative amplitude</th>
<th>Presentation side</th>
<th>Factors</th>
<th>F-values</th>
<th>p-Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>300–500 ms (N400)</td>
<td>LC &gt; LN</td>
<td>rvf/LH</td>
<td>Novelty</td>
<td>F[1,23] = 13.5</td>
<td>0.001**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nov. x Ant.</td>
<td>F[6,138] &lt; 1</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nov. x Hem.</td>
<td>F[1,23] = 5.1</td>
<td>0.03*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nov. x Hem. x Ant.</td>
<td>F[6,138] = 1.2</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>LC = LN</td>
<td>lvf/RH</td>
<td>Novelty</td>
<td>F[1,23] = 1.1</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nov. x Ant.</td>
<td>F[6,138] = 1.2</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nov. x Hem.</td>
<td>F[1,23] = 1.5</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nov. x Hem. x Ant.</td>
<td>F[6,138] = 2.3</td>
<td>0.08</td>
</tr>
<tr>
<td>600–1200 ms (LatePositivity)</td>
<td>LC = LN</td>
<td>rvf/LH</td>
<td>Novelty</td>
<td>F[1,23] = 1.0</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nov. x Ant.</td>
<td>F[6,138] &lt; 1</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nov. x Hem.</td>
<td>F[1,23] = 1.8</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nov. x Hem. x Ant.</td>
<td>F[6,138] = 1</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>LN &gt; LC Frontally</td>
<td>lvf/RH</td>
<td>Novelty</td>
<td>F[1,23] &lt; 1</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nov. x Ant.</td>
<td>F[6,138] = 4.4</td>
<td>0.007**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nov. x Hem.</td>
<td>F[1,23] = 1.9</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nov. x Hem. x Ant.</td>
<td>F[6,138] = 3.0</td>
<td>0.04*</td>
</tr>
</tbody>
</table>

Relative amplitude describes relative negativity for the N400 and relative positivity for the late positivity.
4. Discussion

Participants viewed sentences that varied in the predictability of the final word and, for low-predictability sentences only, also varied in the conventionality/novelty of the sentence final word’s meaning. To assess hemispheric asymmetries in sensitivity to these factors, sentence final words were presented in either the participants’ right visual field (rvf/LH) or left (lvf/RH). Results suggest that the two hemispheres were similarly sensitive to the predictability of the sentence final word, but differed in their sensitivity to its semantic novelty. Presentation to the rvf/LH gave rise to early effects of semantic novelty, evident on the N400 component, and, in an unexpected result, suggested novel meanings were actually easier to process than conventional ones. Presentation to the lvf/RH gave rise to late effects of semantic novelty, evident 600–1200 ms after word onset. Late effects included a frontal positivity reminiscent of that reported by Davenport and Coulson (2011), who employed central presentation of these same materials. As in Davenport and Coulson (2011), the present study revealed a larger frontal positivity for novel (LN) than conventional (LC) meanings.

Below, the effects of predictability and novelty are reviewed in detail. These effects are then interpreted in light of prominent theories of hemispheric asymmetry in semantic processing. We argue that the results of the present study are not wholly consistent with any of the hypotheses in play in the literature, but seem most consistent with the Federmeier’s (2007) PARLO hypothesis, which posits a predictive role for LH and an integrative role for RH. We therefore propose an extension of the PARLO model to account for the novelty-related positivity observed following lvf/RH presentation.

4.1. Predictability effects

In the present study, the largest effect of predictability was the reduced N400 elicited by words in predictable sentence contexts (HC) compared to words in unpredictable (“low cloze”) contexts (LC). This finding is consistent with previous observations that N400 amplitude is inversely correlated with cloze probability (DeLong, Urbach, & Kutas, 2005; Kutas, Lindamood, & Hillyard, 1984). Further, the difference in N400 amplitude for the two conventional meaning conditions (HC minus LC) was similar in size with presentation to the rvf/LH and the lvf/RH. This finding is in keeping with prior ERP studies that report similar cloze probability effects with hemi-field presentation (e.g., Coulson et al., 2005; Federmeier & Kutas, 1999), and suggests that when comprehension requires the activation of a conventional meaning, both hemispheres can benefit from sentence context.

Alternatively, one might argue that predictability effects on the N400 were similar because the same brain regions were engaged, irrespective of presentation side. That is, perhaps the presentation side manipulation in the present study was simply ineffective. We find this unlikely for a number of reasons. First, participants had more difficulty reading words presented in lvf/RH, in keeping with the well-known right visual field (LV) advantage for reading (Bradbaw & Nettleton, 1983). The analyses reported in Section 3.2 included only trials that participants indicated they actually were able to read. In these trials, presentation side modulated both the latency (P1) and the amplitude (N1) of the visual ERP components, indicating the increased participation of the targeted hemisphere (see Fig. 1). Finally, while presentation side did not modulate the size of N400 predictability effects, it did impact their topographic profile (see Table 3), indicating at least some differences in the neural generators active with rvf/LH versus lvf/RH presentation.

In addition to the N400, the predictability factor also influenced a late frontal positivity. Fig. 2 shows that with presentation to both the rvf/LH and the lvf/RH, LC sentences elicited less positive late responses than HC sentences over posterior scalp sites, but larger late positivities over anterior scalp sites (see also Fig. 4). Results largely replicate the findings of Davenport and Coulson (2011), an earlier study that employed central presentation of these materials. These data are also consistent with prior studies suggesting a dissociation between frontal and posterior positivities elicited in language comprehension tasks (e.g., Coulson & Severens, 2007). Interpreting their data, Coulson and Severens (2007) pointed to the memory literature where posterior positivities are viewed as reflecting the reactivation of stored information, and frontal positivities as indexing the monitoring and evaluation of retrieved information (Ranganath & Paller, 2000; Rugg & Yonelinas, 2003). Our findings are broadly consistent with this characterization, as expected words elicited larger positivities over posterior scalp sites, while less predictable words elicited larger positivities over anterior sites.

Our comparison of ERPs elicited by HC and LC materials largely replicate those of Coulson and Van Petten (2007). They compared high-cloze literal sentences, low-cloze literal sentences, and low-cloze novel metaphorical sentences in a divided visual field ERP experiment. Comparing ERPs to words used in their conventional literal sense, Coulson and Van Petten (2007) found that “low cloze” words that were not predictable from the preceding sentence contexts elicited a larger frontal positivity than words which were expected (“high cloze”). Moreover, this effect was observed only with rvf/LH presentation, suggesting the left hemisphere is crucial for its generation. While results of the present study were somewhat more equivocal regarding the crucial importance of rvf/LH presentation for eliciting an effect of predictability on the frontal positivity, the predictability effect was clearly more prominent with presentation to the rvf/LH (see Fig. 4).

Results of the present study also bear some resemblance to those reported by Coulson and Wu (2005) in a study of one-line jokes. Coulson and Wu (2005) found that probe words such as “infidelity” elicited a larger frontal positivity following unrelated non-jokes (“The replacement player hit a home run with my ball.”) than related jokes (“The replacement player hit a home run with my girl.”). Coulson and Wu’s (2005) data supported the dissociation between the posterior positivity, which was larger for related probes, and the frontal positivity, which was larger for unrelated probes. When probes were lateralized, unrelated probes elicited larger frontal positivities only with rvf/LH presentation, suggesting this effect has a prominent left hemisphere generator.

Late frontal positivities with a similar time course and topography have been observed in a number of prior ERP language studies examining how semantic congruity or the expectedness affects ERPs to words in sentences (see Van Petten and Luka, 2006 for a review). For example, in a study comparing ERPs to congruent versus anomalous endings of sentences, Swick, Kutas, and Knight (1998) found congruity effects on both the N400 and the frontal positivity in neurotypical participants, but only N400 effects in patients with lesions in prefrontal cortex. As most patients in this study had left hemisphere lesions, it suggests the left frontal cortex is crucial for the generation of the frontal positivity. Exploring the functional significance of this component, Federmeier et al. (2007) reported a frontal positivity elicited by unexpected words in highly constraining sentence contexts. Because a similar positivity was not observed to unexpected words in weakly constraining contexts, Federmeier and colleagues (2007) suggested the frontal positivity indexed the registration of a prediction error, and the brain’s attempt to compensate for it. Consistent with this interpretation, DeLong, Urbach, Gropp and...
Kutas (2011) found a negative correlation between the amplitude of a late positivity measured 500–1200 ms post-word onset at frontal electrode sites and the cloze probability of the eliciting word. In highly constraining sentence contexts, the less expected the word, the larger the frontal positivity (DeLong et al., 2011).

An important study by Thornhill and Van Petten (2012) addressed the question of whether the frontal positivity indexes violations of specifically lexical expectations, or of semantic expectations more generally. Participants read high-constraint sentences (e.g., “He was afraid that doing drugs would damage his…”) ending either in the most expected word (brain), an unexpected word semantically related to the best completion (mind), or an unexpected word that was unrelated to the best completion (reputation). Participants also read low-constraint sentences with the same three kinds of endings (“Everyone on the scene gathered around to look at the accident/crash/celebrity.”). It was only in the high-constraint conditions that the unexpected completions elicited larger frontal positivities than the best completion. Further, both the related unexpected word (mind) and the unrelated unexpected word (reputation) elicited these larger frontal positivities, suggesting that the frontal positivity is sensitive to violations of both word-form expectations and category-level semantic expectations. Thornhill and Van Petten (2012) concluded that a N400/late positivity pattern occurs when a word provides new semantic information, disconfirming a comprehender’s a priori hypotheses.

Taken together, these data suggest the frontal positivity is generated in prefrontal cortex, and predominantly reflects activity in the LH. While its functional significance is somewhat elusive, the frontal positivity clearly reflects some aspect of the brain’s response to unexpected events, including unexpected probes as well as words which are unexpected due to the prior sentence context. In a comprehensive review of the ERP literature on semantic expectancy violations, Van Petten and Luka (2012) note that late frontal positivities have been almost exclusively generated in prefrontal cortex, and predominantly reflects activity localized to the mid-ventrolateral prefrontal cortex, that select contextually relevant information from information activated via both automatic and controlled retrieval processes (see Badre & Wagner, 2007 for a review). However, the exact functional significance of the frontal positivity evoked by plausible, but unexpected, words in sentence contexts, and its relationship to learning and memory processes discussed above remains an important topic for further research.

4.2. Effects of novelty/conventionality

Although predictability had a similar impact on N400 amplitudes in the two visual fields, semantic novelty did not (see Fig. 3). Relative to the low-predictability conventional (LC) condition, the low-predictability novel (LN) condition elicited reduced amplitude N400 with rvf/LH presentation, but not with presentation to the lvf/RH. This suggests that with lvf/RH presentation, semantic retrieval demands indexed by the N400 component were similar for the two conditions; and, with rvf/LH presentation, those demands were actually greater for the conventional meanings than they were for the novel ones. Given that most models of hemispheric asymmetry predict a right-hemisphere advantage for semantic novelty rather than a left-hemisphere one, this result is inconsistent with the predictions of both the coarse coding model and the graded salience hypothesis.

Most models of hemispheric asymmetry in meaning activation assume that, other things being equal, conventional meanings will be processed more easily than novel ones, presumably because conventional meanings are retrieved while novel ones must be constructed. Our finding that, relative to the LC condition, the LN condition elicited reduced N400 in rvf/LH and similar amplitude N400 in lvf/RH suggests that novelty is not necessarily the critical factor in processing difficulty, and points to the possibility that all semantic retrieval involves some degree of creative construction (Coulson, 2006).

Though the direction of the N400 effect was unexpected, results of the present study are, nonetheless, reminiscent of other hemi-field studies that have examined the impact of a semantic manipulation while controlling for the predictability of the critical words. Coulson and Williams (2005), for example, compared ERPs to the critical word in a joke with an equally unexpected non-joke ending (“The replacement player hit a home run with my GIRL/BALL.”). Relative to the joke endings, the non-joke endings elicited reduced amplitude N400 with presentation to the rvf/LH, but not the lvf/RH. As in the present study, Coulson and Williams (2005) found that rvf/LH-initiated N400 amplitude was sensitive to their semantic manipulation while lvf/RH-initiated N400 amplitude was sensitive only to cloze probability, which was similar for joke and non-joke endings. Coulson and Williams (2005) suggested that RH retrieval demands were similar for jokes and non-jokes because semantic activations in the RH included both schemas that were prevalent, such as the baseball frame, and those, such as the sexual frame, that were less obvious, though also compatible with the sentence context.

Results of the present study are also consistent with an account of the predictability-related frontal positivity as reflecting strategic aspects of semantic processing, such as controlled retrieval and interference resolution (e.g., Coulson & Severens, 2007; Coulson & Wu, 2005; Federmeier, 2007). Neuroimaging studies suggest the left frontal lobe is important for a variety of cognitive control processes important for retrieving information from long-term memory, selecting information that is relevant, and inhibiting information that is not (see Badre & Wagner, 2007 for a review). Left frontal cortex has been shown to play an important role in strategic semantic operations, even in word-level processing (Gold et al., 2006), and top-down mechanisms for activating contextually relevant information are presumably even more important for understanding words in the complex sentence contexts employed here. Our sentence comprehension task no doubt posed demands on so-called post-selection processes, localized to the mid-ventrolateral prefrontal cortex, that select contextually relevant information from information activated via both automatic and controlled retrieval processes (see Badre & Wagner, 2007 for a review). However, the exact functional significance of the frontal positivity evoked by plausible, but unexpected, words in sentence contexts, and its relationship to learning and memory processes discussed above remains an important topic for further research.
Similarly, Federmeier and Kutas (1999) examined ERPs to expected (PALMS) and two sorts of unexpected completions (PINES, TULIPS) of two-sentence contexts, such as “They wanted to make the hotel look more like a tropical resort. So along the driveway they planted rows of...”. One of the unexpected completions (PINES) was from the same taxonomic category (viz. trees) as the expected completion, while the other was not. As in the present study, Federmeier and Kutas (1999) found amplitude differences for the N400 elicited by these two sorts of unexpected completions with presentation to the rvf/LH, but not the lvf/RH. The authors attributed this asymmetry to different semantic strategies implemented by the two hemispheres, a model that was subsequently labeled the PARLO hypothesis (Production Affects Reception in Left hemisphere Only). According to this model, the LH specializes in a predictive strategy, which allows it to pre-activate semantic features on the basis of context. Because the unexpected related ending shares many semantic features with the expected ending, it is facilitated in rvf/LH, though not as much as the expected ending. By contrast, the RH specializes in an integrative strategy, incorporating each word as it comes into the evolving model of sentence meaning (see Federmeier, 2007 for a review).

Analogously, the N400 novelty effect observed here with rvf/LH presentation may reflect differences in the extent to which the LN versus LC sentence frames allowed participants to predict contextually relevant features of sentence final words. LN stimuli were designed to promote conceptual mappings between sentence final words and some antecedent in the sentence context, either by implying a comparison between the concepts, or some sort of a substitution of one thing for another. For example, in the LN sentence, “At one time, this movie house was a CATHEDRAL,” there is a mapping between the movie house and the cathedral that might allow one to pre-activate some relevant information about this particular cathedral – for example, the size of the building. While the meaning evoked by “cathedral” in the LC sentence “He always felt scared when he was alone in the CATHEDRAL,” is more conventional than that in the LN example, (i.e. it is a typical cathedral rather than a cathedral-turned-movie-theater), the preceding context is somewhat less specific, and consequently less useful for a predictive processor.

Interestingly, the LC and LN conditions here were equated for easily quantifiable manifestations of contextual support, including cloze probability, sentence constraint, and LSA-assessed semantic similarity between the context and the final word (see Table 2). The critical difference between our two low-predictability conditions may be that the LN materials involved mappings between two concepts of similar specificity, while the LC materials often involved an antecedent that was more abstract than the sentence final word. Because they were designed to promote conceptual mappings, the critical word in the LN materials had to share enough conceptual structure with its antecedent to support substitution, comparison, pretense, and so on. For instance, they might have similar affordances, appearance features, or functional features. This was not universally the case for the LC condition, as these materials were designed primarily with the goal of producing sentence frames that rendered the critical words plausible, yet unpredictable. Consequently, sentences in the LC condition either described one concept straightforwardly as an example of another (e.g., “For many years, the Bastille was a jail,”) or implied the presence of a stereotypical feature of the critical word (e.g., an animal’s habitat, in “The ranger said that somewhere in the state park is a bear.”). We suggest, therefore, that the graded predictive capacity attributed to the LH can include the degree of match between the conceptual structure evoked by a word, and that evoked by an antecedent in its context.

Results of the present study contrast with a similar study by Coulson and Van Petten (2007) that examined the impact of divided visual field presentation on ERPs to words (such as, “cosmetic”), used either literally (as in, “I definitely consider eyeliner to be a cosmetic.”) or metaphorically (as in, “I’ve discovered that happiness is an incredible cosmetic.”). As noted in the introduction, metaphorical meanings rely on the existence of conceptual mappings between domains – mappings presumed to bear some similarity to those underlying the novel literal meanings in the LN materials in the present study. In the present study, however, presentation side modulated the size of N400 novelty effects (LC versus LN), whereas Coulson and Van Petten (2007) found very similar sized N400 metaphoricity effects (low-cloze literal versus low-cloze metaphorical) with presentation to both visual fields. Given our explanation of hemispheric asymmetry in the processing of low predictability novel (LN) materials, one might reply to our explanation by questioning why metaphors, which also rely on a mapping between the target word and an antecedent in the sentence context, were not similarly facilitated with rvf/LH presentation.

We suggest that whereas the LN materials involved two concepts of similar specificity, the metaphors often involved an antecedent that was more abstract than the critical word. For example, “happiness” is more abstract than “cosmetic” in “I’ve discovered that happiness is an incredible cosmetic.” Moreover, the relevant features of happiness (i.e. that it makes people more attractive) are not predictable from the context, and can only be inferred after the reader encounters “cosmetic”. Coulson and Van Petten (2007) did employ some examples where the antecedent might initially be interpreted in a concrete way (e.g. “theatre” in “Actors used to think of the theatre as a cathedral,”), but required an abstract reading (viz. “theatre” in its institutional sense) for correct interpretation of the metaphor. Even in this example, the relevant features of a theatre (a place where actors create art and the audience undergoes a potentially transformative experience) are not predictable from the context, and can only be retrieved after reading “cathedral”. So, while the LN contexts activated more specific target-relevant information than the LC ones, the contexts for the metaphorical meanings in Coulson and Van Petten’s (2007) study activated more general target-relevant information than did their low cloze literal counterparts, many of which were employed in the LC condition in the present study.

Presentation side was much more consequential for the late positive response to our manipulation of semantic novelty than for the predictability effects discussed above. As shown in Fig. 3, LN stimuli elicited a larger frontal positivity than LC only with presentation to lvf/RH, suggesting that the right hemisphere is more sensitive than the left to semantic novelty. This result contrasts with the literature on predictability violations, most of which suggests predominantly left hemisphere generators for frontal positivities. Moreover, it also contrasts with the claim advanced by Davenport and Coulson (2011) that the frontal positivity elicited by novel literal sentences is an enhancement of the predictability-related positivity. Whereas our presentation side manipulation suggested the left hemisphere as the primary source of prefrontal positivities elicited by predictability manipulations, the right hemisphere was found to dominate the positivity related to semantic novelty.

Indeed, prior work in our laboratory suggests that frontal positivities, at least those elicited by creative language, are generated by sources in both cerebral hemispheres. In a study of ERPs elicited by the critical word in jokes relative to unexpected, but non-funny, controls, (“When my mechanic couldn’t fix my brakes, he decided to just fix my HORNS/TIRES”), Coulson and Williams (2005) found that joke endings elicited a larger frontal positivity with presentation to both visual fields. However, presentation side
did shift the topography of the brain response, as the positivity was bilateral with presentation to the rvf/LH, and slightly right-lateralized with presentation to the lvf/RH. These data suggest the positivity reported by Coulson and Williams (2005) had bilateral generators with a right hemisphere focus.

Reviewing the ERP literature on memory and categorization, Folstein and Van Petten (2011) note that prefrontal positivities index executive processes, and suggest that the core processes associated with these ERP effects involve coordination between working- and long-term memory. Moreover, ERP studies of episodic memory suggest that the amplitude of the late frontal positivity indexes the difficulty of domain general processes for integrating disparate bits of information (Kuo & Van Petten, 2006). Prefrontal cortex has been implicated in problem solving tasks involving relational complexity, including neuroimaging studies of healthy adults (Christoff et al. 2001; Kroger et al., 2002), as well as impaired performance by patients with lesions in these areas (e.g., Roca et al., 2010). Although most tasks associated with prefrontal activation elicit bilateral activity, right hemisphere activation predominates in tasks involving retrieval cues or rules which are internally generated by the participant, as opposed to being driven by external aspects of the stimulus (see Christoff, 2009 for a review). Larger frontal positivities for semantically novel materials can thus be interpreted as arising from the need to retrieve and integrate contextually relevant aspects of conceptual structure from different domains, such as a room in the basement and a jail, a movie theater and a former cathedral, or a rug in a cabin and a bear in a play.

The importance of the right hemisphere for semantic novelty may have gone unnoticed in prior studies due to a failure to precisely equate materials with respect to the degree of sentence constraint (e.g. Coulson and Van Petten, 2007). The LC and LN (literal) materials in the present study were matched in terms of their predictability and the degree of constraint imposed by the preceding sentence context. This contrasts with a DVF study of ERPs to words used in sentence contexts supporting literal versus metaphorical meanings by Coulson and Van Petten (2007). Coulson and Van Petten (2007) controlled for cloze probability but not constraint in their low-cloze literal and low-cloze metaphorical conditions. By controlling the degree to which sentence contexts afford the prediction of a particular word, as well as the expectedness of the critical words, the present study allowed us to observe right hemisphere participation in the construction of novel literal meanings in response to conceptual mappings.

The RH semantic novelty effect in the present study also fits with the topography of the prefrontal positivity elicited in Davenport and Coulson’s (2011) study of these materials with central presentation. Although statistical testing did not support lateral asymmetry of the positivity, visual inspection of the scalp map of the novelty positivity suggested an anterior RH focus. Finally, the RH focus of the semantic novelty effect identified here for literal meanings is in keeping with reports that the RH plays a critical role in the comprehension of novel metaphoric meanings (e.g., Giora, 2007; Pobric et al., 2008).

4.3. Hemispheric asymmetry

As noted above, the coarse coding hypothesis (described in detail in Jung-Beeman, 2005) assumes that frontal and temporal language areas are organized in qualitatively similar ways and implement qualitatively similar processes. These processes differ quantitatively in the degree to which more distant semantic associates are activated and selected during processing. One shortcoming of this model is its reduction of semantic novelty to a rather ill-specified concept of semantic distance. Moreover, the absence of any mechanism for implementing grammatical regularities flies in the face of fifty years of linguistic research (see e.g. Chomsky, 1957). The coarse coding portrait of slightly different activation, integration, and selection processes operating in parallel in the two hemispheres is broadly consistent with the ERP results observed here—especially the very similar predictability effects with both presentation sides. However, the proposal that each hemisphere has qualitatively similar mechanisms is inconsistent with our finding that novelty modulated the N400 in rvf/LH but not in lvf/RH. Similarly, our finding of a rvf/LH-initiated frontal positivity to predictability but not novelty, and a lvf/RH-initiated frontal positivity to novelty but not predictability also undermine the proposal that the two hemispheres differ mainly in the speed and extent of semantic activation processes.

Taken at first blush, results of the present study can be seen as supporting the graded salience hypothesis, as it posits qualitatively different comprehension mechanisms in LH and RH (Giora et al., 2000). The LH purportedly houses a fast, automatic mechanism of semantic activation, whereas the RH houses a slow, deliberate mechanism of meaning construction, specialized for less familiar or expected meanings. In keeping with this model, we observed semantic novelty effects on the N400 exclusively with rvf/LH presentation, presumably reflecting the LH memory mechanism, and on the late frontal positivity exclusively with presentation to the lvf/RH, perhaps reflecting the operation of the RH constructive mechanism. One wrinkle, though, is that while the graded salience hypothesis predicts that novel or otherwise non-salient language will elicit a larger N400 in LH, representing the greater difficulty in activating non-salient conceptual material, our rvf/LH N400 results suggested the novel literal meanings used here were activated with less difficulty than their conventional literal counterparts.

We suggest that, at least in right-handed individuals, the two hemispheres differ in the organizations of their lexical/semantic networks. Federmeier (2007) argues that hierarchical forward models used for speech production in the LH can also be used for prediction during language comprehension. We argue that the LH’s rich knowledge of statistical patterns in language is implemented in a semantic network organized largely according to the co-occurrence patterns of language experience and in the statistical regularities present in the comprehender’s knowledge of abstract combinatorial structure. In the RH, the semantic network of word and concept representations is arranged according to declarative memory structures, akin to frames or mental spaces (Coulson, 2001; Fauconnier, 1997), and is less tied to linguistic knowledge than in the LH.

This RH network structure may result in facilitating plausible sentence completions as well as, perhaps, other words in the frames activated by context, but not their lexical associates or same-category associates (Federmeier & Kutas, 1999). The words ‘palms’ and ‘pines’ may appear frequently in the same linguistic contexts, but real palms and pines rarely appear in the same environments and experiences. The RH semantic network also facilitates (at least, compared to LH) some types of linguistically novel expressions that can be interpreted based on the relational structure of world knowledge, such as jokes, sarcasm, and other phenomena that are impaired with RH damage. RH can even predict upcoming words, when successful prediction relies not on familiar patterns of words, but on familiar patterns of events in the world, as in predictive causal inferences (Virtue et al., 2006a; Virtue, Parrish, & Jung-Beeman, 2008; Beeman et al., 2000).

4.4. Conclusion

4.4.1. Predictability

For words used in their conventional literal senses, the present study revealed differences as a function of their predictability from
the preceding sentence contexts. Our predictability manipulation affected both the well-known N400 component and the positivities that follow it. Divided visual field presentation had little impact on the size of the N400 effect, suggesting both hemispheres benefit from contextual support (Coulson et al., 2005). Although the predictability-related late positivities following the N400 were not markedly impacted by presentation side, their more widespread distribution over the scalp with rvf/LH presentation suggests an important role for the LH in their generation. The present study is in keeping with prior work that has dissociated the parietal positivities elicited by predictable words from the frontal positivities elicited by words that were less predictable. We have suggested that the parietal positivities index brain activity related to the reactivation of stored knowledge, while the frontal positivities index brain activity related to processes for controlled retrieval and selection from semantic memory.

4.4.2. Semantic novelty

In keeping with the broad outlines of the graded salience hypothesis, results of the present study suggested a dissociation between the fairly automatic semantic retrieval processes indexed by the N400 component, and the more controlled processes indexed by the frontal positivity measured 600–1200 ms post-onset. Our manipulation of semantic novelty affected N400 amplitude exclusively with rvf/LH presentation, consistent with the claim in the graded salience hypothesis that the LH predominates in the rapid retrieval of lexical semantic information that is presumably indexed by the N400 (see Lau, Phillips, and Poeppel, 2008 for a review). Further, in accordance with the graded salience model’s proposal that slower, controlled aspects of semantic processing are dominated by the RH, our novelty manipulation affected the late frontal positivity exclusively with lvf/RH presentation. This frontal positivity was argued to index prefrontal cortex activity related to the retrieval and integration of contextually relevant aspects of conceptual structure, and was more pronounced in the novel than conventional materials.

Contrary to the predictions of both graded salience and coarse coding, our finding that semantically novel meanings elicited less negative N400 than conventional ones with rvf/LH presentation suggested that our novel meanings posed lighter demands on retrieval processes indexed by the N400 component than did conventional uses of the same words. In fact, the critical variable predicting N400 amplitude with rvf/LH presentation may be the match between the specificity of the critical word and the contextual information that allows listeners to predict contextually relevant aspects of that critical word’s conceptual structure. The late frontal positivity, by contrast, was larger for semantically novel meanings with lvf/RH presentation, suggesting that the frame activated by the critical word in the LN conflicted to some degree with the frames activated by the sentence context, posing a greater demand on controlled retrieval and integration processes compared to the conventional literal meanings. In contrast to the graded salience hypothesis that argues that the RH constructive meaning construction mechanisms have no LH counterpart, we suggest that this RH-dominated frontal positivity may be the counterpart to the LH-dominated positivity sensitive to the predictability manipulation. But where learning and memory mechanisms in the LH are particularly tuned for linguistic contingencies, those in the RH are tuned to contingencies arising from experience in the world.

References


