Available online at www.sciencedirect.com
ScienceDirect
Brain and Language 100 (2007) 188–207
Brain and Language
www.elsevier.com/locate/b&l

Understanding metaphors: Is the right hemisphere uniquely involved? ☆

Natalie A. Kacinik [a,*], Christine Chiarello [b]

[a] Center for Neuroscience, University of California, 1544 Newton Crt., Davis, CA 95616-8768, USA
[b] University of California, Riverside, USA

Accepted 18 October 2005
Available online 1 December 2005

Abstract

Two divided visual field priming experiments examined cerebral asymmetries for understanding metaphors varying in sentence constraint. Experiment 1 investigated ambiguous words (e.g., SWEET and BRIGHT) with literal and metaphoric meanings in ambiguous and unambiguous sentence contexts, while Experiment 2 involved standard metaphors (e.g., *The drink you gave me was a meteor*) with sententially consistent and inconsistent targets (i.e., POTENT vs COMET). Similar literal and metaphor priming effects were found in both visual fields across most experimental conditions. However, RH processes also maintained activation of sententially inconsistent literal meanings following metaphoric expressions. These results do not strongly support the RH as the preferred substrate for metaphor comprehension (e.g., Anaki, Faust, & Kravetz, 1998; Bottini et al., 1994), and suggest that processes in both hemispheres can support metaphor comprehension, although not via identical mechanisms. The LH may utilize sentence constraint to select and integrate only contextually relevant literal and metaphoric meanings, whereas the RH may be less sensitive to sentence context and can maintain the activation of some alternative interpretations. This may be potentially useful in situations where an initial understanding must be revised.

Keywords: Figurative language; Metaphors; Cerebral hemispheres; Language laterality; Semantic ambiguity; Priming; Lexical decision; Sentence comprehension

1. Introduction

A fundamental pursuit in cognitive science is the quest to get to the meaning of "meaning" by understanding language comprehension (i.e., how concepts are represented in our semantic memory, and how these representations are activated and retrieved when reading text or listening to discourse). Many valuable contributions to this quest have come from studies aimed toward understanding the neuropsychological basis of language processing (e.g., Burgess & Simpson, 1988; Caramazza & Hillis, 1990; Faust & Kravetz, 1998; Kutas & Hillyard, 1984; Zaidel, 1978). Although neuropsychological investigations use a variety of methods (e.g., visual half-field studies, neuroimaging and electrophysiological techniques, studying split-brain patients and other brain-injured populations), they generally aim to understand language processes in terms of the brain systems subserving those processes.

Divided visual field (DVF) research has been particularly useful for understanding language comprehension in terms of the functioning of the cerebral hemispheres. This research (see Beeman & Chiarello, 1998, for a review) has shown that although there is generally an overall advantage

☆ This paper is dedicated to the memory of Stella Arambel (Liu) who recently passed away at the beginning of a promising career. Her research formed part of the foundation for the work reported here and has significantly influenced our understanding of cerebral asymmetries in sentence comprehension. Support for this study was provided by a University of California, Riverside dissertation grant to the first author and by NSF Grant BCS-0079456 to the second author. These experiments formed part of Natalie Kacinik's doctoral dissertation and she thanks her committee members, Curt Burgess and Seana Coulson. We also acknowledge Ahn Tran, Tzy-Fang Chen, Spencer Shucard, Chris Lock, Laura Halderman, Cathy Robinson, Robin Watson, Nicole Segovia, Esther Koeshadi, and Vanessa de Sagun, for their help with various aspects of this project. Finally, we want to thank the reviewers for their thoughtful comments and suggestions, as well as Gwen Schmidt for a useful discussion of relevant issues.
* Corresponding author. Fax: +1 530 757 8827.
E-mail address: nakacinik@ucdavis.edu (N.A. Kacinik).

0093-934X/$ - see front matter
doi:10.1016/j.bandl.2005.10.010

for linguistic stimuli presented to the RVF/LH, the RH is able to process and understand language to a certain extent. Moreover, it does so in a manner that is complementary, but qualitatively different to the LH. Processing in the LH tends to be fast, deep, and narrowly focused, whereas RH processes tend to be slower and broader in scope, such that several alternate meanings may remain active over longer durations (Atchley, Burgess, & Keeney, 1999; Burgess & Simpson, 1988; Chiarello, 2003). LH processing also appears more suited for comprehending sentences because it uses grammatical information and sentence constraint to integrate sentence meaning, while RH processes are less sensitive to syntactic structure, relying mainly on word-level semantic relations (Faust, 1998; Faust & Chiarello, 1998a, 1998b).

Most DVF investigations have focused on literal language, but the most intriguing challenge for theories of natural language comprehension involves the use of figurative expressions. In figurative language the intended meaning differs from the meaning of what is literally expressed, such that the concept of "meaning" itself is extended to its limits (Geiger & Ward, 1999; Hoffman, 1984). Several researchers (e.g., Bottini et al., 1994; Hoffman, 1984; Ortony, 1993) have noted that the use of figurative language is not restricted to poetic or literary devices, but occurs very frequently and is pervasive to all human communication and cognition. It has been estimated that figures of speech occur at the rate of about 4 per minute of speech (Abkarian, Jones, & West, 1992). Therefore, to be complete, neurocognitive theories must account for figurative aspects of language such as understanding metaphors.

Although the LH is generally considered the dominant neural substrate for linguistic processing, RH processes may be preferentially involved in the comprehension of metaphors and other figurative forms (e.g., Anaki et al., 1998; Bottini et al., 1994; Burgess & Chiarello, 1996; Sabbagh, 1999). This conclusion, however, is primarily based on research conducted with brain-injured individuals (e.g., Brownell, Potter, Bihrle, & Gardner, 1984, 1990; Kempler, Van Lancker, Marchman, & Bates, 1999; McIntyre, Pritchard, & Lombroso, 1976). It is thus unclear to what extent these results can be used to make inferences about the nature of processing in the "normal" (non-injured) RH and LH. Although some studies of normal participants support the RH as more involved in metaphor comprehension (e.g., Anaki et al., 1998; Bottini et al., 1994; Mashal, Faust, & Hendler, in press), results from other investigations are either equivocal (Faust & Weisper, 2000) or fail to show preferential RH metaphor processing (Coulson & Van Petten, 2000; Lee & Dapretto, 2003; Rapp, Leube, Erb, Grodd, & Kircher, 2004). Moreover, the evidence from several recent studies of brain-lesioned participants has either only weakly supported (e.g., Gagnon, Goulet, Giroux, & Joanette, 2003), or failed to support the RH metaphor hypothesis (e.g., Giora, Zaidel, Soroker, Batori, & Kasher, 2000; Tompkins, 1990). A summary of this research is presented in Table 1, which also illustrates the considerable variability in the materials and procedures used in prior studies. It is thus difficult to draw firm empirical conclusions about each hemisphere's ability to understand metaphoric language.

There are several theoretical reasons why RH processes may be better suited than LH processes for comprehending figurative language. Some researchers have proposed greater RH involvement in the various higher-level, top-down, and more complex sentence integration processes assumed to occur during metaphor comprehension (Bottini et al., 1994; Burgess & Chiarello, 1996; Martin & McDonald, 2003; Sabbagh, 1999). Examples of these processes include generating inferences (Bottini et al., 1994; Coulson & Matlock, 2001; Hoffman, 1984), analogical reasoning (Gentner, 1989; Gentner, Bowdle, Wolff, & Boronat, 2001), conceptual blending, mapping, and elaboration (Coulson & Van Petten, 2002; Gentner & Wolff, 2000; Kintsch, 2000), and social aspects of communication such as pragmatics (Sabbagh, 1999; Sadock, 1993). Considerable research has shown that the RH does indeed seem to be preferentially involved in such high-level processing (e.g., Happe, Brownell, & Winner, 1999; Luo et al., 2003; Mason & Just, 2004; Robertson et al., 2000; Sabbagh, Moulson, & Harkness, 2004).

In contrast, other accounts have focused on more basic bottom-up semantic activation processes (e.g., Anaki et al., 1998; Beeman, 1998; Burgess & Chiarello, 1996), with the RH claimed to activate a broad range of meaning including distantly related concepts and peripheral features, and to simultaneously maintain the activation of multiple meanings, even if they are inconsistent with a given context. LH processes, on the other hand, may only select and maintain the activation of the most closely related concepts and central aspects of meaning. Such proposals are based on demonstrations that contextually inconsistent or grammatically incongruous words are often primed in the RH but not in the LH (Arambel & Chiarello, 2006; Faust & Chiarello, 1998a), that only dominant and strongly associated meanings tend to be maintained in the LH (e.g., Anaki et al., 1998; Burgess & Simpson, 1988; Nakagawa, 1991), whereas both dominant and subordinate meanings (e.g., Atchley et al., 1999; Burgess & Simpson, 1988), non-associated category members (Collins, 1999; Koivisto, 1997), and metaphoric meanings (Anaki et al., 1998) all show RH activation, particularly at long SOAs.

These claims can be incorporated into Beeman's Fine-Coarse Coding theory (Beeman, 1993, 1998; Beeman et al., 1994), which postulates that RH functioning is such that it weakly activates "broad semantic fields," whereas the LH "finely codes" information, activating small semantic fields consisting of only the closest and most central aspects of meaning. The broader RH activation of semantic representations is assumed to result in the overlap of some semantic fields, allowing relations between those concepts to emerge, and result in the activation of concepts that "inferentially connect those distantly related words" (Beeman & Chiarello, 1998, p. 261). Understanding metaphors is assumed to

Table 1
Summary of the participants, stimuli, procedures, and main findings from previous hemispheric studies of metaphor processing

Study	Participants	Stimuli	Procedure	Major results
McIntyre et al. (1976)	RH and LH temporal lobe epileptic patients	Descriptions of emotionally evocative scenes	Select word (5 choices) most applicable to scene	More metaphoric interpretations made by LH than RH epileptic pts
Winner and Gardner (1977)	RHI and LHI stroke patients	Pictures and sentences of conventional metaphoric phrases (e.g., *He has a heavy heart*)	Select 1 of 4 pictures to match sentence, and verbally explain metaphoric phrase	RHI chose inappropriate literal pictures more often than LHI pts and controls, but RHI pts could verbally explain metaphor meaning
Brownell et al. (1984, 1990)	RHI and LHI stroke patients	Words with literal and metaphoric meanings (e.g., *deep—wise vs lake*)	Choose 2 out of 3 words most similar in meaning	RHI select correct metaphorical target less often than LHI pts
Van Lancker and Kempler (1987), Kempler et al. (1999)	RHI and LHI stroke patients	Familiar idiomatic expressions (e.g., *She's got him eating out of her hand*) and pictorial depictions	Select 1 of 4 pictures that matches verbally read sentence	LHI pts more accurate on familiar idiomatic items, while RHI group performed better with novel literal sentences
Klepousniotou and Baum (2005)	RHI and LHI stroke patients	Ambiguous homonymous (BANK), metonymous (RABBIT), and metaphorical (MOUTH) words in sentences biased towards dominant or subordinate meaning	Lexical decision on target related to subordinate or dominant meaning of auditory sentence prime	LHI generally similar to controls, but RHI pts had difficulty using context to select appropriate meaning, and did not show facilitation for subordinate metaphoric meanings
**Gagnon et al. (2003)*	*RHI and LHI stroke patients*	*Words with literal and metaphoric meanings*	*Triad task* (e.g., Brownell et al., 1990), *and 2-word relatedness judgments*	*Relative to controls , LHI equally impaired on met and non-met triads, whereas RHI only impaired with met triads. But, no such difference with met items in 2-word task or when patient groups compared directly*
**Rinaldi et al. (2004)*	*RHI patients and controls*	*Pictures and sentences of familiar Italian idiomatic expressions* (e.g., *The man was very respected because he was a big piece)*	*Match sentence to 1 of 4 drawings* (*pictorial task*), *or to 1 of 3 interpretations* (*verbal task*)	*RHI and controls did not differ in verbal task, but RHI chose fewer correct metaphor pictures and more incorrect literal ones*
Tompkins (1990)	**RHI and LHI stroke patients**	**Words with literal and metaphoric meanings**	**Semantic priming with lexical decision on target**	**Similar literal and metaphoric priming for both patient and control groups, in both automatic and extrinsic expectancy conditions**
Giora et al. (2000)	**RHI and LHI stroke patients**	**Only 4 very familiar metaphoric phrases (e.g., broken heart)**	**Verbal explanation of phrase meaning**	**RHI pts performed better than LHI, and no different than controls**
Bottini et al. (1994)	Non-injured	Novel metaphoric sentences (e.g., *The investors were squirrels collecting nuts*)	PET neuroimaging of plausibility judgments	More RH activation for understanding metaphoric vs literal sentences
Mashal et al. (2005)	Non-injured	2-word literally related, unrelated, familiar and novel metaphoric phrases	fMRI for relatedness decisions (literal, metaphoric, unrelated)	Activation in RH homologue of Wernicke's area related to processing novel, but not conventional metaphors
Lee and Dapretto (2003)	**Non-injured**	**Moderately familiar words with literal and figurative meanings**	**fMRI for decisions about last 2 words from triad being similar in meaning**	**Increased LH activation for non-literal vs literal condition**
Rapp et al. (2004)	**Non-injured**	**Simple novel "an X is a Y" metaphors**	**fMRI of positive vs negative connotation judgements**	**More activation in left inferior frontal and temporal gyri for metaphors**
Anaki et al. (1998)	Non-injured	Moderately familiar words with literal and figurative meanings	Divided visual field (DVF) semantic priming paradigm with lexical decision on target	Bilateral metaphoric priming at 200 ms SOA, but only in LVF/RH at 800 ms SOA

**Faust and Weisper (2000)*	*Non-injured*	*Moderately familiar metaphoric expressions*	*DVF metaphor interference paradigm through sentence verification (is sentence literally true or false?)*	*Metaphor targets responded similarly in both VFs, but interference effect larger for RVF/LH*
**Schmidt et al. (2007)*	*Non-injured*	*Literal and metaphoric sentences of varying familiarity*	*DVF paradigm involving sentence plausibility and meaningfulness judgments for lateralized targets*	*LVF/RH advantages for unfamiliar metaphors, RVF/LH advantages found with familiar metaphors. But results not all statistically significant or different from unfamiliar literal sentences.*
Coulson and Van Petten (2000)	**Non-injured**	**Literal and metaphoric sentences**	**ERP study of literal and metaphor sentences with lateralized completions**	**Larger N400 for metaphor sentence completions in LVF/RH than RVF/LH**

Note. From top to bottom, the Table is organized according to study type (e.g., neuropsychological with right and left hemisphere injured patients (RHI, LHI), functional neuroimaging, DVF, and ERPs with neurologically intact participants). The order of studies within each type is generally chronological. Studies in plain font provide evidence for preferential RH involvement in metaphor comprehension, **while those in bold do not.**
Support for the RH metaphor hypothesis from the *italicized studies is either equivocal, or weak at best*, because it is limited to certain kinds of stimuli (e.g., pictures, very unfamiliar metaphors) or depends upon one's interpretation of the data.

involve more distant connotative aspects of meaning (Beeman, 1998; Bottini et al., 1994; Brownell, 2000). These are proposed to be activated by RH coarse coding mechanisms.

An important possibility raised by Beeman (1998) and others (Chiarello, 2003; Faust & Gernsbacher, 1996; Titone, 1998) is that broad RH activation and maintenance of multiple meanings simply reflects difficulty selecting contextually appropriate aspects of meaning and/or suppressing irrelevant ones. For example, sentence comprehension processes in the RH appear to be primarily based upon less constrained activation of the meanings of words in the sentence. This idea has also been incorporated into Fine-Coarse Coding theory: although broad semantic activation by the RH is thought to be necessary for metaphor comprehension, it is not sufficient because LH processes are required to select and integrate the concepts activated by the RH (Beeman, 1998; Beeman, Bowden, & Gernsbacher, 2000). Studies have shown that the LH does indeed appear to be superior than the RH at processing semantic, syntactic, and grammatical constraints to activate and select only contextually relevant meanings (Arambel & Chiarello, 2006; Faust & Chiarello, 1998a; Faust & Kravetz, 1998).

In summary, the contribution of each hemisphere to metaphor comprehension is presently unclear. RH involvement in understanding metaphors may occur at higher levels of linguistic processing, or may simply result from the broad activation and maintenance of multiple aspects of meaning. Of course, RH processes could be involved in both bottom-up and top-down aspects of figurative processing (e.g., Burgess & Chiarello, 1996). With respect to LH processing, although a smaller range of meanings seem to be maintained, the LH appears to be more sensitive to contextual constraint and to be primarily responsible for the selection and integration of sentence meaning. Hence, it is plausible that LH processing of metaphors could occur in supportive sentence contexts.

The purpose of the present study was to investigate these issues for two types of metaphoric expressions and sentence contexts of increasing constraint. Experiment 1 examined hemisphere differences for processing literal and metaphoric meanings of lexical metaphors (polysemous words with a literal and figurative sense), in sentences that were either unambiguous or ambiguous regarding the intended meaning. This experiment was thus designed to examine cerebral asymmetries for literal and metaphoric meaning activation across more or less constrained sentence contexts. In such stimuli, metaphoric meaning is simply understood by activating the extended figurative sense of these concepts. In contrast, Experiment 2 investigated hemispheric processing of standard 2-concept "an X is a Y" metaphors (e.g., His girlfriend's face was a storm). Although understanding these expressions also requires activating more distant aspects of meaning, their comprehension additionally involves more complex conceptual integration processes with the precise metaphoric meaning only emerging upon understanding the entire sentence

(Coulson & Matlock, 2001; Gentner & Wolff, 2000; Gineste, Indurkhya, & Scart, 2000). This experiment thus examined the degree to which each hemisphere is also involved in some higher-level metaphor comprehension processes. Experiment 2 was also designed to determine the extent to which each hemisphere maintains contextually inconsistent aspects of meaning, or can select only contextually appropriate literal and metaphoric meanings.

Specific predictions for each experiment will be discussed herein, but are summarized as follows. For RVF/LH trials processing metaphoric meaning in ambiguous contexts should be more difficult than in a supportive unambiguous sentence. In contrast, if the primary contribution of the RH to metaphor comprehension results from a broader and sustained activation of semantics, then LVF/RH processing of literal and metaphoric meaning should be relatively similar across different types of sentence contexts. Alternatively, if the RH primarily contributes to the higher-level processes involved in metaphor comprehension, then enhanced metaphoric processing for LVF/RH trials should only be demonstrated in the more complex "an X is a Y" metaphoric sentences.

2. Experiment 1

When a novel is described as *mushy*, the word "mushy" is intended to be metaphorical and describe a plot that is particularly emotional and romantic. The comprehension of such lexical metaphors is thought to result from activating underlying cross-domain conceptual correspondences (Gibbs, 1992; Lakoff, 1993). These authors claim that metaphors generally function to explain more difficult, unfamiliar, and abstract conceptual domains such as romance in terms of concepts that are more well known and concrete like an object's firmness.

Lexical metaphor stimuli have been investigated in many previous neuropsychological studies (e.g., Anaki et al., 1998; Brownell et al., 1984, Brownell, Simpson, Bihrle, Potter, & Gardner, 1990; Gagnon et al., 2003; Mashal et al., 2005). Since they have both literal and figurative meanings, lexical metaphors are somewhat similar to ambiguous words. Indeed, when such stimuli were investigated using a DVF priming procedure (Anaki et al., 1998), the results were similar to the findings obtained for the subordinate meanings of typical ambiguous words like BANK (e.g., Atchley et al., 1999; Burgess & Simpson, 1988). In particular, the metaphoric sense was active for both visual fields early in time-course, but was only maintained in the LVF/RH following a longer duration (Anaki et al., 1998). Except for a recent study of brain-injured individuals by Klepousniotou and Baum (2005) previous neuropsychological research with lexical metaphors has only involved studying these stimuli in minimal contexts such as word pairs or triads, rather than in more natural sentence contexts. In this experiment we investigate cerebral asymmetries in normal participants for processing lexical metaphors in sentence contexts that were either ambiguous or unambiguous to the intended meaning.

Several sentence priming experiments with non-metaphoric ambiguous words like SPADE (e.g., Faust & Chiarello, 1998a; Faust & Gernsbacher, 1996; Meyer & Peterson, 2000; Titone, 1998) have shown that when the context is neutral or ambiguous, RVF/LH processing appears to default to a selection of the dominant meaning of the ambiguous word, particularly at longer SOAs. If the context is sufficiently constraining and unambiguous, however, then the contextually appropriate meaning seems to be activated and selected, even if that meaning is much less frequent. These findings, in addition to other results demonstrating LH sensitivity to various sentence constraints (Faust & Kravetz, 1998; Faust & Chiarello, 1998a, 1998b), would predict that both literal and metaphor targets should be primed in the RVF/LH following an unambiguous sentence. However, RVF/LH metaphor priming would not be expected after ambiguous contexts because in those instances the dominant literal meaning should be selected and maintained (Anaki et al., 1998; Beeman, 1998; Meyer & Peterson, 2000; Titone, 1998).

In contrast, RH processes may be less sensitive to sentence constraint. When LVF/RH targets follow sentences biased toward a particular meaning of an ambiguous word, the activation of alternate meanings is maintained, even if the meanings are contextually inconsistent (Beeman, 1998; Faust & Chiarello, 1998a; Faust & Gernsbacher, 1996). Thus, if the RH is less affected by sentence constraint and able to sustain the activation of multiple meanings, then LVF/RH literal and metaphor priming should be of similar magnitude across both ambiguous and unambiguous contexts. However, RH sentence comprehension processes have also been claimed to mainly rely on the bottom-up activation of semantic representations and intra-lexical relations among the words in a sentence (Faust, 1998). Since unambiguous sentences are semantically "richer," because disambiguating words will generally be more strongly related to each other and to the targets (e.g., *I heard they were all* ***consumed*** *by SHARKS/GUILT*, vs *All the small fish were* ***consumed*** *by SHARKS, and The cheating students were* ***consumed*** *by GUILT*), it was predicted that both literal and metaphoric priming would be larger with unambiguous contexts.

In summary, both literal and metaphor priming effects were expected in each visual field after *unambiguous* sentence contexts. Of greatest interest, however, is whether metaphor targets will be primed in either visual field following *ambiguous* contexts. In the latter condition, difficulty generating and maintaining subordinate figurative meanings should not produce RVF/LH priming, but broader semantic activation processes should yield metaphor priming for LVF/RH trials.

2.1. Method

2.1.1. Participants

Participants were 64 (32 male) right-handed, native English speaking UCR undergraduates with normal or corrected-to-normal vision. None participated in the stimulus norming procedures described below. Participants received either course credit or pay ($7/hr).

2.1.2. Materials

Stimulus creation began with a pool of 200 ambiguous lexical metaphor words (e.g., BRIGHT and SPICY). A set of four sentences was generated for every ambiguous word, such that each appeared in both an ambiguous and unambiguous sentence context with a target word that either literally or metaphorically completed the sentence. Ambiguous sentences were constructed so that the exact meaning (i.e., literal or metaphoric) of the sentence, and hence of the lexical metaphor, would be unclear until the subsequent presentation of a lateralized target word (e.g., *We all really admired the* ***bright*** *COLORS/STUDENT*). Unambiguous sentences contained the same critical ambiguous word, but the context was altered such that the meaning of the sentence, and hence the lexical metaphor, was more clearly literally or metaphorically intended (*e.g., It's the building with the* ***bright*** *COLORS* vs *The teacher praised the* ***bright*** *STUDENT*). Sentence length was kept to 42 characters or less, with efforts made to keep ambiguous word position and sentence length similar across conditions.

To validate our stimulus construction, several norming experiments were conducted. First, written interpretations were collected from 44 participants, with every sentence from each set of four interpreted by 11 participants. Final experimental stimuli were generally selected if they were consistently literally or metaphorically interpreted by at least 73% of participants. Literal sentences were interpreted as such by 93% of participants on average, while 91% of participants consistently understood the metaphoric sentences. To compute cloze probabilities, another group of 30 participants were presented with incomplete sentences on a computer and asked to type in a single word that would be a sensible completion to the sentence. Final stimuli were generally selected if unambiguous contexts were completed by appropriate literal or metaphoric words by at least 70% of participants. Unambiguous literal sentences were completed by words indicating a literal understanding of the ambiguous word by a mean of 97% of participants, and metaphoric sentences were metaphorically completed by 89% of participants on average. Fifty-nine percent of completions to ambiguous sentences were literal, whereas only 31% of ambiguous sentences were metaphorically completed, reflecting the dominance of the literal sense of these ambiguous words. Unambiguous sentences were thus understood as being appropriately literally or metaphorically intended, and ambiguous contexts were indeed interpreted as being less constrained, although with a bias toward literal interpretations and completions. Sentences were generally of low or moderate constraint, and cloze probabilities for the experimental literal (22%) and metaphor targets (25%) were not significantly different, $t(284) = -0.80$, *ns*.

Table 2
Mean word length, familiarity, and imageability ratings for literal and metaphoric targets used in Experiment 1

Target	Length		Fam		Image	
	M	*SD*	*M*	*SD*	*M*	*SD*
Literal	5.08	(1.17)	5.35	(0.81)	5.74	(0.71)
Metaphor	5.31	(1.20)	5.27	(0.81)	4.43	(1.00)

On the basis of the norming results 144 sets of items were selected as experimental stimuli. Table 2 provides the mean rated familiarity, imageability, and length of the literal and metaphorically related target words used in the experiment. Familiarity and imageability ratings were obtained from a variety of databases (Altarriba et al., 1999; Bird, Framklin, & Howard, 2001; Chiarello, Liu, & Faust, 2001, 1999; Friendly, Franklin, Hoffman, & Rubin, 1982; Kacinik, Shears, & Chiarello, 2000; Wilson, 1988), or were collected from a group of 20 UCR undergraduates not participating in the experiment. Literal targets were significantly more imageable than metaphor targets,[1] $t(284) = 12.81$, $p < .0001$, but they did not differ in length, familiarity, and word class (i.e., all but one of the targets were nouns). Examples of sentence stimuli are provided in Appendix A.

Each participant saw both the literal and metaphoric targets for a given item, but with one target appearing in a related sentence condition in one visual field, while the other target was shown in the opposite visual field following an unrelated sentence prime. Every participant thus saw a total of 288 target words, which required the creation of four stimulus lists so that each literal and metaphoric target appeared in both types of sentence and relatedness conditions. Each list had two versions so that every target also appeared in each visual field across subjects. Thus, there were 18 critical items per visual field per condition per list.

An additional set of 144 filler sentences paired with non-word targets was also created. Non-words were orthographically legal and pronounceable letter strings created by altering a single letter from words not included in the stimulus list. They were matched to the word targets for length. In addition, so that the type of sentence prime could not be used to predict a word or non-word target, non-word sentences primes were designed to be of similar composition and length as the critical sentences. These 144 non-word targets were combined with the 288 critical stimulus pairs, resulting in a total of 432 experimental trials. Lastly, an additional list of 40 items, similar to the experimental stimuli, was also created for the practice list.

All stimuli were presented in black on a white background. Sentence primes were presented in lowercase

[1] As alluded to in Sections 1 and 2, the metaphoric sense of these words often develops by extending their dominant "literal" meaning to more abstract concepts like personality, relationships, and mental processes (Geiger & Ward, 1999; Gibbs, 1992; Lakoff, 1993). For this reason, it would be impossible to precisely match literal and metaphoric targets on imageability. We will discuss this issue further in Section 4.

18-point Helvetica font, with initial letter capitalized, while targets were displayed using uppercase 20-point Helvetica font. This resulted in target stimuli subtending 0.55° vertical visual angle and horizontal visual angles ranging from 1.25° to 4.00°.

2.1.3. Apparatus

Participants were tested individually in quiet dimly lit testing rooms. They were seated 60 cm in front of an Apple Vision 1710 monitor, with a head rest used to stabilize head position. Power Macintosh 7500/100 computers and the Psyscope software package (Cohen, Macwhinney, Flatt, & Provost, 1993) were used to control the presentation of stimuli, the timing of events, and record responses made by participants. The "0" and "." keys on the computer's numeric keypad were used to register their lexical decision responses with the index and middle fingers of their right hand. Half of the participants used the 0 key for their "word" response. This response mapping was reversed for the other half of the participants.

2.2. Design and procedure

The experiment consisted of a 2 × 2 × 2 × 2 repeated measures design examining sentence condition (ambiguous, unambiguous), target type (literal, metaphor), relatedness (related, unrelated), and visual field (right, left). Eight participants were run on each of the eight stimulus lists. They were tested in single sessions consisting of six experimental blocks of 72 trials each. The experimental blocks were preceded by 40 practice items. Each trial began with a central fixation cross for 500 ms, which was immediately followed and replaced by a centrally presented incomplete sentence. Sentences less than 30 characters were presented for 900 ms, sentences with 31–39 characters were presented for 1200 ms, and sentences with 40–42 characters were presented for 1400 ms. These durations were chosen based on previous work in our lab (Arambel & Chiarello, 2006) and pilot testing. Immediately after the sentence prime disappeared, a 450 ms flickering fixation cross sequence was initiated, with the last fixation cross remaining on the screen for 500 ms. Targets were presented for 150 ms at an eccentricity of 1.96°, 600 ms after the sentence disappeared. The fixation cross thus remained on the screen for 200 ms after the offset of the target.

Participants were told that the experiment was investigating how well people can process sentences and recognize things they are not directly looking at. They were instructed to read each sentence quickly to themselves and told that they would be asked some questions about the sentences after the experiment. Participants were also instructed to immediately fixate and keep their gaze focused on the plus sign as soon as it re-appeared and started flickering. Targets were randomly presented to the RVF or LVF, with the order of stimulus presentation randomized for each participant. Participants were instructed to decide whether each target was a word or non-word as quickly and accurately as possible. They were allowed 4000 ms to respond. The next trial began either 1000 ms after a response was made or the timeout interval had elapsed. After the experiment was complete, participants were given a questionnaire with 24 sentences from the experiment and 24 new sentences similar to those shown in the experiment. They were asked to mark an "X" next to the sentences they remembered seeing in the experiment. This memory test provided evidence that participants read the sentence primes. Mean hit rate was 80% and the mean false-alarm rate was 14%. The entire testing session lasted about 75 min.

2.3. Results

A 2 (ambiguous versus unambiguous context) × 2 (related versus unrelated sentence primes) × 2 (literal versus metaphor target) × 2 (RVF, LVF) repeated measures ANOVA was performed on both the reaction time (RT) and accuracy (% correct) data from word target trials. Analysis of the results was done for both participants ($F1$) and items ($F2$). If a particular RT exceeded that participant's mean RT for a given condition by more than 2.5 standard deviations it was trimmed to the value equal to ±2.5 standard deviations. The means for RT and accuracy can be found in Tables 3 and 4, respectively.

There was a main effect of visual field in both RT and accuracy, [$F1$ $(1, 63) = 11.11$, $MSE = 12{,}382$, $p < .01$; $F2$ $(1, 143) = 50.22$, $MSE = 12{,}367$, $p < .0001$; and $F1$ $(1, 63) = 10.14$, $MSE = 178$, $p < .01$; $F2(1, 143) = 44.12$, $MSE = 180$, $p < .0001$], respectively, indicating that targets were responded to more quickly and accurately when they were presented to the RVF/LH. In the $F1$ analyses, both the RT

Table 3
Experiment 1: Mean RTs and standard deviations for literal and metaphoric targets presented to the RVF and LVF in related and unrelated conditions for ambiguous and unambiguous context conditions

	Sentence context			
	Ambiguous		Unambiguous	
	M	*SD*	*M*	*SD*
Literal				
RVF/LH				
Related	706	(116)	693	(120)
Unrelated	730	(110)	744	(150)
Priming	24 ms		51 ms	
LVF/RH				
Related	735	(120)	717	(109)
Unrelated	769	(146)	761	(131)
Priming	34 ms		44 ms	
Metaphoric				
RVF/LH				
Related	718	(103)	703	(111)
Unrelated	751	(128)	747	(108)
Priming	33 ms		44 ms	
LVF/RH				
Related	742	(113)	715	(110)
Unrelated	773	(139)	766	(127)
Priming	31 ms		51 ms	

Table 4
Experiment 1: Mean percentage correct and standard deviation values for literal and metaphoric targets presented to the RVF and LVF in related and unrelated conditions for ambiguous and unambiguous context conditions

	Sentence context			
	Ambiguous		Unambiguous	
	M	*SD*	*M*	*SD*
Literal				
RVF/LH				
Related	94.5	(6.9)	96.2	(6.3)
Unrelated	91.7	(8.2)	92.7	(9.1)
Priming	2.8%		3.5%	
LVF/RH				
Related	92.5	(9.0)	94.0	(8.5)
Unrelated	89.8	(10.0)	89.2	(9.4)
Priming	2.7%		4.8%	
Metaphoric				
RVF/LH				
Related	93.7	(6.4)	95.4	(5.9)
Unrelated	90.8	(9.0)	90.9	(10.8)
Priming	2.9%		4.5%	
LVF/RH				
Related	90.1	(10.2)	92.3	(8.5)
Unrelated	87.6	(11.7)	89.1	(10.0)
Priming	2.5%		3.2%	

and accuracy analyses by participants showed that there was a main effect of target type, $F1(1, 63) = 4.24$, $MSE = 3159$, $p < .05$, and $F1(1, 63) = 16.37$, $MSE = 29$, $p < .0001$, demonstrating that literal targets were more rapidly and accurately responded to than metaphor targets. A main effect for relatedness was also found for both RT [$F1(1, 63) = 68.99$, $MSE = 5646$, $p < .0001$; $F2(1, 143) = 107.22$, $MSE = 14{,}460$, $p < .0001$] and accuracy [$F1(1, 63) = 39.98$, $MSE = 73$, $p < .0001$; $F2(1, 143) = 64.06$, $MSE = 197$, $p < .0001$], reflecting the fact that targets were facilitated following a related compared to an unrelated sentence prime. A significant main effect was also found for the sentence context condition in both RT [$F1(1, 63) = 7.67$, $MSE = 3{,}276$, $p < .01$; $F2(1, 143) = 6.33$, $MSE = 16{,}711$, $p < .05$] and accuracy [$F1(1, 63) = 8.86$, $MSE = 38$, $p < .01$; $F2(1, 143) = 8.31$, $MSE = 234$, $p < .005$], indicating that responses to targets were made more quickly and accurately following unambiguous compared to ambiguous contexts. There was a significant context condition by relatedness interaction in the RT data, however, [$F1(1, 63) = 8.23$, $MSE = 2262$, $p < .01$; $F2\ (1, 143) = 3.75$, $MSE = 19{,}942$, $p = .055$], which was only marginally significant in the accuracy data [$F1(1, 63) = 3.06$, $MSE = 34$, $p = .09$; $F2(1, 143) = 2.78$, $MSE = 173$, $p = .098$]. This interaction indicates that the magnitude of both literal and metaphor priming tended to be larger after the unambiguous (47 ms and 4%) compared to ambiguous sentence primes (31 ms and 2.7%). None of the other interactions were significant.

To investigate a priori hypotheses about the extent to which literal and metaphor priming would occur in each visual field after ambiguous versus unambiguous contexts, analyses were also conducted for the RVF and LVF separately. Results generally followed a similar pattern to the overall analysis. The relatedness by context condition interaction was significant for RT for both the RVF/LH [$F1(1, 63) = 5.16$, $MSE = 2280$, $p < .05$; $F2(1, 143) = 3.31$, $MSE = 15{,}423$, $p = .07$] and marginal in the LVF/RH [$F1\ (1, 63) = 3.53$, $MSE = 2022$, $p = .06$; $F2(1, 143) = 1.51$, $MSE = 16{,}926$, $p = .22$]. None of the other interactions were significant. In terms of the predictions, it is particularly important to note that the three-way target type by relatedness by context condition interaction was not significant in either visual field ($Fs < 1$) for either RT or accuracy. These findings indicate that both the literal and metaphor priming effects obtained in each visual field were statistically equivalent, although all priming effects tended to be larger following unambiguous compared to ambiguous sentence contexts (see Tables 3 and 4).

2.4. Discussion

Experiment 1 was designed to investigate hemisphere differences in comprehending ambiguous words with literal and metaphoric meanings when they occur in relatively more or less constrained sentence contexts. Lexical metaphors were presented in sentence contexts that were either ambiguous or biased towards a specific meaning. The LVF/RH results were generally as predicted: similar literal and metaphor priming effects were obtained with both ambiguous and unambiguous sentences, although the magnitude of priming was greater after unambiguous contexts. These results indicate that RH processing can derive benefit from both literal and figurative aspects of meaning, and provide further evidence that RH processes can maintain the activation of multiple meanings (Atchley et al., 1999; Burgess & Simpson, 1988; Faust & Chiarello, 1998a; Faust & Gernsbacher, 1996). In addition, the finding that priming effects increased from ambiguous to unambiguous sentences suggests that the RH has some sensitivity to sentence constraint, in accordance with previous claims (e.g., Chiarello et al., 2001; Coulson, Federmeier, Van Petten, & Kutas, 2005; Federmeier & Kutas, 1999; Liu, 2002). Because the unambiguous sentences were semantically “richer” these greater priming effects may be due to stronger semantic relations between the sentence and target words rather than message-level processes per se.

The occurrence of literal and metaphoric priming in the RVF/LH after unambiguous sentences also supported predictions that LH sentence processes would take advantage of sentence constraint to activate and select the most contextually consistent meaning, regardless of whether it was literal or figurative. RVF/LH priming was also found for both literal and metaphor targets after ambiguous sentences. Based on previous DVF studies (Anaki et al., 1998; Burgess & Simpson, 1988; Meyer & Peterson, 2000; Titone, 1998), it had been predicted that LH processing would default to the activation and selection of only dominant literal meanings when presented in ambiguous sentences. Hence, the occurrence of RVF/LH priming for metaphor targets after ambiguous contexts was unexpected.[2]

To account for this finding, it is important to note that the relation between the literal and figurative sense of lexical metaphors is not arbitrary because the metaphoric sense is generally extended from the literal meaning (Geiger & Ward, 1999; Lakoff, 1993; Rumelhart, 1993). This is in contrast to typical ambiguous words like BAT, whose meanings are mutually exclusive and therefore must engender competition because only a single meaning can be selected. Since the literal and figurative senses of a lexical metaphor are related, they may not need to compete for activation in the same way (Frisson & Pickering, 2001). Indeed, Frisson and Pickering (1999, 2001) suggest that the initial processing of such words may occur by activating a very general underspecified meaning that is compatible with all the senses. It should also be noted that, unlike some prior studies (e.g., Faust & Gernsbacher, 1996), the present stimuli were designed so that both literal and metaphor targets were always consistent with the ambiguous context. If the literal and metaphoric senses do not have to compete for activation because they share a common underspecified meaning, then as long as they do not become semantically incongruous with the context, the processor may not have to choose which sense to adopt (Frisson & Pickering, 1999, 2001). The current findings indicate that LH processes can maintain the activation of various related senses of a word, provided they are consistent with the sentence context. This is in contrast to non-metaphoric ambiguous words presented in ambiguous sentences, where the LH must select between distinct incompatible meanings and may default to the most dominant meaning (e.g., Meyer & Peterson, 2000; Titone, 1998).

In summary, contextual constraint, rather than meaning dominance, may be the critical factor determining hemisphere differences in literal versus metaphoric meaning activation in sentences. To confirm this, future studies should examine cerebral asymmetries for cases where the sentence-final target is unexpected or even contextually inconsistent (e.g., *She's much prettier without those* ***crooked*** *LAWYERS*, *Matt was cheated by those* ***crooked*** *TEETH*).

The activation of contextually appropriate versus contextually irrelevant aspects of meaning was explored in Experiment 2 using more complex 2-concept "an X is a Y" metaphors (e.g., *His girlfriend's face was a storm*). Although activating figurative aspects of word meaning is undoubtedly involved in the comprehension of such metaphoric expressions, they are assumed to additionally involve more complex conceptual blending and sentence integration processes (Bottini et al., 1994; Coulson & Matlock, 2001; Gentner & Wolff, 2000). There is some evidence indicating preferential involvement of the RH in such higher-level aspects of comprehension (e.g., Happe et al., 1999; Luo et al., 2003; Mason & Just, 2004; Robertson et al., 2000). However, others have argued that the RH is simply involved in the broad activation and maintenance of semantic representations, but the actual selection and integration required for complete comprehension must be done by LH processes (Beeman, 1998; Beeman et al., 2000). The goal of Experiment 2 was to evaluate these possibilities.

3. Experiment 2

The typical conceptualization of a "metaphor" is represented by multi-word metaphoric expressions like *her lawyer is a shark* which are often semantically anomalous if interpreted literally (Glucksberg & Keysar, 1993). Comprehension involves recognizing that one concept (a shark), is being used to illuminate an aspect of another "topic" concept (the lawyer). The similarity or analogy between these otherwise dissimilar domains must be inferred and mapped between these concepts in order to understand the phrase (i.e., since sharks are vicious and tenacious, her lawyer must also be vicious and tenacious). The process of comprehending these metaphors is also assumed to involve selecting and enhancing the activation of metaphorically relevant features, while suppressing those inappropriate for the metaphoric interpretation (Gernsbacher, Keysar, Robertson, & Werner, 2001; Glucksberg, Newsome, & Goldvarg, 2001). Interestingly, several researchers have noted that the juxtaposition of conceptual domains involved in interpreting these metaphors often entails a meaning that emerges from processing the metaphor as a whole, rather than from the comprehension of individual words (Coulson & Matlock, 2001; Gineste et al., 2000; Tourangeau & Rips, 1991). These metaphoric expressions thus differ from the lexical metaphors used in Experiment 1, where the figurative sense is part of that word's representation and whose comprehension generally occurs by directly activating the metaphoric meaning.

Sentential consistency and meaning selection were investigated in the current experiment by having *X is a Y* literal and metaphoric sentence primes paired with targets related to either the literal or metaphoric meaning in a fully crossed 2×2 design (i.e., *literal sentence—literal target*, *metaphor sentence—metaphor target*, *literal sentence—metaphor target*, and *metaphor sentence—literal target*). Table 5 provides examples of stimulus items across these different conditions. Sentential consistency refers to whether the target is consistent and contextually appropriate with the meaning of the sentence context as a whole (i.e., whether the target correctly represents the literal or metaphoric meaning of the entire sentence, such that a literal sentence followed by a literal target, and a metaphor sentence with a metaphor target are sententially consistent conditions, and the literal sentence—metaphor target and metaphor sentence—literal target represent the sententially inconsistent cases). Relatedness, on the other hand, refers to whether there is any sort of lexical-semantic relation between the target word

[2] We have since replicated this pattern of results in another experiment using a rapid serial visual presentation (RSVP) procedure.

and the critical concept(s) in the sentence (generally the metaphor vehicle or "Y" concept of the metaphoric sentence) even though that specific relation may not reflect the meaning of the sentence as a whole. For the example in Table 5, the target WILTED is related to the literal meaning of petals, but is sententially inconsistent with the meaning of petals in the metaphoric sentence "*Henry thought her eyes were* ***petals***." Similarly, the metaphor target LOVELY is consistent with and represents the meaning of petals in that metaphoric sentence, but is inconsistent with the meaning of petals in the literal sentence "*That plant keeps losing its* ***petals***." If meaning availability is broad and unconstrained, then one could observe priming for related targets following inconsistent sentences.

There were related and unrelated cases for all four of the sententially consistent and inconsistent conditions described above. Unrelated sentence prime and target pairs were obtained by re-pairing targets with completely unrelated sentence primes. Priming effects were computed by subtracting responses to related targets from unrelated targets. To preserve the orthogonal nature of the design, this was done separately for both sententially consistent or inconsistent sentence primes. However, it should be noted, as illustrated in Table 5, that the variable of sentential "consistency" does not really mean anything in relation to the unrelated sentence prime and targets, since all of these stimulus pairs are essentially unrelated. Predictions differed for the consistent and inconsistent sentences within each visual field.

3.1. LVF/RH

Priming was expected when literal targets followed consistent literal sentences. If the RH is preferentially involved in the higher-level processes assumed to be involved in understanding more complex metaphors, then the current experiment should demonstrate the strongest RH contribution to metaphoric processing. Hence, we predict priming for *sententially consistent* metaphor targets in the LVF/RH. Further, if RH processes are sensitive to a message-level representation of sentence meaning (e.g., Coulson et al., 2005; Federmeier & Kutas, 1999; Liu, 2002), then *sententially inconsistent* literal and metaphor targets should not be primed in the LVF/RH. Alternatively, if semantic activation in the RH is generally broad and unconstrained by sentence context, with multiple meanings active simultaneously, then priming would also be expected for sententially inconsistent, but "related" literal and metaphor targets.

3.2. RVF/LH

Priming was expected when literal targets followed consistent literal sentences. If the LH is not involved in higher level processing of more complex metaphors, then *sententially consistent* RVF/LH metaphor priming may not occur, or be smaller than the priming effect obtained for the LVF/RH. Alternatively, the findings from Experiment 1 suggest that LH sentence comprehension processes will facilitate the activation of metaphoric meaning and show significant priming for consistent metaphor targets in the RVF/LH. Further, if the LH can process sentences to select and maintain the activation of contextually relevant meanings, then neither inconsistent literal nor inconsistent metaphor targets should be primed in the RVF/LH. Indeed, it is possible that any sententially inconsistent literal and metaphoric aspects of meaning may even be suppressed to show an inhibitory (i.e., negative priming) effect (Gernsbacher et al., 2001).

3.3. Method

3.3.1. Participants

Participants consisted of 48 (24 male) right-handed, native English speaking UCR undergraduates with normal or corrected-to-normal vision. They were not involved in either norming study described below, nor in Experiment 1. Students participated for either 1 h of course credit and $3.00, or received $10.00.

3.3.2. Materials

Stimulus selection began by generating 210 metaphoric "an X is a Y" sentences. Some were taken from published studies (e.g., Blasko & Connine, 1993; Bottini et al., 1994; Camac & Glucksberg, 1984; Coulson & Matlock, 2001; Coulson & Van Petten, 2002; Goldvarg & Glucksberg, 1998; Katz, Paivio, Marschark, & Clark, 1988), and

Table 5
Examples of Experiment 2 stimulus items across the experimental conditions

Sententially consistent sentence primes and related targets	
Literal sentence—literal target	*That plant keeps losing its petals—WILTED*
Metaphor sentence—metaphor target	*Henry thought her eyes were petals—LOVELY*
Sententially inconsistent sentence primes and related targets	
Literal sentence—metaphor target	*That plant keeps losing its petals—LOVELY*
Metaphor sentence—literal target	*Henry thought her eyes were petals—WILTED*
Sententially "consistent" sentence primes and unrelated targets	
Literal sentence—literal target	*Vincent operates that bulldozer—WILTED*
Metaphor sentence—metaphor target	*The drunk customer was a bear—LOVELY*
Sententially "inconsistent" sentence primes and unrelated targets	
Literal sentence—metaphor target	*The racing team waited in the pit stop—LOVELY*
Metaphor sentence—literal target	*This morning the lake was a mirror—WILTED*

metaphor dictionaries (e.g., Miall, 1982; Palmatier, 1995; Palmatier & Ray, 1989; Sommer & Weiss, 1996), but most were created by the experimenter. A literal sentence was also generated for each metaphor item. For example, the literal sentence "*Tonight we may be able to see a* ***meteor***" was created to pair with the metaphoric sentence "*The drink you gave me was a* ***meteor***." Literal and metaphor sentences were designed to be similar in length and in the number of content and function words. Mean lengths for metaphor and literal sentences were 36.9 and 37.7 characters, respectively, and they did not differ significantly, $t(318) = -1.76$, $p = .08$ (two-tailed).

Target words related to the literal and metaphoric meaning of each sentence were also generated (e.g., COMET and POTENT, for the above sentences, respectively). Literal targets were selected to represent literal aspects of vehicle concepts incongruent with the meaning of the metaphor sentence. Similar attempts were made to have metaphor targets be inappropriate with the literal meaning, but this was not always possible because metaphoric meaning can arise from salient features of a concept's literal meaning. For example, the metaphor target AID is a central feature of the meaning of *crutch*, as in the metaphor *For some people alcohol is a crutch*, but it would also be related to literal uses of crutch, as in *Rob broke his leg and needed a crutch*.

Several norming experiments were conducted to validate our stimulus selection. First, written interpretations were collected for metaphoric sentences to assess whether metaphoric meaning would be consistently understood by most individuals. At least 25 participants wrote their interpretation of what each metaphoric sentence meant. The interpretations were grouped by conceptual similarity, so that the frequency of concepts in response to each sentence could be tallied. These interpretations were used to eliminate or modify some of the metaphoric sentences and targets.

Sentence–target relatedness ratings were then collected on the remaining set of 204 items which were split into four counter-balanced lists. Each list contained both literal and metaphor sentences and targets in similar conditions to those eventually used in the experiment. One of the targets was paired with a related sentence that was either sententially consistent (e.g., metaphor sentence—metaphor target or literal sentence—literal target) or inconsistent with the meaning of the target (e.g., metaphor sentence—literal target or literal sentence—metaphor target). The other target was paired with a completely unrelated sentence. See Table 5 (and Appendix A) for examples of stimuli across these different conditions. The relatedness ratings were collected from a different group of 48 participants (12 for each list), who were asked to decide (using a 5-point scale, 1 = not at all related and 5 = strongly related) the degree to which they thought the target word was related to the meaning of the sentence.

A 2 (consistent vs inconsistent sentence) × 2 (related vs unrelated) × 2 (literal vs metaphor target) repeated measures ANOVA of these ratings supported the suitability of these stimuli. There was a main effect of relatedness, $F(1, 47) = 1069.08$, $p < .0001$, indicating that related targets were rated higher (mean = 3.27) than unrelated targets (mean = 1.21). More importantly, however, relatedness was found to significantly interact with the kind of sentence context and target type, $F(1, 47) = 458.57$, $p < .0001$, demonstrating that literal and metaphor targets were deemed more highly related when they were consistent with the sentence context (4.17 and 4.27, respectively) than when they were inconsistent (2.55 and 2.57, respectively)—but note that metaphoric and literal targets were judged to be equally related. This interaction also indicated that although inconsistent targets were judged to be less related than contextually consistent stimuli, they were rated somewhat higher than completely unrelated items, $F(1, 47) = 329.18$, $p < .0001$. This result reflects the fact that participants may have noticed a relation between an inconsistent target and a lexical item(s) in the sentence, or that targets were still perceived to be related but this relation was weaker and more distant.

The final experimental set of 160 literal and metaphoric sentence prime–target pairs was generally selected if mean relatedness ratings were 3.5 or greater (out of 5). As shown in Table 6, both literal and metaphor targets were rated as being strongly related to their contextually consistent sentences, with metaphor targets slightly more related, $t(318) = -1.99$, $p = .05$. In addition, although metaphor targets were again significantly less imageable than literal targets, $t(318) = 12.85$, $p = .0001$, they did not differ in length or familiarity (see Table 6).

The final set of experimental stimuli consisted of 320 critical sentence primes and targets, organized into four lists with each literal and metaphoric target occurring in both types of sentence (consistent, inconsistent) and relatedness conditions (see Appendix A for examples). There were two versions of each list, so that every target appeared in both visual fields across subjects. Twenty critical items were thus shown per visual field per condition per list. These 320 stimuli were combined with an additional set of 160 literal and metaphoric filler sentences paired with non-word targets. Non-word targets were matched to word targets for length. Lastly, a similar set of 40 stimuli was created for the practice list.

3.3.3. Design and procedure

A 2 × 2 × 2 × 2 repeated measures design examining sentence condition (consistent, inconsistent), target type (literal, metaphor), relatedness (related, unrelated), and visual field (right, left) was used. Procedure was the same as for

Table 6
Mean relatedness ratings, word length, familiarity, and imageability ratings for literal and metaphoric targets used in Experiment 2

Target	Relatedness		Length		Fam		Image	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Literal	4.17	(0.44)	5.40	(1.21)	5.21	(0.86)	5.63	(0.72)
Metaphor	4.27	(0.46)	5.58	(1.17)	5.24	(0.85)	4.44	(0.93)

Experiment 1, with the following exceptions. Each of the six experimental blocks contained 80, rather than 72, trials. Sentences less than 30 characters were presented for 1000 ms, sentences with 31–39 characters were presented for 1400 ms, and sentences with 40–42 characters were presented for 1600 ms. These durations were based on pilot testing that indicated these sentence were slightly more difficult to read and understand than stimuli from Experiment 1. Stimuli were presented using Power Macintosh G4 computers and Apple flat-screen monitors. Results from the post-experiment memory test indicated that participants had again paid attention to and read the sentence primes, because the mean hit rate was 77% and the mean rate of false-alarms was 14%.

3.4. Results

A 2 (consistent versus inconsistent sentence) × 2 (related versus unrelated targets) × 2 (literal versus metaphor target) × 2 (RVF, LVF) repeated measures ANOVA was performed on both the RT and accuracy (% correct) data. Recall that sentential consistency refers to whether the target did (*literal sentence—literal target* and *metaphor sentence—metaphor target*) or did not appropriately represent (*literal sentence—metaphor target* and *metaphor sentence—* literal target) the meaning of the sentence context as a whole, whereas relatedness refers to whether there was any semantic relation between the critical word(s) in the sentence prime and target, even if that relation was sententially inconsistent.

The visual field main effect was significant in both RT and accuracy [$F1(1, 7) = 17.27$, $MSE = 19{,}863$, $p < .0001$; $F2(1, 159) = 70.76$, $MSE = 9866$, $p < .0001$; and $F1(1, 47) = 8.41$, $MSE = 276$, $p < .01$; $F2(1, 159) = 61.79$, $MSE = 125$, $p < .0001$], respectively, with RVF/LH targets responded to more quickly and accurately (741 ms, 92.2%) than those in the LVF/RH (783 ms, 88.7%). The relatedness main effect was also significant for both RT [$F1(1, 63) = 68.99$, $MSE = 5545$, $p < .0001$; $F2(1, 159) = 46.00$, $MSE = 12{,}739$, $p < .0001$] and accuracy [$F1(1, 63) = 39.98$, $MSE = 60$, $p < .0001$; $F2$ (1, 159) = 28.97, $MSE = 171$, $p < .0001$] with related targets processed more quickly and accurately (747 ms, 91.8%) than unrelated targets (777 ms, 89.1%). Both the RT and accuracy data also showed that there was a main effect of target type [$F1(1, 47) = 63.57$, $MSE = 3159$, $p < .0001$; $F2(1, 159) = 14.04$, $MSE = 55{,}772$, $p < .0005$; and $F1(1, 47) = 30.00$, $MSE = 52$, $p < .0001$; $F2(1, 159) = 11.33$, $MSE = 465$, $p = .001$], indicating that literal targets were more rapidly and accurately responded to (746 ms, 91.9%) than metaphor targets (778 ms, 89.0%).

These main effects, however, were qualified by several interactions. For accuracy, relatedness interacted with target type [$F1(1, 47) = 12.26$, $MSE = 30$, $p < .001$; $F2(1, 159) = 6.89$, $MSE = 176$, $p < .01$] such that semantic priming for literal targets (4.2%) was generally larger than for metaphor targets (1.4%). For RT, relatedness interacted with sentence context condition [$F1(1, 47) = 8.78$, $MSE = 2714$, $p < .01$; $F2(1, 159) = 7.55$, $MSE = 10{,}092$, $p < .01$] indicating that semantic priming for targets consistent with the sentence context was generally greater (41 ms) than for targets following inconsistent sentences (18 ms). The RT results also showed that target type interacted with visual field [$F1(1, 47) = 5.51$, $MSE = 2839$, $p < .05$; $F2(1, 159) = 6.97$, $MSE = 10{,}772$, $p < .01$]. A larger RVF advantage was obtained for literal targets (52 ms) than for metaphor targets (33 ms), regardless of whether targets were consistent with sentence primes. Most importantly, however, there was a significant four-way relatedness by sentence context condition by target type by visual field interaction for RT [$F1(1, 47) = 5.17$, $MSE = 2840$, $p < .05$; $F2(1, 159) = 3.24$, $MSE = 11{,}033$ $p = .074$]. Although this interaction was not obtained for accuracy, there was no evidence for a speed-accuracy tradeoff in the pattern of RT and accuracy means across conditions.

To test a priori predictions about the extent of literal and metaphor priming in each VF following consistent and inconsistent sentence contexts, and to explore the above four-way interaction, separate analyses were conducted on the RT results for each visual field.

For the RVF/LH, the only interaction found to be significant was relatedness by sentence context condition [$F1(1, 47) = 4.80$, $MSE = 3361$, $p < .05$; $F2(1, 159) = 3.55$, $MSE = 10{,}092$, $p = .061$], indicating that priming was larger when targets were consistent with the sentence (36 ms) compared to when they followed a contextually inconsistent sentence (10 ms), for both literal and metaphor targets. The RVF/LH priming results for both RT and accuracy are illustrated in Fig. 1. The 36 ms priming effect following consistent sentences was found to be significant, $F1(1, 47) = 28.17$, $MSE = 2214$, $p < .0001$, whereas the 10 ms priming effect for sententially inconsistent targets was not significant, $F1(1, 47) = 1.25$, $MSE = 3923$, *ns*, and not less than zero, suggesting inconsistent targets were not suppressed.

With respect to the LVF/RH, although the relatedness by sentence condition interaction was marginally significant [$F1(1, 47) = 3.23$, $MSE = 2575$, $p < .08$; $F2(1, 159) = 3.19$, $MSE = 12{,}718$, $p < .08$] these variables also interacted with target type, resulting in a significant three-way interaction, [$F1(1, 47) = 3.14$, $MSE = 5451$, $p = .083$; $F2(1, 159) = 5.81$, $MSE = 10{,}748$, $p < .05$]. When that interaction was further broken down by the type of target, relatedness was found to interact with sentence condition for metaphor [$F1(1, 47) = 5.62$, $MSE = 4388$, $p < .05$; $F2(1, 159) = 8.33$, $MSE = 12{,}234$, $p < .005$], but not literal targets, both $F1$ and $F2 < 1$. These results indicate that although there was less LVF/RH priming for metaphor targets following inconsistent literal sentences than consistent metaphor sentences, similar priming effects were obtained for literal targets regardless of whether they were presented after a consistent literal or inconsistent metaphor sentence. These LVF/RH RT and accuracy priming results are shown in Fig. 2. No other interactions were found to be significant in either the RT or accuracy results.

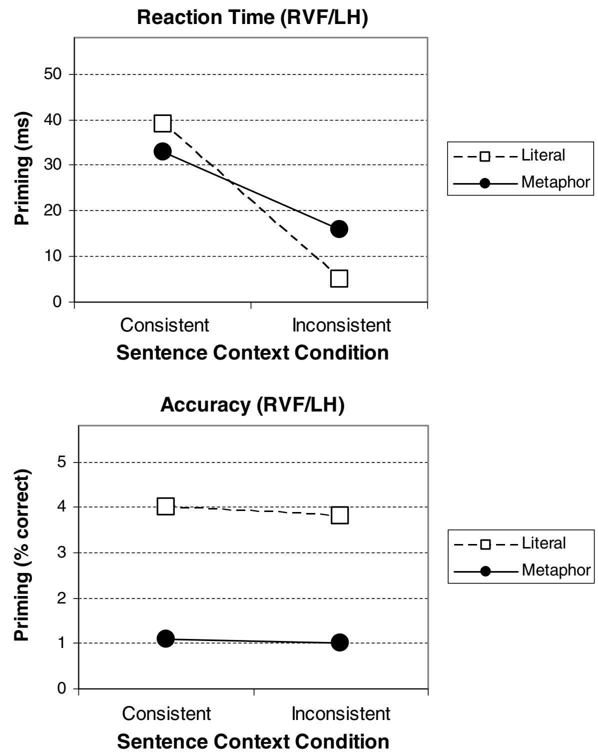

Fig. 1. Experiment 2: RT (ms) and accuracy (% correct) priming in the RVF/LH for literal and metaphor targets across each sentence context conditions.

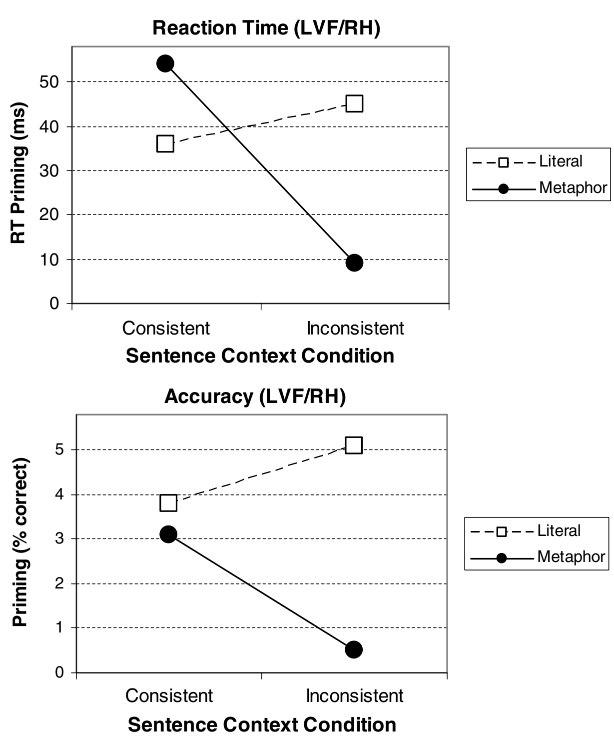

Fig. 2. Experiment 2: RT (ms) and accuracy (% correct) priming in the LVF/RH for literal and metaphor targets across each sentence context condition.

Finally, separate analyses were also performed for literal and metaphor targets in the sententially consistent conditions to test a priori predictions about whether literal and metaphor priming effects were similar in size for each visual field. Although the magnitude of LVF/RH priming for sententially consistent metaphor targets appears larger than the priming effect obtained in the RVF/LH, none of the relatedness by visual field interactions for either literal or metaphor targets were significant in either the RT or accuracy data, most Fs < or near 1. These results indicate that similar priming effects were obtained for both literal and metaphor targets in either visual field when they were consistent with the meaning of the sentence.

3.5. Discussion

Experiment 2 was conducted to examine cerebral asymmetries for interpreting more complex "an X is a Y" metaphoric expressions. Also of interest was investigating claims about each hemisphere's ability to select contextually appropriate aspects of meaning. Complete metaphoric and literal sentences were paired with targets related to the meaning of either the literal or metaphor sentence. The RVF/LH results were generally as predicted. Both literal and metaphor targets were significantly primed when they were sententially consistent. The occurrence of priming for sententially consistent literal targets had been expected and provides further support to many current theoretical claims of meaning activation and sentence processing in the LH (e.g., Beeman, 1998; Chiarello et al., 2001; Faust, 1998; Faust & Chiarello, 1998a, 1998b). Of greater interest is the finding that consistent metaphor targets also showed priming in the RVF/LH. This finding contradicts the notion of the RH as the preferred substrate for metaphor comprehension (e.g., Bottini et al., 1994; Kempler et al., 1999; Sabbagh, 1999), and indicates that along with understanding lexical metaphors (Experiment 1), LH processes can also support the conceptual selection and integration processes needed to understand more complex metaphoric expressions.

Also according to expectations, no RVF/LH priming was found for either literal or metaphor targets when they were sententially inappropriate, supporting claims that the LH is adept at processing sentence contexts to activate, select, and integrate only those aspects of meaning that are contextually relevant (Beeman, 1998; Beeman et al., 2000; Faust & Chiarello, 1998a). The current findings, along with those from Experiment 1, provide strong evidence for LH metaphor comprehension such that understanding literal and metaphor meaning seems to be accomplished by similar processes in the LH. Finally, it is worth noting that although this experiment indicates that LH processes are mainly responsible for meaning selection, the lack of an inhibitory effect for inconsistent targets does not support the claim that selection involves actively suppressing irrelevant information (Gernsbacher et al., 2001; Glucksberg et al., 2001).

The LVF/RH findings also generally followed predictions. Literal and metaphor targets showed similar priming when they were sententially *consistent*, and the magnitude of these priming effects was equivalent to the literal and metaphoric priming effects obtained in the RVF/LH for sententially congruent targets. These findings indicate that both hemispheres were able to benefit from the sentence context to activate the contextually appropriate meaning, regardless of whether the sentence was literal or figurative. Regarding the LVF/RH in particular, this experiment provides further evidence that the RH is involved in metaphor comprehension, and that this involvement generalizes to more complex "an X is a Y" metaphoric expressions. However, because the size of the priming effect for sententially consistent metaphor targets was similar to that of the LH, these findings argue against the notion that either hemisphere is considerably more involved in understanding multi-word metaphoric expressions.

In contrast to the sententially consistent conditions, a different pattern of results occurred for inconsistent targets in the LVF/RH. No priming was found for metaphor targets preceded by an inconsistent literal sentence, providing further support that the RH is sensitive to some aspects of sentence comprehension. This finding also demonstrates metaphoric meaning only emerges upon presentation of the metaphoric expression as a whole because literal sentences did not prime metaphor targets. Sententially inappropriate literal targets, on the other hand, were primed by inconsistent metaphor sentences, and this effect was equivalent to the priming obtained when these literal targets followed a consistent literal sentence. This indicates that RH sensitivity to sentence context does not result in an exact representation of sentence meaning because some contextually inappropriate literal aspects of meaning remained active in the RH.

Recall that the norming study showed that literal and metaphor targets were judged to be equally related to their inconsistent sentences (2.55 and 2.57, respectively). This finding was also confirmed with a computational way of assessing semantic relatedness, Latent Semantic Analysis (LSA, by Landauer & Dumais, 1997; Landauer, Foltz, & Laham, 1998). The LSA model is able to capture the semantic relationships between lexical items without taking into account syntax, grammatical structure, and word order. LSA cosines for sententially inconsistent literal (.264) and metaphor targets (.261) were statistically equivalent, $t(315) = -0.183$, *ns*. Hence there was no evidence for differences in the relation of literal and metaphor targets to the inconsistent sentences in either the LSA cosines or relatedness ratings. Thus, it seems unlikely that the discrepant priming results for inconsistent literal and metaphor targets were due to underlying differences in semantic relatedness.

Although the general relatedness of literal and metaphoric sentence primes and targets was controlled, it is possible that there were differences in how strongly literal and metaphor targets were related to individual lexical items, particularly the final words, in each sentence. This possibility can't be ruled out entirely, but it is unlikely because substantial differences between the relational strength of literal and metaphor targets to individual words in the sentences would probably also have been reflected in the sentence-target relatedness norms that we did collect. The reason we chose to focus on and obtain relatedness ratings between targets and the meaning of the sentence, rather than individual words, was based on other data demonstrating that lexical priming effects (i.e., single word prime and target) do not generalize to sentence priming situations with those stimuli, even in relatively minimal and ambiguous sentence contexts (Kacinik, 2003).

Therefore, the main conclusion that should be drawn from these findings is that during the processing of metaphor sentences, RH-initiated processing broadly activates and maintains the literal meaning of words in the sentence, even once the metaphoric interpretation has been achieved and they are no longer relevant. A potential explanation is that metaphors span and merge two very different conceptual domains (e.g., face and storm, as in *His girlfriend's face was a storm*). Integrating the meaning of these concepts so that the metaphor can be understood does not simply entail transferring a single or even several features, but involves re-structuring the entire semantic space so that the metaphoric meaning emerges from this altered conceptual space (Coulson & Matlock, 2001; see Coulson & Van Petten, 2000 & Kintsch, 2000, for empirical demonstrations). Broadly activating both literal and figurative aspects of meaning for each concept are most likely essential to this process. Literal sentences, in contrast, generally consist of more closely related concepts (e.g., ship and storm, as in *The ship was headed toward a storm*) and probably do not require such extensive conceptual semantic activation and integration processes. Although both hemispheres appear to be involved in the semantic mapping and re-structuring processes required in metaphor comprehension, the exact manner by which each hemisphere contributes to this process remains to be specified. However, on the basis of the current findings, it is clear that RH involvement in these metaphoric conceptual blending processes results in the maintenance of literal aspects of meaning after they are no longer active in the LH, even when they are inconsistent with the sentence context. While this could simply be a consequence of less precise RH sentence processing and poorer selection abilities (Arambel & Chiarello, 2006; Beeman, 1998; Chiarello, 2003), it might also be advantageous in situations requiring the revision of an initial interpretation (Beeman, 1998; Chiarello, 2003; Coulson & Williams, 2005). Thus, the RH may be crucial in situations where a metaphor was initially understood in one way, but subsequent context indicated this as being incorrect, and necessitating the formation of an alternate interpretation.

These results also provide additional evidence that the most crucial aspect of RH processing for metaphor comprehension is not a broad activation of word meaning per se, since the scope of available meanings was found to depend on the preceding sentence context. For literal sentences, in particular, meaning activation is more focused and limited to literal aspects of meaning, whereas if the expression is a metaphor both literal and metaphoric aspects of meaning are activated and maintained during LVF/RH trials even when they are sententially inappropriate.

4. General discussion

The present study systematically investigated the extent to which each hemisphere is typically involved in understanding metaphors of increasing linguistic complexity. Experiment 1 found similar literal and metaphoric meaning activation of lexical metaphors across both VFs/hemispheres following supportive sentence contexts, even if the context was ambiguous, although priming effects were generally larger after unambiguous sentences. One argument could be that the lack of hemispheric differences for literal and metaphoric meaning activation found in Experiment 1 represents a null result. Experiment 2 used a similar paradigm to investigate more complex metaphors and replicated the finding that literal and metaphoric meanings were activated bilaterally if they were sententially consistent. However, an interesting cerebral asymmetry also occurred in Experiment 2 because, in contrast to the RVF/LH, the LVF/RH maintained the activation of sententially inappropriate literal aspects of meaning after metaphoric sentences. Hence it is highly unlikely that the bilateral priming of Experiment 1 can be attributed to the failure to demonstrate a true lateralized effect.

According to most previous claims, it had been predicted that processing metaphoric meaning would be difficult for RVF/LH presentations, particularly in ambiguous contexts, whereas for LVF/RH presentations semantic activation had been expected to be generally broad and unconstrained by sentence context. Results did not entirely support these predictions because metaphoric meaning remained active for RVF/LH trials even after ambiguous contexts. With regard to RH processes, although there was evidence for sustained broader meaning activation, the LVF/RH also showed some sensitivity to contextual constraint. An interesting issue for future research will be to determine exactly which aspects of sentence context can affect RH processing, and how much context is necessary to facilitate RH metaphor comprehension. For instance, would multi-word primes similar to those used in Beeman et al. (1994) summation priming studies, be sufficient to cause metaphor priming, or must the metaphor be expressed in a relatively "normal" sentence context to produce priming?

Although the type of sentence context significantly affected the degree of literal and metaphoric meaning activation in each hemisphere, the most striking and unexpected outcome from this investigation was the remarkable similarity of literal and metaphor priming effects in both hemispheres, particularly when the meaning was contextually consistent. Indeed, across the entire study the only condition showing a difference was in Experiment 2, where no RVF/LH priming occurred for inconsistent targets, but inappropriate literal aspects of meaning remained active in the LVF/RH after metaphoric sentences. Hence, these results support only in part the claims from Fine-Coarse Coding theory (Beeman, 1998; Beeman et al., 2000) and other investigators (Arambel & Chiarello, 2006; Chiarello, 2003; Faust & Gernsbacher, 1996) that RH processes activate meaning more broadly, and that the LH appears to be primarily responsible for processing sentence constraints to select and integrate only contextually appropriate aspects of meaning.

Prior to discussing the implications of these findings in more detail, we first consider some important issues that may challenge our interpretation of the results. First, metaphor targets in both experiments were significantly less imageable than the literal targets (see Tables 2 and 6). It is our contention that this imageability difference stems from the basic nature of literal and metaphoric meaning (see Footnote 1), and that it would be impossible to match a large set of items on imageability. The literal and metaphoric expressions used in the fMRI study of Rapp et al. (2004) also differed in imageability, but they did not find corresponding activation in regions like the precuneus, traditionally thought to be involved in imagery. However, there are indications that the RH may be relatively disadvantaged for processing low imageable words (Bub & Lewine, 1988; Day, 1979, but see Kacinik & Chiarello, 2003), and a recent ERP study of comparable stimuli has shown that the brain may process metaphoric and abstract meaning in a similar manner (Lovett & Coulson, 2002). To investigate this possibility in the present study, the imageability of each target word was correlated with that item's average RT and accuracy priming effects for each visual field in each sentence context condition. Many of the correlations were close to 0, with r values ranging from .252 to .009. Considering the general weakness of these correlations, along with the fact that most conditions did not show visual field differences for literal and metaphor targets, it seems doubtful that the current results were affected by the imageability difference between the literal and metaphor targets.

The second issue deals with the stimulus presentation procedure used in the present study. Primes were centrally presented to both hemispheres with enough time for information to be transferred between the hemispheres before presentation of the lateralized target. Since many of the priming conditions failed to show cerebral asymmetries, it is possible that this procedure obscured potential differences between left and right hemispheric sentence processing. However, this is unlikely because the same presentation procedure was used in many previous studies that have found asymmetrical priming for targets presented to the LVF/RH and RVF/LH following various sentence contexts (e.g., Arambel & Chiarello, 2006; Faust & Chiarello, 1998a, 1998b; Meyer & Peterson, 2000; Titone, 1998). Moreover, recent research where ERPs were recorded to laterally presented targets after central sentence primes provides converging evidence that both hemispheres are involved in sentence processing, with lateralized target words successfully shifting the balance of processing more heavily to the contralateral hemisphere (see Coulson et al., 2005; Coulson & Williams, 2005; Federmeier & Kutas, 1999 for more thorough discussion). Hence, central presentation of sentence primes should not eliminate the possibility of obtaining asymmetrical priming such as that observed in Experiment 2.

Finally, although the current results are generally in accordance with prior research that has not supported the RH as the preferred substrate for metaphor comprehension (Coulson & Van Petten, 2000; Faust & Weisper, 2000; Lee & Dapretto, 2003; Rapp et al., 2004), the present study was limited to relatively simple and familiar verbal metaphors in a priming paradigm and lexical decision task. Some recent research has indicated that RH processes may be more important for understanding very unfamiliar and more complex metaphors (Bottini et al., 2007; Mashal et al., 2005; Schmidt, DeBuse, & Seger, 2007). It is also possible that greater RH involvement would occur with pictorial stimuli (Rinaldi, Marangolo, & Baldassarri, 2004; Winner & Gardner, 1977), with other figurative forms (Coulson & Williams, 2005; Kempler et al., 1999; Van Lancker, 1990), and in more naturalistic discourse situations involving higher-level inferences and pragmatic processing (Brownell, Gardner, Prather, & Martino, 1995; Sabbagh, 1999). Regardless of these limitations, the main strength of the present investigation involved the systematic study of normal participants with a large, carefully designed, and normed set of stimuli using the same basic paradigm. The findings from the current study will now be used to more thoroughly discuss the manner in which each hemisphere is sensitive to the meaning of literal and metaphoric sentences.

4.1. RVF/LH processing

One aim of this research was investigating the extent to which LH processes are involved in understanding metaphoric meaning in relatively natural sentence contexts. It was shown that although the RVF/LH ultimately selects and integrates only sententially appropriate aspects of meaning, a broad range of meanings (literal, figurative) was also maintained as long as the meanings remained consistent with the sentence context. It has been claimed that the LH language processor operates to develop the most immediately accurate representation of meaning (Arambel & Chiarello, 2006; Beeman, 1998; Chiarello et al., 2001). To this end, LH processes are proposed to take advantage of top-down processing and constraints from linguistic (i.e., semantic, grammatical, and syntactic) and real world knowledge domains to select and integrate only contextually consistent meanings (Arambel & Chiarello, 2006; Chiarello et al., 2001; Faust, 1998; Federmeier & Kutas, 1999). Since the present study indicates that RVF/LH sentence comprehension processes treat literal and metaphoric meaning in a comparable manner, LH processing of these constraints is claimed to be fundamentally similar, regardless of the literal or figurative contents of the sentence and how those concepts may interact and blend together. This may explain why RVF/LH metaphor priming was so reliable across experiments, even with ambiguous contexts. If the LH is as successful at using all constraints to process literal and metaphoric meaning, as currently suggested, this would predict that a context would have to "garden-path" LH processing away from a given meaning for any comprehension difficulties to occur. This may explain why ambiguous contexts were not sufficient to cause difficulties with LH activation of metaphoric meanings.

4.2. LVF/RH processing

The main purpose of this study was determining whether RH processes are preferentially involved in metaphor comprehension, and the extent to which the RH's contribution involves higher levels of language processing, or is simply due to broader and more sustained semantic activation processes. The issue of "preferential RH metaphor comprehension" could imply that RH processes are more important than those of the LH for understanding metaphors, or alternatively, it could imply that the RH is more involved in processing metaphors than literal language. In all but one condition of the present study, literal and metaphor priming effects in the RH were similar in magnitude and equivalent to the priming of literal and metaphor targets in the LH. Hence, no matter how one considers the question of "preferential RH involvement," this investigation does not support the hypothesis of the RH being the generally preferred substrate for understanding metaphors.

However, the one condition that showed divergent results across VFs may provide an indication of potential differences in the underlying processing mechanisms by which the RH and LH comprehend metaphoric meaning. Since sententially inappropriate literal targets were primed in the LVF/RH after a metaphor sentence, RH processing of a metaphoric expression may be different from that of a literal sentence, and also from LH processing of metaphor. Compared to literal sentences, which generally do not involve the integration of very different conceptual domains, metaphor comprehension is a more complex process where it is less evident which aspects of meaning will ultimately be relevant for the interpretation. For example, *That actress is a flamingo* could have a variety of interpretations (e.g., she was FLASHY, SKINNY, had LONG LEGS, wore lots of PINK), all of which are compatible with different features of a "flamingo." It is therefore likely that all literal and figurative aspects of meaning will remain broadly active during metaphor processing only in the RH.

Hence, RH processing may be unique in maintaining the activation of these meanings even if they are no longer consistent with the sentence. We claim that these processes are similar to those responsible for the ability to maintain the activation of semantically related words even when they are grammatically incorrect (Arambel & Chiarello, 2006), preceded by non-sensical or scrambled sentences (Faust, Babkoff, & Kravetz, 1995; Faust & Chiarello, 1998b), contextually inappropriate (Faust &

Gernsbacher, 1996), or redundant in the context of a consistent sentence (Coulson et al., 2005). The current findings thus appear to be another indication that the RH can maintain various possible interpretations depending on the word meanings in the sentence, rather than a single coherent representation of the sentence meaning as a whole (Chiarello, 2003). This likely results from RH difficulty with selecting only contextually appropriate meanings and/or suppressing those that are irrelevant (Arambel & Chiarello, 2006; Faust & Chiarello, 1998a; Faust & Gernsbacher, 1996). An intriguing possibility is that this sustained activation of inconsistent meanings may also serve a useful purpose, by acting as a safety net or backup system in the event that the interpretation of an expression needs to be revised (see Burgess & Chiarello, 1996; Chiarello, 2003; Chiarello et al., 2001; Faust & Chiarello, 1998a, for similar proposals). This is possible because exactly which features are important may not be immediately apparent during metaphor comprehension, and may even change as the discourse context unfolds.

In conclusion, this study was aimed at determining whether the RH is preferentially involved in metaphor comprehension, and specifying the extent of LH involvement in understanding metaphors. The LH and RH were found to be generally similar in their access to metaphoric meaning if it was supported by the sentence context. For this reason, there is not enough evidence to conclude that the RH is the preferred neural substrate for comprehending metaphors. Rather, both hemispheres clearly may be involved, although the specific processes underlying their contribution(s) to metaphor comprehension remain to be specified. However, because the RH did not discard the irrelevant literal aspects of meaning of more complex metaphoric expressions, RH processing may be preferentially involved in cases where an initial interpretation needs to be modified.

Appendix A

Context condition	Target type	Sentence prime	Target word
Examples of stimuli from Experiment 1 (the complete list of stimuli from both experiments is available from the first author)			
Ambiguous	Literal	Janine really liked Mary's **sweet**	DESSERT
Ambiguous	Metaphor	Janine really liked Mary's **sweet**	MANNER
Unambiguous	Literal	The guests wanted more of the **sweet**	DESSERT
Unambiguous	Metaphor	The boss liked his employee's **sweet**	MANNER
Ambiguous	Literal	You must do something about that **spoiled**	MILK
Ambiguous	Metaphor	You must do something about that **spoiled**	BOY
Unambiguous	Literal	Clean your fridge and toss the **spoiled**	MILK
Unambiguous	Metaphor	The nanny couldn't control the **spoiled**	BOY
Ambiguous	Literal	It's so nice to be around such a **warm**	FIRE
Ambiguous	Metaphor	It's so nice to be around such a **warm**	PERSON
Unambiguous	Literal	The campers gathered around the **warm**	FIR
Unambiguous	Metaphor	I've always thought Karen was a **warm**	PERSON
Ambiguous	Literal	We could barely endure that **dry**	SUMMER
Ambiguous	Metaphor	We could barely endure that **dry**	SPEECH
Unambiguous	Literal	The farmer worried about the **dry**	SUMMER
Unambiguous	Metaphor	The senator gave a surprisingly **dry**	SPEECH
Ambiguous	Literal	The group closely monitored the **soaring**	EAGLE
Ambiguous	Metaphor	The group closely monitored the **soaring**	PRICES
Unambiguous	Literal	The small squirrel hid from the **soaring**	EAGLE
Unambiguous	Metaphor	The shopper couldn't afford the **soaring**	PRICES
Ambiguous	Literal	Kate's lucky that she quickly **grasped** the	RAILING
Ambiguous	Metaphor	Kate's lucky that she quickly **grasped** the	TOPIC
Unambiguous	Literal	I would have fallen had I not **grasped** the	RAILING
Unambiguous	Metaphor	The students have finally **grasped** the new	TOPIC
Ambiguous	Literal	Roberta was really upset about the **sick**	PATIENT
Ambiguous	Metaphor	Roberta was really upset about the **sick**	JOKE
Unambiguous	Literal	There's a new nurse treating that **sick**	PATIENT
Unambiguous	Metaphor	He really hurt my feelings with that **sick**	JOKE
Ambiguous	Literal	Grandma always complains about her **foggy**	CLIMATE
Ambiguous	Metaphor	Grandma always complains about her **foggy**	MEMORY
Unambiguous	Literal	Regions on the coast tend to have a **foggy**	CLIMATE
Unambiguous	Metaphor	Much of my childhood is only a **foggy**	MEMORY
Ambiguous	Literal	Harry says they plan to **launch** another	MISSILE
Ambiguous	Metaphor	Harry says they plan to **launch** another	PRODUCT
Unambiguous	Literal	The navy was ordered to **launch** the new	MISSILE
Unambiguous	Metaphor	The whole office helped to **launch** this new	PRODUCT

Appendix A (*continued*)

Metaphor sentence	Metaphor target	Literal sentence	Literal target
Examples of stimuli from Experiment 2			
Their math professor is a fossil	OLD	The explorer discovered a fossil	BONE
I'm sorry that meeting was a marathon	TEDIOUS	He is seriously training for a marathon	RACE
Those poor workers are sheep	OBEY	The farmer tried to gather the sheep	HERD
That teacher's class is a sedative	BORING	The patient was told to take a sedative	DRUG
Unfortunately his attitude is a cancer	HARMFUL	The test revealed evidence of a cancer	DISEASE
The train I take to work is a bullet	RAPID	Buried in his chest was a bullet	KILLED
The drink you gave me was a meteor	POTENT	Tonight we may be able to see a meteor	COMET
The problem they face is a cactus	TOUGH	The only thing growing there is cactus	DESERT
The patient in that bed is a ghost	PALE	They believe this inn has a ghost	HAUNTED
The new student's mind is a sponge	EAGER	That grime will need a better sponge	CLEAN
The farmer thought the city was a hive	BUSY	That honey is straight out of a hive	BEE
That political candidate is a pit bull	FIERCE	On our walk yesterday we saw a pit bull	DOG
During the ordeal his wife was his anchor	SUPPORT	In that bay they decided to drop anchor	BOAT
Up in the sky, the clouds were cotton	FLUFFY	My new pajamas are made of cotton	FABRIC
His girlfriend's face was a storm	ANGRY	The ship was headed toward a storm	CLOUDS
The swimmer was a torpedo	FAST	The submarine fired a torpedo	WEAPON
Our professor is an encyclopedia	SMART	There's an explanation in the encyclopedia	BOOK
The tree in the park is an umbrella	SHADY	It's cloudy so take an umbrella	RAIN
The saleswoman's smile was sunshine	CHEERY	Yesterday we laid out in the sunshine	TANNING
My old coach was granite	STRICT	This cliff consists of solid granite	ROCK
The nurse's touch was medicine	SOOTHES	The doctor prescribed some medicine	PILLS
This morning the lake was a mirror	CALM	I accidentally dropped the mirror	SHATTER
Kim's fiancee's shoulder was a pillow	COMFORT	The maid placed a mint on the pillow	BED
The office rumor was a disease	SPREAD	A virus is the cause of Norm's disease	ILLNESS
The drunk customer was a bear	VIOLENT	The zookeeper was struck by the bear	CLAWED
Vanessa felt her skin was sandpaper	DRY	The varnish was polished with sandpaper	SMOOTH
This afternoon the mood was vinegar	BITTER	I think the salad needs some more vinegar	TASTED
The account James landed was a homerun	TRIUMPH	We tied the game with that homerun	BALL
This morning the streets were oil	SLICK	The fish was fried in oil	COOK
Ken looked outside and saw the sky was ash	GLOOMY	After the fire, all that remained was ash	BURNED

References

Abkarian, G. G., Jones, A., & West, G. (1992). Young children's idiom comprehension: Trying to get the picture. *Journal of Speech and Hearing Research, 35*, 580–587.

Altarriba, J., Bauer, L. M., & Benvenuto, C. (1999). Concreteness, context availability, and imageability ratings and word associations for abstract, concrete, and emotion words. *Behavior Research Methods, Instruments and Computers, 31*, 578–602.

Anaki, D., Faust, M., & Kravetz, S. (1998). Cerebral hemispheric asymmetries in processing lexical metaphors. *Neuropsychologia, 36*, 350–353.

Arambel, S.R., Chiarello, C. (2006). Priming nouns and verbs: Differential influences of semantic and grammatical cues in the two cerebral hemispheres. *Brain and Language, 97*, 12–24.

Atchley, R. A., Burgess, C., & Keeney, M. (1999). The effect of time course and context on the facilitation of semantic features in the cerebral hemispheres. *Neuropsychology, 13*, 389–403.

Beeman, M. (1993). Semantic processing in the right hemisphere may contribute to drawing inferences from discourse. *Brain and Language, 44*, 80–120.

Beeman, M. (1998). Coarse semantic coding and discourse comprehension. In M. Beeman & C. Chiarello (Eds.), *Right hemisphere language comprehension: Perspectives from cognitive neuroscience* (pp. 255–284). Mahwah, NJ: Erlbaum.

Beeman, M. J., Bowden, E. M., & Gernsbacher, M. A. (2000). Right and left hemisphere cooperation for drawing predictive and coherence inferences during normal story comprehension. *Brain and Language, 71*, 310–336.

Beeman, M., & Chiarello, C. (1998). *Right hemisphere language comprehension: Perspectives from cognitive neuroscience*. Mahwah, NJ: Erlbaum.

Beeman, M., Friedman, R., Grafman, J., Perez, E., Diamond, S., & Lindsay, M. (1994). Summation priming and coarse semantic coding in the right hemisphere. *Journal of Cognitive Neuroscience, 6*, 26–45.

Bird, H., Framklin, S., & Howard, D. (2001). Age of acquisition and imageability ratings for a large set of words, including verbs and function words. *Behavior Research Methods, Instruments and Computers, 33*, 73–79.

Blasko, D. G., & Connine, C. M. (1993). Effects of familiarity and aptness on metaphor processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*, 295–308.

Bottini, G., Corcoran, R., Sterzi, R., Paulesu, E., Schenone, P., Scarpa, P., et al. (1994). The role of the right hemisphere in the interpretation of figurative aspects of language: A positron emission tomography activation study. *Brain, 117*, 1241–1253.

Brownell, H. (2000). Right hemisphere contributions to understanding lexical connotation and metaphor. In Y. Grodzinsky, L. P. Shapiro, & D. Swinney (Eds.), *Language and the brain: Representation and processing* (pp. 185–201). San Diego, CA: Academic Press.

Brownell, H. H., Potter, H. H., Bihrle, A. M., & Gardner, H. (1984). Sensitivity to lexical denotation and connotation in brain-damaged patients: A double dissociation? *Brain and Language, 22*, 253–265.

Brownell, H. H., Simpson, T. L., Bihrle, A. M., Potter, H. H., & Gardner, H. (1990). Appreciation of metaphoric alternative word meanings by left and right brain-damaged patients. *Neuropsychologia, 28*, 375–383.

Brownell, H. H., Gardner, H., Prather, P., & Martino, G. (1995). Language, communication, and the right hemisphere. In H. S. Kirshner (Ed.), *Handbook of neurological speech and language disorders. Neurological disease and therapy* (Vol. 33, pp. 325–349). New York, NY: Marcel Dekker.

Bub, D., & Lewine, J. (1988). Different modes of word recognition in the left and right visual fields. *Brain and Language, 33*, 161–188.

Burgess, C., & Chiarello, C. (1996). Neurocognitive mechanisms underlying metaphor comprehension and other figurative language. *Metaphor and Symbolic Activityic Activity, 11*, 67–84.

Burgess, C., & Simpson, G. B. (1988). Cerebral hemispheric mechanisms in the retrieval of ambiguous word meanings. *Brain and Language, 33*, 86–104.

Camac, M. K., & Glucksberg, S. (1984). Metaphors do not use associations between concepts, they are used to create them. *Journal of Psycholinguistic Research, 13*, 443–455.

Caramazza, A., & Hillis, A. E. (1990). Spatial representation of words in the brain implied by studies of a unilateral neglect patient. *Nature, 346*, 267–269.

Chiarello, C. (2003). Parallel systems for processing language: Hemispheric complementarity in the normal brain. In M. T. Banich & M. Mack (Eds.), *Mind, brain, and language: Multidisciplinary perspectives* (pp. 229–250). Mahwah, NJ: Erlbaum.

Chiarello, C., Liu, S., & Faust, M. (2001). Bihemispheric sensitivity to sentence anomaly. *Neuropsychologia, 39*, 1451–1463.

Chiarello, C., Shears, C., & Lund, K. (1999). Imageability and distributional typicality measures of nouns and verbs in contemporary English. *Behavior Research Methods, Instruments and Computers, 31*, 603–637.

Cohen, J. D., Macwhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavioral Research Methods, Instruments, & Computers, 25*, 257–271.

Collins, M. (1999). Differences in semantic category priming in the left and right cerebral hemispheres under automatic and controlled priming conditions. *Neuropsychologia, 37*, 1071–1088.

Coulson, S., Federmeier, K. D., Van Petten, C., & Kutas, M. (2005). Right hemisphere sensitivity to word- and sentence-level context: Evidence from event-related brain potentials. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31*, 129–147.

Coulson, S., & Matlock, T. (2001). Metaphor and the space structuring model. *Metaphor and Symbolic Activity, 16*, 295–316.

Coulson, S., & Van Petten, C. (2000). *ERPs to parafoveally presented metaphors: The role of the right hemisphere*. Poster presented at the 7th annual meeting of the Cognitive Neuroscience Society, San Francisco.

Coulson, S., & Van Petten, C. (2002). Conceptual integration and metaphor: An ERP study. *Memory and Cognition, 30*, 958–968.

Coulson, S., & Williams, R. F. (2005). Hemispheric asymmetries and joke comprehension. *Neuropsychologia, 43*, 128–141.

Day, J. (1979). Visual half-field recognition as a function of syntactic class and imageability. *Neuropsychologia, 17*, 515–520.

Faust, M. (1998). Obtaining evidence of language comprehension from sentence priming. In M. Beeman & C. Chiarello (Eds.), *Right hemisphere language comprehension: Perspectives from cognitive neuroscience* (pp. 161–182). Mahwah, NJ: Erlbaum.

Faust, M., Babkoff, H., & Kravetz, S. (1995). Linguistic processes in the two cerebral hemispheres: Implications for modularity vs interactionism. *Journal of Clinical and Experimental Neuropsychology, 17*, 171–192.

Faust, M., & Chiarello, C. (1998a). Lexical ambiguity resolution by the two hemispheres. *Neuropsychologia, 36*, 827–836.

Faust, M., & Chiarello, C. (1998b). Constraints on sentence priming in the cerebral hemispheres: Effects of intervening words in sentences and lists. *Brain and Language, 63*, 219–236.

Faust, M. E., & Gernsbacher, M. A. (1996). Cerebral mechanisms for suppression of inappropriate information during sentence comprehension. *Brain and Language, 53*, 234–259.

Faust, M., & Kravetz, S. (1998). Levels of sentence constraint and lexical decision in the two hemispheres. *Brain and Language, 62*, 149–162.

Faust, M., & Weisper, S. (2000). Understanding metaphoric sentences in the two cerebral hemispheres. *Brain and Cognition, 43*, 186–191.

Federmeier, K. D., & Kutas, M. (1999). Right words and left words: Electrophysiological evidence for hemispheric differences. *Cognitive Brain Research, 8*, 373–392.

Friendly, M., Franklin, P. E., Hoffman, D., & Rubin, D. C. (1982). The Toronto Word Pool: Norms for imagery, concreteness, orthographic variables, and grammatical usage for 1080 words. *Behavior Research Methods and Instrumentation, 14*, 375–399.

Frisson, S., & Pickering, M. J. (1999). The processing of metonymy: Evidence from eye movements. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*, 1366–1383.

Frisson, S., & Pickering, M. J. (2001). Obtaining a figurative interpretation of a word: Support for underspecification. *Metaphor and Symbolic Activity, 16*, 149–171.

Gagnon, L., Goulet, P., Giroux, F., & Joanette, Y. (2003). Processing of metaphoric and non-metaphoric alternative meanings of words after right- and left-hemispheric lesion. *Brain and Language, 87*, 217–226.

Geiger, O., & Ward, L. M. (1999). Metaphors and the mental lexicon. *Brain and Cognition, 68*, 192–198.

Gentner, D. (1989). The mechanisms of analogical learning. In S. Vosniadou & A. Ortony (Eds.), *Similarity and analogical reasoning* (pp. 199–241). New York, NY: Cambridge University Press.

Gentner, D., Bowdle, B. F., Wolff, P., & Boronat, C. (2001). Metaphor is like analogy. In D. Gentner, K. J. Holyoak, & B. N. Kokinov (Eds.), *The analogical mind: Perspectives from cognitive science* (pp. 199–253). Cambridge, MA: MIT Press.

Gentner, D., & Wolff, P. (2000). Metaphor and knowledge change. In E. Dietrich & A. B. Markman (Eds.), *Cognitive dynamics: Conceptual and representational change in humans and machines* (pp. 295–342). Mahwah, NJ: Erlbaum.

Gernsbacher, M. A., Keysar, B., Robertson, R. R. W., & Werner, N. K. (2001). The role of suppression and enhancement in understanding metaphors. *Journal of Memory and Language, 45*, 433–450.

Gibbs, R. W. (1992). Categorization and metaphor understanding. *Psychological Review, 99*, 572–577.

Gineste, M.-D., Indurkhya, B., & Scart, V. (2000). Emergence of features in metaphor comprehension. *Metaphor and Symbolic Activity, 15*, 117–135.

Giora, R., Zaidel, E., Soroker, N., Batori, G., & Kasher, A. (2000). Differential effects of right- and left-hemisphere damage on understanding sarcasm and metaphor. *Metaphor and Symbolic Activity, 15*, 63–83.

Glucksberg, S., & Keysar, B. (1993). How metaphors work. In A. Ortony (Ed.), *Metaphor and thought* (2nd ed., pp. 401–424). New York, NY: Cambridge University Press.

Glucksberg, S., Newsome, M. R., & Goldvarg, Y. (2001). Inhibition of the literal: Filtering metaphor-irrelevant information during metaphor comprehension? *Metaphor and Symbolic Activity, 16*, 277–293.

Goldvarg, Y., & Glucksberg, S. (1998). Conceptual combinations: The role of similarity. *Metaphor and Symbolic Activity, 13*, 243–255.

Happe, F., Brownell, H., & Winner, E. (1999). Acquired 'theory of mind' impairments following stroke. *Cognition, 70*, 211–240.

Hoffman, R. R. (1984). Recent psycholinguistic research on figurative language. *Annals of the New York Academy of Sciences, 433*, 137–166.

Kacinik, N. A. (2003). Hemispheric processing of literal and metaphoric language. Unpublished doctoral dissertation. University of Califonia, Riverside.

Kacinik, N. A., & Chiarello, C. (2003). An investigation of hemisphere differences for moderately imageable words across high and low image contexts. *Brain and Cognition, 53*, 239–242.

Kacinik, N., Shears, C., Chiarello, & C. (2000). Familiarity for nouns and verbs: Not the same as, and better than, frequency. In *Proceedings of the 22nd Annual Meeting of the Cognitive Science Society*, 1035. Hillsdale, NJ: Erlbaum.

Katz, A. N., Paivio, A., Marschark, M., & Clark, J. M. (1988). Norms for 204 literary and 260 nonliterary metaphors on 10 psychological dimensions. *Metaphor and Symbolic Activityic Activity, 3*, 191–214.

Kempler, D., Van Lancker, D., Marchman, V., & Bates, E. (1999). Idiom comprehension in children and adults with unilateral brain damage. *Developmental Neuropsychology, 15*, 327–349.

Kintsch, W. (2000). Metaphor comprehension: A computational theory. *Psychonomic Bulletin and Review, 7*, 257–266.

Klepousniotou, E., & Baum, S. R. (2005). Processing homonymy and polysemy: Effects of sentential context and time-course following unilateral brain damage. *Brain and Language, 93*, 308–326.

Koivisto, M. (1997). Time course of semantic activation in the cerebral hemispheres. *Neuropsychologia, 35*, 497–504.

Kutas, M., & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature, 307*, 161–163.

Lakoff, G. (1993). The contemporary theory of metaphor. In A. Ortony (Ed.), *Metaphor and thought* (2nd ed., pp. 202–251). New York, NY: Cambridge University Press.

Landauer, T. K., & Dumais, S. T. (1997). A solution to Plato's problem: The Latent Semantic Analysis theory of the acquisition, induction, and representation of knowledge. *Psychological Review, 104*, 211–240.

Landauer, T. K., Foltz, P., & Laham, D. (1998). An introduction to latent semantic analysis. *Discourse Processes, 25*, 259–284.

Lee, S., & Dapretto, M. (2003). *Metaphorical vs. literal word meanings: fMRI evidence against a selective role of the right hemisphere*. Poster presented at the 10th annual meeting of the Cognitive Neuroscience Society, New York.

Liu, S. R. A. (2002). Order and anomaly: An investigation of the semantic and syntactic contributions to sentence processing in the left and right cerebral hemispheres. Unpublished doctoral dissertation, University of California, Riverside.

Lovett, C., & Coulson, S. (2002). *Sidewalks and evidence: Event-related potential effects of metaphoricity and concreteness*. Poster presented at the 9th annual meeting of the Cognitive Neuroscience Society, San Francisco.

Luo, Q., Perry, C., Peng, D., Jin, Z., Xu, D., Ding, G., et al. (2003). The neural substrate of analogical reasoning: An fMRI study. *Cognitive Brain Research, 17*, 527–534.

Martin, I., & McDonald, S. (2003). Weak coherence, no theory of mind, or executive dysfunction? Solving the puzzle of pragmatic language disorders. *Brain and Language, 85*, 451–466.

Mashal, N., Faust, M., & Hendler, T. (2005). The role of the right hemisphere in processing nonsalient metaphorical meanings: Application of principal components analysis to fMRI data. *Neuropsychologia, 43*, 2084–2100.

Mason, R. A., & Just, M. A. (2004). How the brain processes causal inferences in text: A theoretical account of generation and integration component processes utilizing both cerebral hemispheres. *Psychological Science, 15*, 1–7.

McIntyre, M., Pritchard, P. B., & Lombroso, C. T. (1976). Left and right temporal lobe epileptics: A controlled investigation of some psychological differences. *Epilepsia, 17*, 377–386.

Meyer, A. M., & Peterson, R. R. (2000). Structural influences on the resolution of lexical ambiguity: An analysis of hemispheric asymmetries. *Brain and Cognition, 43*, 341–345.

Miall, D. S. (1982). *Metaphor: Problems and perspectives*. Atlantic Highlands, NJ: Humanities Press.

Nakagawa, A. (1991). Role of anterior and posterior attention networks in hemispheric asymmetries during lexical decisions. *Journal of Cognitive Neuroscience, 3*, 313–321.

Ortony, A. (1993). *Metaphor and thought* (2nd ed.). New York, NY: Cambridge University Press.

Palmatier, R. A. (1995). *Speaking of animals: A dictionary of animal metaphors*. Westport, CT: Greenwood Press.

Palmatier, R. A., & Ray, H. L. (1989). *Sports talk: A dictionary of sports metaphors*. Westport, CT: Greenwood Press.

Rapp, A., Leube, D., Erb, M., Grodd, W., & Kircher, T. (2004). Neural correlates of metaphor processing. *Cognitive Brain Research, 20*, 395–402.

Rinaldi, M. C., Marangolo, P., & Baldassarri, F. (2004). Metaphor comprehension in right brain-damaged patients with visuo-verbal and verbal material: A dissociation (re)considered. *Cortex, 40*, 479–490.

Robertson, D. A., Gernsbacher, M. A., Guidotti, S. J., Robertson, R. R. W., Irwin, W., Mock, B. J., et al. (2000). Functional neuroanatomy of the cognitive process of mapping during discourse comprehension. *Psychological Science, 11*, 255–260.

Rumelhart, D. E. (1993). Some problems with the notion of literal meanings. In A. Ortony (Ed.), *Metaphor and thought* (2nd ed., pp. 71–82). New York, NY: Cambridge University Press.

Sabbagh, M. A. (1999). Communicative intentions and language: Evidence from right-hemisphere damage and autism. *Brain and Language, 70*, 29–69.

Sabbagh, M. A., Moulson, M. C., & Harkness, K. L. (2004). Neural correlates of mental state decoding in human adults: An event-related potential study. *Journal of Cognitive Neuroscience, 16*, 415–426.

Sadock, J. M. (1993). Figurative speech and linguistics. In A. Ortony (Ed.), *Metaphor and thought* (2nd ed., pp. 42–57). New York, NY: Cambridge University Press.

Schmidt, G. L., DeBuse, C. J., & Seger, C. A. (2007). Right hemisphere metaphor processing? Characterizing the lateralization of semantic processes. *Brain and Language*, *100*, 127–141.

Sommer, E., & Weiss, D. (1996). *Metaphors dictionary*. Detroit, MI: Visible.

Titone, D. (1998). Hemispheric differences in context sensitivity during lexical ambiguity resolution. *Brain and Language, 65*, 361–394.

Tompkins, C. A. (1990). Knowledge and strategies for processing lexical metaphor after right or left hemisphere brain damage. *Journal of Speech and Hearing Research, 33*, 307–316.

Tourangeau, R., & Rips, L. (1991). Interpreting and evaluating metaphors. *Journal of Memory and Language, 30*, 452–472.

Van Lancker, D. (1990). The neurology of proverbs. *Behavioural Neurology, 3*, 169–187.

Van Lancker, D., & Kempler, D. (1987). Comprehension of familiar phrases by left-but not by right-hemisphere damaged patients. *Brain and Language, 32*, 265–277.

Wilson, M. (1988). MRC Psycholinguistic Database: Machine-usable dictionary, Version 2.00. *Behavior Research Methods, Instruments, and Computers, 20*, 6–10. Available from: www.psy.uwa.edu.au/MRCDataBase/uwa_mrc.htm.

Winner, E., & Gardner, H. (1977). The comprehension of metaphor in brain-damaged patients. *Brain, 100*, 717–723.

Zaidel, E. (1978). Lexical organization in the right hemisphere. In P. Buser & A. Rougeul-Buser (Eds.), *Cerebral correlates of conscious experience* (pp. 177–197). Amsterdam: Elsevier.