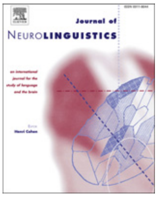
Journal of Neurolinguistics 26 (2013) 1–21

Contents lists available at SciVerse ScienceDirect

Journal of Neurolinguistics

journal homepage: www.elsevier.com/locate/jneuroling



Review

Hemispheric differences in figurative language processing: Contributions of neuroimaging methods and challenges in reconciling current empirical findings

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A R T I C L E I N F O

Article history:
Received 1 November 2011
Received in revised form 3 July 2012
Accepted 3 July 2012

Keywords:
Figurative language processing
Right hemisphere
Metaphors
Idioms
fMRI
Divided visual field experiments
Familiarity

A B S T R A C T

The following review critically synthesizes the literature on hemispheric differences in idiom and metaphor comprehension. It has long been debated whether figurative language is inherently different from literal language and is processed specifically in the right hemisphere (RH), or rather, whether figurative and literal language form a continuum rather than a dichotomy, and call upon a similar network of brain areas. In this paper, a number of neuropsychological, behavioral and neuroimaging studies are reviewed in the context of major theoretical accounts of metaphor and idiom comprehension. Specifically, the role played by the RH in metaphor and idiom processing is evaluated, and advancements that neuroimaging methods have made to our understanding of figurative language comprehension are assessed. This review also highlights a number of critical methodological discrepancies between studies, and emphasizes how such inconsistencies in operational definitions, stimuli and tasks pose a serious challenge to reconciling the debate on hemispheric differences, and do not allow for a clear-cut conclusion of which neural networks underlie figurative language processing.

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http://dx.doi.org/10.1016/j.jneuroling.2012.07.001

1. Introduction

The greatest thing by far is to be a master of metaphor.
It is the one thing that cannot be learned from others;
It is also a sign of genius, since a good metaphor implies an eye for resemblance.
∼ Aristotle, De Poetica, 322 B.C.

In our everyday language, we often hear people describe life as a roller-coaster ride, speak of broken hearts and open minds, and compare sly politicians to foxes. Occasionally, we give someone a taste of our own medicine, we lend them our ears and we bend over backwards to get something accomplished. When we hear such expressions, whether they are commonly used or constructed on the fly, we know not to take them literally. In fact, if taken literally, most idiomatic and metaphoric expressions would be implausible or false. Instead, in order to grasp their intended meaning, we must often search beyond the strict literal sense of the constituent words and make a conceptual leap between two distant semantic domains which are normally unrelated to each other. The fact that figurative (or non-literal) language is so pervasive in our speech and understood effortlessly has intrigued philosophers and researchers from the time of Aristotle, and has been the subject of much research over the past few decades. More recently, our knowledge of the cognitive processes underlying figurative language comprehension – largely gained from neuropsychological investigations such as patient studies and behavioral investigations such as divided visual field experiments – has benefitted from advances in neuroimaging techniques. The aim of the current paper is to provide a critical review of the research examining the neurocognitive mechanisms for processing figurative language, with a specific emphasis on idioms and metaphors. Other forms of non-literal language such as sarcasm, humor and indirect requests will not be addressed. This review centers on the longstanding debate of whether figurative language is inherently different from literal language, or whether figurative and literal language form a continuum rather than a dichotomy and call upon similar processing strategies and brain areas during comprehension.

This paper focuses on one of the major areas of controversy in research on figurative language comprehension: the question of HEMISPHERIC SPECIALIZATION in the comprehension of idioms and metaphors. Although there is also considerable debate around the question of how figurative language is stored and accessed during online processing, due to space constraints, the current review will not address the cognitive theories and recent neuroimaging research examining the *time-course* of access of idioms and metaphors. With respect to hemispheric specialization, it remains a much debated question whether, and to what extent, the right hemisphere (RH) is specialized for the comprehension of idiomatic and metaphoric language compared to the left hemisphere (LH), due to hemispheric differences in meaning analysis and integration. Whereas some neuropsychological and neurolinguistic evidence has supported the "RH is special" theory (Anaki, Faust, & Kravetz, 1998; Bottini et al., 1994; Winner & Gardner, 1977), other studies have found no RH involvement (Faust & Weisper, 2000; Kacinik & Chiarello, 2007; Lee & Dapretto, 2006; Rapp, Leube, Erb, Grodd, & Kircher, 2004; Stringaris, Medford, Giampetro, Brammer, & David, 2007) and still some others have argued that the degree of RH recruitment depends on lexical and contextual factors rather than figurativity per se (Mashal, Faust, & Hendler, 2005; Mashal, Faust, Hendler, & Jung-Beeman, 2007; Schmidt, De Buse, & Seger, 2007). To date, there is still no consensus on what precise aspects of figurative language the right hemisphere may be particularly sensitive to.

The controversial findings in the literature will be critically synthesized within the framework of main theoretical accounts of hemispheric differences in processing idioms and metaphors. First, the review will cover early neuropsychological studies, as these patient data played a key role in motivating the "RH is special" theory. Next, the debate of whether the RH *is* indeed primarily responsible for processing figurative language will be evaluated in the light of divided-visual field experiments, as well as several neuroimaging studies. The goals of this paper are threefold: (1) to review the role of the RH in processing idioms and metaphors, by contrasting evidence for and against this theory, from a range of methodologies; (2) to evaluate the contributions of neuroimaging studies, and assess whether these findings have extended the knowledge gained from behavioral paradigms, and (3) to highlight a number of important and largely under-studied discrepancies across studies which (a) make it difficult to synthesize the literature and decisively resolve the "RH is special" debate, and (b) need to be systematically investigated and disentangled in current/future research in order to convincingly argue in favor of hemispheric differences or to adopt one particular theory over another.

It will be argued that, although neuroimaging proves to be a useful method for shedding some light on this question, and although both behavioral and neuroimaging paradigms have greatly advanced our knowledge about hemispheric differences in figurative language processing beyond early findings from patient studies, much work remains to be done, as most of the inconsistent results that fuel the debate seem to arise from methodological or theoretical issues across studies. For example, studies differ in how they operationally define and select metaphors and idioms. Some studies only examine metaphoric word pairs without a sentential context and, at times, it is not clear whether these should be considered metaphors at all or whether the metaphoric meaning has grown to be so conventional over time that these could actually be construed as ambiguous *literal* words (e.g. "bright student", "stinging insult") (Anaki et al., 1998; Mashal et al., 2005). Furthermore, some researchers have failed to control for the degree of familiarity or novelty of the figurative expressions tested in their experiments, a variable which has been strongly argued to affect the neural mechanisms underlying semantic processing (Beeman, 1998; Giora, 1997, 2003). Moreover, studies differ considerably in the task performed by participants, some of which involve more complex judgment processes that are more cognitively demanding and that may more heavily involve brain areas not typically activated in online figurative language comprehension. This paper aims to increase awareness of how these factors are likely to affect the processing of literal and non-literal language, and are likely to contribute to the heterogeneity of empirical findings on the role of the RH.

While it is an obvious and well-known fact that methodological differences across studies will lead to different results, the argument here is that these differences must be systematically investigated in future experiments, in order to assess the relative impact of each of these factors on modulating neural activation patterns and hemispheric differences during figurative language processing. Otherwise, neglecting to do so could hinder our understanding of whether – and how exactly – the RH is specifically involved in processing figurative vs. literal language. It is necessary to reconcile these differences in order to properly assess the contribution of the RH in figurative language processing.

Thus, it will be argued that conclusions from studies evaluating the role of the RH are not as clear-cut and as decisive as they could potentially be, due to these methodological and theoretical limitations which currently make it unclear whether the RH *does* in fact have a special role to play in the processing of metaphoric and idiomatic language, or not. The question also arises of whether we should stop thinking along the lines of dichotomies such as literal vs. figurative language, and RH vs. LH in our empirical investigations, in favor of a continuum-based approach and a systematic consideration of the many factors that may drive different patterns of processing and neural activity.

2. Idiomatic and metaphoric language

2.1. Definitions

A *metaphor* can be formed by a pair of words, a sentence or a whole text, and makes an implicit comparison between ideas from different knowledge domains which are usually not associated with one another, in order to attribute salient properties of one category to another (Gibbs, 1999; Glucksberg & Keysar, 1990). For example, understanding the sentence "this idea is a gem" requires establishing a connection between the topic of the *metaphor* (idea) and its *vehicle* (gem) beyond the literal meaning of the words, as an idea is not literally a gem but shares some salient properties with one, such as preciousness or uniqueness (Mashal et al., 2005). Over time, metaphoric expressions can become so commonly used in everyday language that speakers no longer recognize them as metaphoric. These are termed "dead metaphors" (Bowdle & Gentner, 2005).

Idioms are phrases of two or more words and are considered to be over-learned, highly familiar and, to a certain extent, syntactically unproductive expressions for which the figurative meaning has no obvious semantic overlap with the individual words in the phrase (Cacciari & Glucksberg, 1991). Classic examples include "to kick the bucket" ("to die suddenly") and "skating on thin ice" ("taking a big risk").

While some claim that the figurative meaning of such expressions cannot be derived from the meanings of the individual words forming the idiom, others argue that the mental link is not necessarily arbitrary, but is determined by how speakers conceptualize the domains to which idioms refer (Gibbs & Beitel, 1995; Lakoff & Johnson, 1980). Related idiomatic expressions (such as fuming, boiling, or blowing one's top) are the result of underlying conceptual metaphors (i.e., anger is fluid in a heated container) that are readily and unconsciously available in the speaker's mind.

In this view, idioms and metaphors are rather closely related forms of figurative language and some of the same questions regarding the neural mechanisms underlying figurative language comprehension in the brain are relevant to both types of expressions. It is mainly for this reason that the current review addresses both types of figurative language, along with the fact that there is a paucity of reviews in the field that have brought idioms and metaphors together in an attempt to provide a comprehensive picture of non-literal language processing (Thoma & Daum, 2006). Although idioms and metaphors may differ from one another on some dimensions, it may be useful to discuss and evaluate theoretical accounts and empirical evidence of hemispheric asymmetries in light of both types of non-literal expressions.

2.2. Factors affecting comprehension of figurative language

Figurative language, as a whole, does not form a homogenous class of non-literal expressions but, rather, there is a great deal of variability among items within figurative language, both within idioms and within metaphors. Both types of figurative language vary on a number of dimensions which have been shown to affect comprehension processes and, as will be discussed in the context of recent neuroimaging studies, to modulate the neural activation patterns during figurative language comprehension. As it will be argued that a careful examination of the relative role of these factors is needed in order to be able to draw reliable conclusions from behavioral and neuroimaging investigations of idiom/metaphor processing, some space will be devoted to defining each of these factors and to highlighting some of the inconsistencies in their treatment across studies.

Familiarity of an idiom or metaphor has been defined as the degree of subjective experience a speaker has with a figurative expression (Schweigert, 1986). *Familiarity* is a critical factor as it has been suggested that familiar idioms and metaphors are processed differently than novel or unfamiliar expressions. It is assumed that the figurative meaning of a familiar metaphor or idiom has been encountered often and may be stored as an alternate meaning of the words in the string. Thus, it can be retrieved in the same was as any ambiguous literal word. However, for unfamiliar expressions, a meaning must be constructed online once the expression is encountered, and the figurative meaning is understood by an analogical process whereby salient properties of the topic and vehicle in the metaphor are compared (Bowdle & Gentner, 2005; Glucksberg, 2001). In some studies, *familiarity* is used interchangeably with *conventionality*, with "conventional metaphors/idioms" being synonymous to "familiar metaphors/idioms" and "novel metaphors/idioms" being equivalent to "unfamiliar metaphors/idioms" (e.g., Bottini et al., 1994; Eviatar & Just, 2006; Faust & Mashal, 2007; Mashal et al., 2007; Schmidt et al., 2007; Stringaris et al., 2007). However, one group of researchers (Blasko & Connine, 1993) has made a clear distinction between the two factors: according to these authors, *subjective familiarity* is only one aspect of *conventionality*. Familiarity is a property of the entire expression and refers to a vehicle-topic pairing that has been encountered before. On the other hand, *conventionality* is determined by the vehicle of the expression which has become polysemous due to repeated and consistent figurative use. According to Blasko & Connine, then, a conventional expression may be either familiar or unfamiliar whereas most other researchers consider familiar metaphors as conventional.

Moreover, although *familiarity* is considered a key factor in the comprehension of figurative expressions, researchers in the field have not been consistent in their operational definitions and their method of measuring the variable; some researchers have obtained familiarity ratings from their participants on a five- or seven-point scale (Arzouan, Goldstein, & Faust, 2007; Faust & Mashal, 2007; Mashal et al., 2007), others have used normed measures from databases (Schmidt et al., 2007; Stringaris et al., 2007), whereas others have retrieved their novel/unfamiliar metaphors from books or poetry while considering all other "commonly used" metaphors as conventional/familiar (Bottini et al., 1994; Pobric, Mashal, Faust, & Lavidor, 2008). Some researchers have considered the familiarity of the expression (idiom or metaphor) as a whole (Blasko & Connine, 1993; Proverbio, Crotti, Zani, & Adorni, 2009; Schmidt et al., 2007), while others have measured the familiarity of individual constituents (Faust & Weisper, 2000; Stringaris et al., 2007). Few researchers explicitly define *familiarity*; as a result, we often cannot tell whether *familiarity* is based more on frequency of occurrence or on speakers' actual familiarity with the meaning of the phrase.

A second key dimension along which idioms and metaphors vary is *frequency* – another factor which has, unfortunately, not been consistently accounted for across experimental studies on figurative language comprehension. Some researchers consider the frequency of occurrence of individual words in figurative expressions (e.g., Anaki et al., 1998; Arzouan et al., 2007; Faust & Weisper, 2000; Libben & Titone, 2008; Pobric et al., 2008) whereas others consider the frequency of the entire metaphoric or idiomatic string (Faust & Mashal, 2007; Stringaris et al., 2007). Furthermore, some researchers obtain their frequency measures from normed databases (Pobric et al., 2008; Proverbio et al., 2009; Stringaris et al., 2007), while others recruit participants to rate the experimental stimuli on a frequency scale (Arzouan et al., 2007). It is also important to note that familiarity and frequency are correlated and often used interchangeably in their operational definitions. Thus, the relative role of each factor remains unclear, although both appear to influence the comprehensibility of figurative expressions to some extent. The same might be true of *predictability* – the degree to which the words in an idiom or metaphor are predicted from the preceding context as they are encountered. Predictability is also likely to correlate with familiarity (Libben & Titone, 2008; Titone & Connine, 1994) and so the relative role of each of these factors is still to be disentangled in future studies.

Idioms and metaphors also vary in *literal plausibility*, and this may lead to differences in comprehension processes – whereas figurative expressions with plausible literal interpretations (e.g. to kick the bucket) create ambiguity at a phrasal level (Titone & Connine, 1999), literally implausible expressions (e.g. to be on cloud nine) only make sense when interpreted figuratively. Another important feature of figurative expressions is their degree of *compositionality* or *decomposability* (also referred to as *transparency*), which refers to the extent to which the meaning of the string can be recovered from the meanings of the individual words. While the words constituting "to talk a mile a minute" provide clues for the figurative meaning of "fast speech rate", the idiom "it's raining cats and dogs" is *non-decomposable* or *opaque* (Gibbs, Nayak, & Cutting, 1989). Decomposability is affected by contextual bias and influences the comprehensibility of figurative expressions; while *transparent* non-literal expressions and metaphors are accessed in a context-independent fashion, *opaque* expressions rely more on contextual information (Gibbs & Nayak, 1989).

3. Specialization of RH for figurative language processing

3.1. Early neuropsychological evidence of a special RH role

An important motivation for the RH theory in figurative language comprehension comes from neuropsychological studies in patients suffering from unilateral brain damage. These studies have suggested that focal lesions in the L and R hemisphere differentially affect figurative language comprehension. There have been several reports that, unlike LH-damaged patients who show preserved appreciation for metaphor and idiomatic uses of language, RH-damaged patients show decreased sensitivity to the connotative meanings of words and exhibit overly literal interpretations of non-literal expressions (Brownell, Potter, Michelow, & Gardner, 1984; Van Lancker and Kempler, 1987; Winner & Gardner, 1977).

One pioneering study was conducted by Winner and Gardner (1977) where the task involved matching orally-presented metaphoric expressions such as "His heart felt heavy" to pictorial depictions of either the literal meaning of the metaphor (a large heart, heavy in weight) or to the figurative meaning (a person crying). Whereas LH-damaged patients made appropriate metaphoric interpretations, patients with RH damage were as likely to choose the literal depictions as the metaphoric ones. This finding was replicated in a similar experiment testing idiomatic expressions such as "He's turning a new leaf" in comparison to novel literal sentences such as "He's sitting deep in the bubbles" (Van Lancker and Kempler, 1987). The findings showed that LH-damaged patients performed worse than

RH-damaged patients on the novel literal sentences which required detailed syntactic analysis, but outperformed RH-damaged patients on the figurative sentences.

However, these findings have not gone unchallenged (Gagnon, Goulet, Giroux, & Joanette, 2003; Giora, Zaidel, Soroker, Batori, & Kasher, 2000; Papagno et al., 2002). Firstly, even in the study by Winner and Gardner (1977), RH-damaged patients were able to accurately explain the metaphorical meaning of the sentences when asked to do so verbally, despite their poor performance on the picture-matching task. In line with this finding, Rinaldi, Marangolo and Baldassarri (2004) reported that RH-damaged patients tended to inappropriately select literal over metaphoric meanings in a picture-matching task, but performed well in a verbal task. Thus, these findings suggest that task demands may affect RH-damaged patients' degree of impairment and difficulty in figurative language processing. However, other researchers have questioned the specific role of the RH altogether and have failed to show the hypothesized distinction between RH- and LH-damaged patients' figurative language comprehension abilities. A study by Giora et al. (2000) reported counterevidence to the "RH is special" theory beyond the task differences observed in Winner and Gardner (1977) and Rinaldi et al. (2004). In their study, it was actually the LH-damaged patients who made more errors when requested to orally explain the meaning of conventional metaphors with a literally implausible meaning (such as "broken heart" or "hard man"). Furthermore, Gagnon et al. (2003) tested LH-damaged and RH-damaged patients on two tasks: (1) a word triad task that involved associating metaphoric and non-metaphoric meanings to a target word and (2) a word dyad task where the patients had to decide whether or not there was a semantic relationship between two words. Half of these dyads contained a semantic relationship and were derived from the word-triads, whereas the other half contained no semantic relationship. According to the authors, the goal of this task was to detect whether RH-damaged patients have a "genuine semantic deficit" which stands in their way of comprehending metaphoric language. The results showed that both LH- and RH-damaged groups were impaired in processing metaphoric word meanings and detecting semantic relationships between two words. Therefore, given that LH-damaged patients also exhibited similar difficulties as RH-damaged patients, the hypothesis of a specific contribution of the RH in processing metaphoric language was refuted by the authors. Thus, early neuropsychological studies offer mixed evidence in support of the RH theory for figurative language comprehension.

There are several important limitations of this early patient research which may account for these mixed findings. First, in many studies, patients' visual-perceptual abilities were not assessed, and the severity of patients' aphasia and the modalities of neuropsychological assessment were not described in detail. Second, early studies did not reliably differentiate lesion sites within the RH, nor did they control for the time of onset of aphasia or whether patients underwent language intervention (see Oliveri, Romero, & Papagno, 2004 for a review). In addition, the number of patients and the number of stimuli were limited in these studies. Moreover, as noted earlier, differences in tasks have also likely contributed to discrepant findings, suggesting that the modality of testing may account for some of the difficulties observed in patients with RH deficits. Thus, early neuropsychological studies of figurative language comprehension in brain-damaged populations did not provide much information about brain function other than a generalized assumption that the RH may somehow be involved in processing non-literal language.

3.2. The divided-visual field paradigm and theories of hemispheric differences in semantic processing

Another line of research investigating meaning activation in *healthy* adults has shed light on potential hemispheric differences in semantic processing. Although these studies have focused on lexical ambiguities present in *literal* language, reported differences in how the two hemispheres select and maintain the activation of multiple meanings of words are highly relevant to the way each hemisphere processes figurative language, compared to literal language, as comprehending idiomatic and metaphoric expressions involves the processing of semantically divergent domains.

A technique that has been used to explore the role of the RH in neurologically intact individuals is the *divided visual field priming paradigm*. By presenting stimuli outside the fovea, it is possible to selectively stimulate the visual cortex in the LH or RH. The common procedure entails the selective presentation of prime-target pairs to the right visual field (LH) or to the left visual field (RH). A lexical decision task typically follows. Although the information is rapidly transmitted to other brain regions, including those in the other hemisphere, differences in the initial stages of processing can indicate hemisphere-specific computations (Chiarello, 1991).

These studies, investigating meaning processing in literal language, have revealed that the LH and RH differentially process semantic information (Burgess & Simpson, 1988; Chiarello, 1991). Findings from Chiarello, Burgess, Richards, and Pollock (1990) indicated that, although both hemispheres show evidence of semantic priming with words that are associatively and semantically related (such as doctor – nurse), the RH shows an advantage over the LH in priming for words that have weak or indirect semantic relations (such as dull – moody, lawyer – nurse). Other studies have shown that contextually-irrelevant meanings of ambiguous words are primed in the RH but not in the LH, especially at relatively long stimulus-onset-asynchronies (SOA greater than 200 ms) between the prime and the target (Arambel & Chiarello, 2006; Faust & Chiarello, 1988). Similarly, although dominant and subordinate meanings of ambiguous words show priming in either hemisphere, the subordinate meanings tend to decay rapidly in the LH, while the RH maintains activation of both meanings of the ambiguous word (Burgess & Simpson, 1988; Burgess, Tanenhaus, & Hoffman, 1994).

Based on these findings, the RH is claimed to activate a broad range of meanings, including distantly related concepts, and to simultaneously maintain the activation of multiple meanings, even if they are inconsistent with a given context. The LH, on the other hand, selectively maintains activation of only dominant, closely-related and contextually appropriate meanings.

A prominent theory of LH-RH differences in semantic processing is Beeman's (1998) *Coarse Coding Hypothesis* which postulates that the two hemispheres differ in the level of granularity at which they encode semantic information; while in the LH, word meanings are represented by localized semantic fields, such that a small number of relevant meanings can be rapidly accessed, the RH represents word meanings in broader and more distributed semantic fields. The coarse coding of the RH allows for it to activate, select and integrate a broad range of meanings and features. The coarser coding of semantic representations in the RH results in an overlap of some semantic fields, and allows for associations to emerge between distantly related concepts which are inferentially connected to one another (Beeman, 1998).

This specialized ability of the RH may not only apply to the access and interpretation of multiple meanings of ambiguous (literal) words, but to inferring the figurative meaning of non-literal language, which also depends on the continued activation of alternate word meanings and on establishing links between words with distant semantic relationships (Faust & Lavidor, 2003). A number of divided visual field studies have, therefore, investigated hemispheric differences in meaning processing with respect to figurative language.

In addition, advances in neuroimaging techniques such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) have offered opportunities to test hypotheses about hemispheric differences in semantic processing and to evaluate whether the RH has a special role to play in figurative language comprehension. The greatest advantage of imaging research over behavioral or neuropsychological research is that it is able to provide a relatively direct measure of the localization of different cognitive processes underlying non-literal language processing, in terms of specific neural networks that are more or less activated during the processing of certain kinds of linguistic stimuli. However, to date, most of the research in this area has been conducted on processing metaphors, while neuroimaging studies have hardly investigated idiom processing.

In the section that follows, evidence from divided visual field experiments and neuroimaging research will be presented, along with any shortcomings within these studies that must be kept in mind when interpreting their results. These findings, supporting the RH is special theory, will then be contrasted to divided visual field experiments and neuroimaging studies that *challenged* theories advocating for a preferential involvement of the RH (in Section 3.4).

3.3. *The RH is special*

A key divided visual field experiment was conducted by Anaki et al. (1998). Subjects were presented with metaphoric or literal prime-target associations either to their left visual field (RH) or right visual field (LH), at two different SOAs (200 and 800 ms). A lexical decision task was performed in response to the target words, which were either related to the metaphoric meaning of the prime (stinging – insult) or to the literal meaning (stinging – mosquito), or unrelated (stinging – carpet). In the short SOA condition, priming effects were found for metaphorically-related targets in both visual fields, while literally-related targets were facilitated only in the LH. In the long SOA condition, metaphorically-related targets were primed only in the RH and literally-related targets only in the LH. These results are in line with the claim that, during later stages of semantic processing, the LH is more selective in processing alternate word meanings whereas the RH maintains the activation of multiple interpretations (Beeman, 1998; Chiarello, 1991). Thus, the authors take these findings as supporting the hypothesis that the RH plays an enhanced role in figurative language processing. However, it can be argued that the stimuli used in this study were not exactly metaphoric, given their conventionality, but seemed to fall more within the range of lexically ambiguous polysemous words in the domain of *literal* language. It is not clear what the difference is between these stimuli (such as stinging – unkind vs. stinging – sharp) and those used in the divided visual field semantic priming experiments with *literal* word pairs having dual meanings (such as novel – fresh vs. novel – story; from Faust & Lavidor, 2003). Thus, although Anaki and colleagues' data are consistent with previous reports of a broader semantic activation that is less susceptible to decay in the RH compared to the LH, it is not entirely clear based on this experimental design that these effects are due to *figurativity* per se, or simply due to hemispheric differences in semantic activation, be it for literal or non-literal language.

In terms of neuroimaging studies, probably the most influential, and one of the earliest, neuroimaging investigation of the role of the RH in figurative language comprehension was a PET study by Bottini et al. (1994). Subjects were presented with novel, unconventional sentential metaphors that were either literally plausible ("The old man had a head full of dead leaves") or literally implausible ("The old man had a head full of barn doors") as well as with literal sentences, and were asked to perform a plausibility judgment task on these sentences. Processing of metaphors was associated with similar activations as for literal sentences in the left hemisphere (including prefrontal and basal frontal cortex, the middle and inferior temporal gyri and the temporal pole, parietal cortex and precuneus) but additionally gave rise to activation in a number of areas in the RH, particularly the right inferior frontal gyrus and right posterior temporal cortex. Based on these results, the authors suggested that the RH plays a special role in the interpretation of figurative language, and that the increased involvement of the RH may reflect a special cognitive process such as accessing world knowledge and drawing inferences from the context in order to resolve the ambiguity of the sentence. Despite these pioneering findings, this study has been criticized for having used complex sentences which were not well-matched across the figurative and literal conditions. In fact, the behavioral results revealed that subjects made significantly more errors when interpreting the metaphoric sentences than the literal sentences. Thus, given these shortcomings, the involvement of the RH might *not* be specific to processing figurative language, but may have occurred in response to having to process complex syntactic and/or semantic sentence structures – in other words, due to properties of the stimuli and the task.

3.4. No preferential involvement of the RH

Several other studies investigating differential processing of figurative language in the left and right hemispheres have failed to find clear support for a special role of the RH in the comprehension of non-literal meanings.

In a divided visual field study by Faust and Weisper (2000), subjects were presented with incomplete sentences as primes, followed by target words which were literally true, literally false or metaphoric completions of the sentence. Their task was to decide whether the sentences were true or false. Performance was found to be slower and less accurate for metaphoric target words than for literally false target words, irrespective of the hemisphere of presentation. Based on these results, the authors argued against a specialized role of the RH in figurative language comprehension.

A divided visual field study using sentential metaphors also failed to find a unique role for the RH in metaphor comprehension (Kacinik & Chiarello, 2007). Metaphoric ("His girlfriend's face was a storm") and literal ("The ship was headed towards a storm") sentence primes were paired with single word targets that were either consistent or inconsistent with the intended meaning of the preceding sentence in a fully crossed experimental design (literal sentence + literal target, metaphor sentence + metaphor target, literal sentence + metaphor target, or metaphor sentence + literal target). Length, familiarity and word class (all targets except one were nouns) were controlled, but literal targets were more imageable than metaphor targets. Although the RH showed a priming effect for the metaphorically-related primes in context, metaphoric targets also showed priming to the same extent in the LH. Because the size of the priming effect for metaphor targets was the same in both the LH and RH, this finding argues against the notion that the RH is the preferred substrate for and is considerably more involved in metaphor comprehension. Rather, both hemispheres appear to be involved, although the authors argue that their relative role is still to be clarified. However, the experimental stimuli were limited to relatively simple and familiar "*An A is a B*" metaphors. It may be the case that special RH processes may be recruited for understanding more complex and unfamiliar metaphors, a possibility that will be discussed in the next section.

In an event-related fMRI study testing hemispheric differences in processing metaphoric sentences in German, Rapp et al. (2004) presented subjects with moderately unfamiliar "*An A is a B*" sentences that were either metaphoric ("The lovers' words are harp sounds") or literal ("The lovers' words are lies") and asked them to judge whether the sentence had a positive or negative connotation. Across the two conditions, sentences did not differ on syntactic or semantic complexity and on positive connotation. The results revealed that greater activation was elicited for metaphoric than literal sentences in the left inferior frontal cortex, inferior temporal cortex and posterior middle/inferior temporal cortex, but not in the RH. It was concluded that activation in the left inferior frontal cortex may reflect semantic inferencing processes involved during the interpretation of metaphoric language. The authors suggested that while the RH might contribute to the general appreciation of complex semantic and syntactic structures, LH frontal and temporal areas might engage in the decoding of word meaning in metaphoric contexts. In sum, these findings argue against a special role of the RH in processing figurative language. However, it is important to note several limitations of this experiment. Firstly, familiarity was calculated on the basis of an internet search of the metaphors used in the study (therefore, familiarity here seems equivalent to frequency), without reporting any normative data or controlling familiarity in a more systematic way, such as by obtaining familiarity ratings from subjects. As there is no reason to assume that these metaphors are structurally frozen and invariable, it seems possible that any variation in wording would have failed to generate a result in the internet search. Therefore, it is possible that what they construed as newly created or novel metaphors were actually quite familiar to the subjects, and affected the relative contributions of the two hemispheres. Furthermore, judging the emotional content of the sentences is a different task than those performed in previous studies (judging whether the sentence is true or performing a lexical decision task). It is unclear how the nature of the task could have contributed to different patterns of brain activation, and heavier involvement of the LH.

Similarly, an fMRI study by Lee and Dapretto (2006) showed that the comprehension of metaphoric word meanings mainly led to activation of LH areas (prefrontal and temporoparietal regions) rather than the RH. Subjects listened to sets of 3 adjectives and were required to decide whether the last 2 adjectives were similar in meaning. One condition required accessing the literal meaning of the middle word (hot – cold – chilly), whereas another condition required accessing the middle word's metaphoric meaning (hot – cold – unfriendly). These findings of LH activations argue against a selective role of the RH in processing figurative language. The authors explain their results by suggesting that prior studies reporting greater RH involvement may have been affected by the complexity of the figurative expressions under investigation, rather than to a true RH specialization in the comprehension of metaphors. However, as mentioned earlier in the context of the study by Anaki et al. (1998), it is not clear to what extent these word triplets involve true metaphors, or simply polysemous literal words. In addition, in "hot – cold – chilly", the last word in the triad is primed by the first two words, but this is not the case for "hot – cold – unfriendly", as hot and unfriendly are unrelated. Thus, the LH activations may simply be due to a priming effect and may have little to do with figurativity.

Returning within the context of metaphoric sentences, Stringaris et al. (2007) conducted an fMRI study in which participants read metaphoric ("Some surgeons are butchers"), literal ("Some surgeons are fathers") or anomalous ("Some surgeons are shelves") sentences, and had to decide whether the sentences were meaningful or meaningless. This explicit task was meant to get subjects to focus on the attempt to extract the meaning from the sentences, to distinguish between the different sentence types strictly on the basis of semantics. The final words of the literal and metaphoric sentences were matched on imageability, familiarity, frequency, concreteness and length. The authors hypothesized that previous findings suggesting a selective role of the RH in the comprehension of figurative language were not specific to figurativity, but were due to task complexity and to stimuli that were not carefully matched across conditions. In line with their expectations, metaphoric sentences elicited greater activation than literal sentences in *left* lateralized cortical regions, including left IFG, as in the study by Rapp et al. (2004): left precentral gyrus, left inferior parietal lobe as well as in the right middle temporal gyrus. Thus, having controlled for task effects and having carefully matched their stimuli, they did not find any supporting evidence for a predominant role of the RH in metaphoric comprehension. The neural substrate underlying figurative language and literal language was shown to differ, but not in terms of increased activation of the RH in non-literal language processing. The authors also proposed that the left thalamus might be specifically involved in deriving meaning from metaphors and constructing novel ad-hoc representations, whereas the left IFG may become increasingly activated during a more extensive search for semantic integration. It is not clear to what extent these hypotheses about the relative role of different brain areas are put forward as a post-hoc explanation of the data and additional studies replicating these effects are necessary to support these assumptions. Furthermore, although the sentence-final words were well-matched across conditions, the familiarity/novelty of the metaphoric expressions as a whole was not controlled. As will be discussed in the following section, differences in familiarity of the figurative expression may recruit different neural networks and may result in hemispheric differences in non-literal language comprehension.

In sum, despite several studies supporting the *RH theory* of metaphoric language comprehension (Anaki et al., 1998; Bottini et al., 1994), these findings have not gone unchallenged (Faust & Weisper, 2000; Kacinik & Chiarello, 2007; Lee & Dapretto, 2006; Rapp et al., 2004; Stringaris et al., 2007) and, as it stands, there is considerable debate surrounding the question of whether the RH is particularly adept at processing figurative language.

4. RH involvement is mediated by familiarity, not figurativity

A number of other researchers have found evidence for RH recruitment in figurative language processing but have attributed this RH activity not to figurativity per se, but to factors such as differences in the familiarity or novelty of the figurative expressions (Mashal et al., 2005; Schmidt et al., 2007). It has been suggested that the studies that did *not* find a RH advantage for processing metaphoric language had failed to address the *familiarity* of the metaphors and had tested only moderately or very familiar expressions which may be preferentially processed in the LH (such as Kacinik & Chiarello, 2007; Rapp et al., 2004). A number of divided visual field experiments and neuroimaging studies will be reviewed below; these researchers focus less on the existence of a strict dichotomy between figurative and literal language, and advocate instead for a continuum that is modulated by familiarity/novelty.

The idea that the RH would be especially adept at processing unfamiliar/novel expressions compared to highly conventionalized or familiar expressions is consistent with *Coarse Coding Hypothesis* (Beeman, 1998), as unfamiliar expressions, irrespective of literality, would involve the activation of distantly related semantic concepts – a broader, less constrained selection and maintenance of meanings which is argued to be a specialty of the RH. In a similar vein, Giora's (1997, 2003) *Graded Salience Hypothesis* is a theoretical account that also attributes hemispheric differences in figurative meaning processing to factors other than figurativity itself, namely the *salience* of a particular meaning, which is said to be "a function of its conventionality, familiarity or frequency". According to this account, the RH is more likely to be involved in processing less salient interpretations and meanings of words, whereas more conventional, familiar and frequent meanings are processed predominantly in the LH. It is not clear, based on Giora's definition of *salience* how the factors of conventionality, frequency and familiarity work together and whether or not they are actually distinct. A problem that permeates the literature on figurative language processing in the brain is that most studies have not made a clear distinction between familiarity and salience and have used them interchangeably in their design as well as in the interpretation of their findings.

In a divided visual field study, Faust and Mashal (2007) tested metaphoric word pairs in Hebrew to examine whether differences in familiarity would affect RH involvement. Subjects were presented with conventional metaphors ("transparent intention"), novel metaphors ("conscience storm"), literal word pairs ("problem resolution"), or unrelated word pairs ("wisdom wash"), and were asked to decide whether the target word was related or unrelated to the preceding prime word (semantic judgment task). Most of the word pairs made up plausible expressions. Ratings of word length, frequency, concreteness and syntactic structure were contained in a pre-test and the stimuli were matched across conditions on these variables. The results revealed that, for novel metaphors, responses to words presented to the LVF/RH were faster and more accurate than those presented to the RVF/LH. In addition, novel metaphoric word pairs were judged as "related" faster in the RH than the LH, and were judged as "unrelated" more slowly in the RH than the LH (in other words, the RH took longer to decide whether the novel metaphoric word pairs were meaningless). However, a clear RH advantage was *not* found for the conventional metaphors. These findings are in line with the *Coarse Coding Hypothesis* – the RH activates a broader range of related meanings than the LH, including novel meanings. The *Graded Salience Hypothesis* is also supported by these findings – the extent of RH superiority may depend on the salience/familiarity of the metaphoric expressions. Therefore, this study illustrates how metaphors cannot be treated as an undifferentiated group of expressions and it is likely for processing differences (and hemispheric differences) to be found between familiar and less familiar metaphors. One confusing aspect of this study, however, was that the authors stated that there are no real correct or incorrect responses to their task in the case of the novel metaphors, as the two words were "unusually combined" (e.g. "conscience storm"). Therefore, the question arises of whether these are truly "novel metaphors" in nature, or whether they can be construed as "unrelated words" altogether.

A similar experimental design was employed in an fMRI study by Mashal et al. (2007) in order to determine whether different functional networks in the brain underlie the comprehension of expressions of varying degrees of salience. The stimuli consisted of conventional metaphors ("bright student"), novel metaphors derived from poetry ("pearl tears"), literal word pairs ("water drops") or unrelated words ("road shift"). The words were all nouns, balanced across the conditions on word frequency, concreteness and abstractness. Familiarity ratings were obtained in a pre-test used to classify the metaphors into either the conventional or novel metaphoric category. The task consisted of a semantic judgment task where the subjects were required to silently decide whether the words in each pair were related metaphorically or literally, or were unrelated. The behavioral data indicated slower response times to novel metaphors compared to conventional metaphors or literal word pairs. The unrelated word pairs were also slower than in the literal or conventional metaphor condition, and no difference was found between conventional metaphors and literal word pairs. In the fMRI analyses, novel metaphors revealed a stronger activation than conventional metaphors in the right posterior superior temporal sulcus (PSTS), the right inferior frontal gyrus (IFG) and the left middle frontal gyrus (MFG). Comparing conventional metaphors to literal words revealed a greater activation in the left IFG, left PSTS and right postcentral parietal cortex. On the other hand, the contrast of novel metaphors and literal word pairs resulted in fewer and smaller active brain areas, and included mainly bilateral frontal regions. Compared to unrelated words, novel metaphors produced greater activation in the right IFG while conventional metaphors produced greater activation in the left and right IFG. The main effect of hemisphere was also significant in two conditions; for both conventional metaphors and unrelated words, a greater activation was found in the LH than in the RH.

Based on these results, the authors argued for a special role of the RH in processing novel metaphoric expressions, particularly the right PSTS which was specifically active for novel metaphors compared to unrelated word pairs. Although both conditions involve distant semantic domains, the novel metaphor condition involves an attempt to map salient features of the topic onto salient features of the vehicle, and to integrate the meaning of the two words, whereas no such integration occurs in the unrelated condition. Thus, it was suggested that the right PSTS may be responsible for the online construction of meaning connections between two distantly related words. In sum, the degree of salience, rather than the literal/figurative distinction, seems to be the critical factor affecting hemispheric specialization. The results are consistent with the GSH which predicts RH involvement in processing unfamiliar, non-salient meanings (novel metaphors) compared to salient meanings (literal word pairs, conventional metaphors). One potential limitation in the current experiment, however, is the difficulty of the task: judging whether the word pairs were related metaphorically or literally is a somewhat metalinguistic task requiring a forced decision and attention that may be uncharacteristic of normal linguistic processing. It may be that a complex task of that nature might recruit processes in the RH. Another point of uncertainty is how exactly the novel metaphors differ in salience and unfamiliarity compared to unrelated word pairs within the context of the GSH. It seems possible to describe unrelated word pairs as being non-salient literal expressions; why, then, would they *not* recruit RH mechanisms, similarly to novel metaphors, if the results were to fully support the GSH?

Schmidt et al. (2007) tested Giora's *Graded Salience Hypothesis* at the sentence level rather than on word pairs. In three divided visual field experiments, they investigated whether the involvement of the RH was due to metaphoricity or to some other aspect of semantic processing. In a first experiment, unfamiliar metaphoric sentences were compared to familiar literal sentences as well as to anomalous sentences. In a second experiment, the anomalous sentence condition was replaced by unfamiliar literal expressions and later by familiar metaphoric sentences in a third experiment, in order to assess whether these expressions would be processed in the LH rather than the RH. The general design in all three experiments was to have a centrally-presented sentence stem followed by one of three different endings, presented either to the RVF/LH or LVF/RH. For example, a sentence such as "The orchestra filled the hall with" was followed by "music" (literal familiar), "sunshine" (unfamiliar metaphoric) or "hail" (anomalous). The tasks involved deciding whether the ending fit the rest of the sentence (Experiment 1), or whether the sentence was plausible, either metaphorically or literally (Experiment 2), or whether or not the sentences were meaningful expressions (Experiment 3). Results supported Giora's (2003) claim that the RH is specialized for processing non-salient verbal stimuli that contain distant semantic relationships, be they literal or metaphoric, whereas the LH is predominantly involved in processing salient meanings. The RH showed an advantage in processing unfamiliar metaphors as well as unfamiliar literal sentences, whereas the LH showed an advantage for processing familiar metaphors. There were, however, no hemispheric differences for literal familiar sentences, and no RH advantage found in the case of anomalous sentence endings.

One important point to note is that many of these studies do not necessarily help tease apart the effects of "semantic distance", "familiarity" and "salience". While Beeman's *Coarse Coding Hypothesis* (1998) attributes the RH's role to the processing of coarse semantic fields or distantly related semantic domains, Giora's GSH expects hemispheric differences based on the degree of salience (often taken as synonymous to the degree of familiarity) of an expression, but does not have much to say about the degree of semantic relatedness of the concepts in the metaphoric (or literal) expression. Thus, although researchers often conclude that their findings of greater RH involvement for unfamiliar expressions, both literal and metaphoric, are compatible with both Beeman's and Giora's claims, the effects of semantic distance are never disentangled from effects of salience and familiarity. It would be interesting to test figurative and literal expressions in which the semantic concepts are <u>distantly</u> related, but where the expression is <u>high</u> in salience and familiarity, or vice versa, i.e. where the figurative or literal expressions contain a <u>close</u> semantic association between concepts, but are <u>low</u> in salience/familiarity. More clearly teasing apart effects of figurativity, salience, familiarity and semantic distance between meanings would be beneficial to research on hemispheric differences in semantic processing, and would be better able to separately evaluate claims made by the *Coarse Coding Hypothesis* and the *Graded Salience Hypothesis* – an approach which, to my knowledge, has not been taken thus far neither in behavioral nor neuroimaging studies.

In a similar vein, Schmidt and Seger (2009) sought to examine the relative effects of figurativity, salience (used synonymously with familiarity) and difficulty of comprehensibility on the recruitment of RH during metaphoric language comprehension. Four conditions were compared in an fMRI experiment: (1) literal sentences, (2) familiar and easily comprehensible metaphors, (3) unfamiliar and easily comprehensible metaphors, and (4) unfamiliar and difficult to understand metaphors. In order to assess the effect of figurativity, all three types of metaphors (familiar-easy, unfamiliar-easy and unfamiliar-difficult) were compared to literal sentences. In this contrast, metaphors were found to recruit the right insula, the left temporal pole and the right inferior frontal gyrus compared to literal language. In order to examine the effect of familiarity, familiar-easy metaphors were compared to unfamiliar-easy metaphors. This contrast revealed a greater activation in the right middle frontal gyrus (MFG) and right IFG for familiar metaphors compared to unfamiliar metaphors. To assess the impact of sentence difficulty on neural activation patterns, unfamiliar-easy metaphors were compared to unfamiliar-difficult metaphors, revealing an increase in activation in the left MFG and bilateral medial frontal activations. Based on these data, the authors concluded that the RH is involved in the processing of metaphoric language and that all three factors – figurativeness, familiarity and difficulty – are important in determining the precise neural mechanisms underlying processing. However, as there were no RH activations unique to the figurativity contrast, the observed RH involvement in metaphor comprehension cannot be primarily due to *figurativity* per se. However, the challenge remains that these factors – figurativeness, familiarity and difficulty ratings – are highly correlated (Katz, Paivio, Marschark, & Clark, 1988), such that highly figurative language tends to be both unfamiliar and difficult to understand. Furthermore, it was never explained what exactly the measure of "difficulty" was based on – was difficulty related to the degree of semantic relatedness (i.e. closeness) or unrelatedness (i.e. distance) between concepts in the sentences, or did it reflect the *decomposability* or *plausibility* of the expression? Also, the authors did not test a "familiar-difficult to understand" condition; it remains unclear whether the patterns of activation in response to "unfamiliar and difficult to understand" metaphors (compared to the "unfamiliar and easy to understand" metaphors) are due to difficulty alone or to a combination of difficulty and unfamiliarity. In addition, the literal sentences used in the experiment did not vary in difficulty or familiarity as the metaphors did and, therefore, comparing different variations of metaphors to one group of literal sentences may lead to misleading results.

As discussed earlier, further systematic research varying each of these factors while carefully controlling for the others is necessary to shed light on their relative effects on hemispheric differences in figurative and literal language processing. Moreover, the authors avoided using highly familiar or conventional metaphors, resulting in metaphors ranging from moderately familiar to very unfamiliar. This may be a reason why they found RH activations in their "familiar metaphors" whereas other researchers have found predominantly LH activations for conventional metaphors. This highlights another limitation in this field of research – familiarity is not systematically measured or accounted for across studies, resulting in different patterns of activation and difficulty in pinpointing the specific neural network involved in processing different types of metaphoric language.

5. Evaluating the contributions of neuroimaging techniques

Neuroimaging studies investigating the question of hemispheric differences in semantic processing and figurative language comprehension have substantially advanced the understanding of the specific role of the RH that researchers had gained from early neuropsychological data, and have added to findings from divided visual field experiments. The view that the RH is uniquely involved in the processing of idiomatic and metaphoric language (Anaki et al., 1998; Bottini et al., 1994; Winner & Gardner, 1977) is no longer supported. However, the opposite view that the RH is not involved in figurative language comprehension (Lee & Dapretto, 2006; Rapp et al., 2004; Stringaris et al., 2007) is also not supported by existing evidence, as a number of studies *did* obtain greater RH activations for metaphor processing. The prevailing view seems to be that both the LH and RH are involved in figurative language comprehension, but in different ways, depending on hemispheric differences in meaning activation. Whereas the RH seems to be more sensitive to modulations in semantic complexity and is adept in processing distantly related concepts as well as unfamiliar or non-salient expressions, the LH is preferentially involved in processing expressions (either literal or figurative) that consist of closely related semantic domains or that have a familiar or salient meaning. In this view, literal and non-literal language do *not* form a strict dichotomy but are, instead, considered along a continuum where factors such as meaning salience, familiarity and semantic complexity come into play. Thus, figurativeness alone is not sufficient to account for hemispheric specialization in meaning activation, but other features affect the degree to which the RH will be recruited during comprehension processes. Given this conclusion (and as it will be further discussed in Section 6), the systematic investigation of factors or task effects becomes pivotal for current and future studies on this topic. It is no longer sufficient to investigate left vs. right hemisphere contributions on figurative language comprehension, if this debate should be resolved, but it is necessary to assess how different degrees of familiarity, conventionality, frequency, plausibility, decomposability, and how engaging in different tasks actually *modulate* the relative involvement of each hemisphere (as some studies have begun to do, as described in Section 4). This is the area in which future studies would be useful.

A unique contribution of neuroimaging research is that it has advanced our understanding of the specific brain areas responsible for different functional processes involved in figurative language comprehension, since early neuropsychological examinations of LH or RH-damaged individuals could not reliably identify precise focal lesions and divided-visual-field studies could not shed light on localization of function beyond gross hemispheric differences. Thus, using advanced imaging techniques such as PET, fMRI and TMS have revealed some key regions of brain activation during the processing of idioms and metaphors compared to literal language, and these findings have moved the discussion beyond the basic left versus right hemisphere dichotomy to a more refined understanding of different neural networks underlying the comprehension of figurative expressions. Overall, studies have shown increased activation for figurative expressions in certain RH areas: **right frontal and temporal areas** such as the **prefrontal cortex** (Bottini et al., 1994), **middle temporal gyrus** (Bottini et al., 1994; Proverbio et al., 2009; Sotillo et al., 2005), **precuneus** (Bottini et al., 1994) and **superior temporal gyrus** (Ahrens et al., 2007; Sotillo et al., 2005). Metaphors have also been shown to activate the **right medial frontal gyrus** (Proverbio et al., 2009; Schmidt & Seger, 2009). Particularly for unfamiliar/novel metaphors, studies have revealed activation in the **right insula** (Mashal et al., 2005; Schmidt & Seger, 2009), the **right IFG** (Ahrens et al., 2007; Mashal et al., 2007; Schmidt & Seger, 2009) and the **right PSTS** (Mashal et al., 2007; Pobric et al., 2008). In the LH, key areas of activation for metaphoric language include the **left IFG**, particularly for familiar metaphors (Ahrens et al., 2007; Eviatar & Just, 2006; Mashal et al., 2007; Proverbio et al., 2009; Stringaris et al., 2007) and the **medial frontal gyrus** (Mashal et al., 2007). The **left precentral gyrus** and the **left inferior parietal lobe** have also been implicated in metaphor comprehension (Stringaris et al., 2007). However, identifying key brain structures is only a first step, as the specific factors contributing to their activation is still poorly understood, as it will be further discussed below. Our long-term goal in this field should be to develop a realistic model of how differences in task demands and the various dimensions both within and across different classes of idioms and metaphors work together and result in distinct patterns of brain activity during figurative language processing.

6. Challenges in synthesizing the literature

In spite of the important contributions highlighted above, however, more research is needed in order to carefully investigate the different factors which modulate activity in the two hemispheres and particularly in certain key brain structures. In addition, experiments on *idiom* comprehension are still necessary, as the studies conducted to date focus mainly on processing *metaphoric* language, both in terms of word pairs and sentential metaphors. It is unclear whether there would be differences in activation patterns across hemispheres for idioms compared to metaphors, and how this would be modulated by differences in characteristics such as compositionality, familiarity/salience and predictability. Crucially, several methodological limitations, discussed throughout this paper, present a true challenge in synthesizing the literature and deriving clear conclusions based on the evidence. Table 1 includes a summary of the divided visual field experiments and neuroimaging studies that have investigated hemispheric differences in figurative language processing. In addition to the studies cited in this paper, additional sources are included in Table 1 in order to provide a comprehensive look at the research that has been conducted to date. These studies encompass a variety of tasks and test different types of figurative language. Their main premise, methodology, stimuli, findings and conclusions are summarized in the table.

One major point is that there is a lack of clear consensus in the literature with respect to what exactly constitutes a metaphor. Researchers have examined the processing of word pairs that can either have a literal or metaphoric meaning. These word pairs can either be highly familiar and lexicalized ("bright student", "broken heart") or can be newly constructed, such that the words in the pair must be compared based on their salient features in order to derive the metaphoric meaning. However, it has been argued whether these word pairs should be considered "true metaphors" (as opposed to ambiguous literal words), as that they have become highly lexicalized over time, due to their high frequency and conventionality. While it is true that the word "bright" for "brilliant" may have originally derived its metaphoric meaning through a comparison with a light source, it can be argued that it is actually difficult to think of the word pair "bright student" as being a metaphor nowadays, rather than having a secondary meaning which is actually no longer figurative in use. It can be argued that it is dangerous to use such stimuli which are at the borderline between being considered literal vs. metaphoric, when directly assessing "figurativity". If one wishes to assess the effect of figurativity on brain mechanisms used during metaphor processing, it might be best to increase the distance as much as possible between literality and figurativity, rather than choosing experimental stimuli where the once-metaphoric meaning has now become highly frequent and conventional over time, that they could actually be construed as ambiguous *literal* words. On the other hand, if one wishes to examine different degrees of figurativity (by assessing "conventionality" as a factor, e.g., Faust & Mashal, 2007), then including a range of metaphors, including these highly conventional ones, is a good idea. However, when only assessing "metaphors" as a group in contrast to words with literal meaning, it may be considered a shortcoming to include these highly conventional, highly frequent "metaphoric" words where it is no longer clear that this is actually a *figurative* interpretation of the word. More importantly, it would also be unwise to mix these kinds of conventional metaphors (close to literal meaning) with more metaphoric word pairs, without explicitly examining "conventionality" as a factor. Moreover, in these studies, metaphoric word pairs are presented without a sentential context; thus, word-level investigations are limited to familiar metaphorical relationships that can be interpreted without a context (Schmidt, Kranjec, Cardillo, & Chatterjee, 2009). The processing of single metaphorically employed words may represent a different cognitive task than processing sentential metaphors and, therefore, reveal different lateralization effects. Furthermore, the processing of sentential metaphors is of interest because they are more similar than word pairs to natural language typically encountered by speakers.

Several other stimuli-based limitations challenge the synthesis of the literature on figurative language comprehension in the brain. One aspect of sentential metaphors which is often not addressed is the level of *syntactic complexity* of the expressions. Although length is often matched between experimental conditions, controlling for different syntactic constructions or lexical factors is often overlooked (Schmidt et al., 2007). Some sentential metaphors are variations of "*An A is a B*" (Bottini et al., 1994; Rapp et al., 2004; Stringaris et al., 2007), whereas others are more complex sentences (Proverbio et al., 2009; Schmidt et al., 2007). Studies also differ in the parts of speech they examine; some researchers have studied metaphors based on nouns (Rapp et al., 2004; Schmidt et al., 2007), others have looked at metaphors based on verbs (Chen et al., 2008) or adjectives (Lee & Dapretto, 2006; Mashal et al., 2005). As brain areas mediating metaphorical uses of various parts of speech may differ, these lexical differences are taken into account in order to obtain a clear picture of the neural basis of figurative language comprehension. Another methodological shortcoming that was touched on earlier on in this paper is the fact that, although factors such as familiarity and frequency may be controlled in some studies, the operational definitions differ across studies, as does the way in which these measures are obtained. It is not easy to tease apart subjective familiarity of an expression and its frequency in a language when asking subjects to provide ratings on a scale (as in Libben & Titone, 2008). Some studies use specific databases to obtain frequency and/or familiarity measures (Stringaris et al., 2005), while other researchers rely on internet-search results as a measure of familiarity (Rapp et al., 2004). In addition, studies investigating hemispheric differences in metaphor processing have often failed to control for factors such as literal plausibility and decomposability/transparency (how the figurative meaning may be derived from the words making up the expression) which are likely to affect the ease or difficulty of processing and perhaps the neural mechanisms (and degree of RH recruitment) involved in figurative language comprehension.

Another methodological factor which makes it difficult to obtain a straightforward picture of the specific brain areas involved in figurative language processing is that there has been considerable variability across studies in the nature of the tasks employed (Schmidt et al., 2009). Tasks have ranged from lexical decisions (Bottini et al., 1994), to literal plausibility judgments (Schmidt et al., 2007), to truth judgments (Faust & Weisper, 2000), to semantic judgment tasks (Faust & Mashal, 2007; Mashal et al., 2005; Proverbio et al., 2009) to judging whether or not the expression was meaningful (Schmidt et al., 2007; Stringaris et al., 2007). One study (Rapp et al., 2004) involved judging whether the sentences had a positive or negative connotation. Some tasks more strongly engage semantic integration processes (e.g. judging whether a word is metaphorically or literally related to another) compared to others (e.g. judging whether a word is a real word or non-word). Furthermore, tasks in which the demand is relatively high may lead to increased RH activation.

The contributions of neuroimaging to the study of figurative language processing are also hindered by several theoretical issues. As discussed in the context of studies supporting the claims of the *Graded Salience Hypothesis* (Giora, 1997, 2003) as well as the *Coarse Coding Hypothesis* (Beeman, 1998), research has not clearly distinguished between familiarity, salience and distance of semantic associations on a theoretical level. These are factors which are difficult to tease apart because they are highly correlated (Katz et al., 1988). It is, therefore, unclear how exactly these variables differ and how they might affect the neural networks underlying figurative and literal language processing, specifically the involvement of the RH. Future research will have to carefully disentangle these variables in order to provide a clearer picture of their relative role in figurative language comprehension.

6.1. Conclusions

The current paper has discussed one of the most hotly-debated questions in the domain of figurative language comprehension: whether the RH has a specific role to play in interpreting idiomatic and metaphoric expressions. Neuropsychological, behavioral and neuroimaging evidence both for and against the "RH is special" theory was critically synthesized and it was shown how characteristics such as meaning salience, familiarity and difficulty of figurative expressions are likely to modulate activity in different areas of the brain, perhaps even rather than figurativity per se. Such a view argues for the existence of a literal-figurative continuum rather than a strict dichotomy, as it was originally believed based on early behavioral and neuropsychological research. These findings are compatible with theories such as the *Coarse Coding Hypothesis* (Beeman, 1998) or the *Graded Salience Hypothesis* (Giora, 1997, 2003) which posit hemispheric differences in the way that distantly related semantic concepts and non-salient/unfamiliar meanings of strings are preferentially processed in the RH compared to the LH. However, although neuroimaging has paved the way and has made substantial contributions to our knowledge of hemispheric differences in semantic processing and in figurative language comprehension, much work is still to be done, particularly with respect to systematically investigating some of the critical methodological and theoretical issues that continue to blur the picture as it stands today.

Conflicts of interest

I declare that there are no actual or potential conflicts of interest, in terms of financial or personal conflicts with other collaborating individuals or organizations.

Acknowledgments

The author is funded by the Richard H. Tomlinson Doctoral Fellowship and the Vanier Canada Graduate Scholarship. Special thanks to Dr. Karsten Steinhauer and Dr. Debra Titone for their valuable comments on previous versions of this manuscript.

Appendix

Table 1
Summary of studies on figurative language (metaphors and idioms) using divided visual field (DVF), PET, fMRI, ERP and rTMS techniques. Main findings are summarized, as well as experimental design, type of figurative language tested, different conditions, characteristics of stimuli and experimental task. Studies are organized based on whether they support or refute claims of RH specificity for metaphor and idiom comprehension, or whether preferential RH involvement depends on factors such as familiarity and salience, rather than figurativity per se. Within each section, the studies are organized chronologically.

Study	Design	Conditions/stimuli	Task	Main findings
RH is special				
1. Bottini et al., 1994	$n = 6$, PET, block design	Novel sentential metaphors "An A is a B" vs. literal sentences Sentences either plausible/implausible	Plausibility judgment	Right frontal/temporal areas activated for metaphors vs. literal sentences (prefrontal cortex, middle temporal gyrus, precuneus
2. Anaki et al., 1998	$n = 56$, DVF (SOA = 200 or 800 ms)	Prime + target word pairs Metaphorically related, literally related, or unrelated	Lexical decision	Short SOA: priming for metaphorically-related in LVF and RVF priming for literally-related only in RVF (LH) Long SOA: priming for metaphorically-related in LVF only priming for literally-related in RVF only
3. Sotillo et al., 2005	$n = 24$ ERP with LORETA spatial analysis	Complex poetry sentences in Spanish. Unfamiliar metaphoric sentence followed by metaphorically related/ unrelated word	Relatedness judgment	Higher N400 activation for metaphoric words localized to right medial temporal gyrus and superior temporal gyrus
No preferential RH role				
4. Faust & Weisper, 2000	$n = 24$ DVF (SOA = 1100 ms)	Incomplete sentence primes followed by literally true, literally false or metaphoric sentence endings "Some A are B" sentences	Truth judgment	Slower RT and lower accuracy for metaphoric endings vs. literal endings, irrespective of hemisphere of presentation
5. Eviatar & Just, 2006	$n = 16$, fMRI (event related)	A 3-sentence story context was followed by metaphoric, ironic or literal sentence ending. Simple, familiar metaphors	Response to comprehension question	Metaphoric endings resulted in larger activation in left IFG and bilaterally in inferior temporal cortex compared to ironic and literal sentences
6. Lee & Dapretto, 2006	$n = 12$, fMRI	Adjective triads, either requiring literal or metaphoric interpretation of middle word	Semantic relatedness judgment on two last adjectives in triad	Metaphoric meanings led to activation of LH prefrontal and temporoparietal regions; no RH activations

(*continued on next page*)

Table 1 (*continued*)

Study	Design	Conditions/stimuli	Task	Main findings
7. Kacinik & Chiarello, 2007	$n = 48$ DVF (SOA = 600 ms)	Complex metaphoric and literal sentences followed by consistent/ inconsistent (figurativity) target words	Lexical decision	Metaphoric target words showed priming in both hemispheres
8. Rapp et al., 2004, 2007	$n = 15$, fMRI (event-related)	Novel metaphoric and literal sentences in German. "An A is a B" (May have been moderately familiar metaphors)	Judge positive/ negative connotation	No RH activations for metaphoric sentences vs. literal sentences
9. Stringaris et al., 2007	$n = 11$, fMRI (event-related)	Metaphoric, literal or non-meaningful sentences with only last word differing across conditions. Conventional "Some As are Bs" metaphors	Meaningful or meaningless judgment	Greater activation for metaphor sentences in LH regions (left IFG, left precentral gyrus, left inferior parietal lobe)
10. Proverbio et al., 2009	$n = 15$, ERP with source reconstruction	Idiomatic and literal Italian (complex) sentences followed by related or unrelated target word. Unfamiliar idioms, either decomposable or not, all literally implausible.	Semantic relatedness judgment between target and preceding sentence	Several LH and RH areas simultaneously active at different stages of processing idioms. Mainly engaged LH during initial access (left IFG), then bilaterally with larger effects over RH (in right MTG and right MFG)
RH activation mediated by familiarity				
11. Mashal et al., 2005	$n = 15$, fMRI (block design, PC analysis)	Metaphoric, literal or unrelated word pairs (Unfamiliar metaphors)	Semantic judgment (decide if literally or metaphorically related)	Unfamiliar metaphors activated a large network of LH and RH areas: left frontal and temporal areas, right Wernicke's area, precuneus and insula
12. Faust & Mashal, 2007	$n = 15$, DVF (SOA = 400 or 1100 ms)	Literal, conventional metaphoric novel metaphoric and unrelated word pairs (prime and target)	Semantic judgment	Facilitation in RH than LH (faster/more accurate responses) for novel metaphors, but not for other word pairs. RH judged NM as "related" faster than LH, and slower as "unrelated" than in LH. No RH advantage for CM.
13. Mashal et al., 2007	$n = 14$, fMRI	Literal, conventional metaphoric, novel metaphoric and unrelated word pairs (prime and target)	Semantic judgment	NM vs. CM: stronger activation in right PSTS, right IFG and left MFG. NM vs. literal: fewer, smaller, bilaterally active regions CM vs. literal: left IFG, left PSTS and right postcentral parietal cortex

Table 1 (*continued*)

Study	Design	Conditions/stimuli	Task	Main findings
14. Ahrens et al., 2007	$n = 8$, fMRI (block design)	Novel (NM) and conventional (CM) metaphors and literal sentences in Mandarin	No task (silent reading)	CM vs. literal sentences: Slight increase of activation in right inferior temporal gyrus NM vs. literal sentences: Increased activation bilaterally in frontal and temporal gyri CM vs. NM: Bilateral activation in MFG and precentral gyrus RH activation in STG; LH activation in IFG and fusiform
15. Arzouan et al., 2007	$n = 29$, ERP with LORETA spatial analysis	Literal, conventional, or novel metaphoric word pairs	Semantic judgment	Novel metaphors elicited activation in right temporal and superior frontal areas
16. Pobric et al., 2008	$n = 12$, rTMS	Literal, conventional, or novel Metaphoric word pairs	Semantic judgment	rTMS of right PSTS disrupted the processing of NM but not CM
17. Schmidt et al., 2007	$n = 90$, DVF	EXP 1: Literal, unfamiliar metaphoric and anomalous sentences EXP 2: Familiar literal, unfamiliar metaphoric and unfamiliar literal EXP 3: Familiar vs. unfamiliar metaphors In all EXPs, sentences identical until final word which differed across conditions	EXP 1: judging whether ending fits the sentence context EXP 2: plausibility judgment EXP 3: meaningful or meaningless judgment	RH advantage for unfamiliar sentences, regardless of figurativity. EXP 1: RH processing time advantage for metaphors; LH processing advantage for literal and anomalous endings EXP 2: Faster RH processing for unfamiliar sentences (both metaphoric and literal). No hemispheric differences for familiar literal sentences. EXP 3: RH advantage for unfamiliar metaphors and LH advantage for familiar metaphors
18. Schmidt & Seger, 2009	$n = 10$, fMRI	(1) Literal, (2) familiar + easy, (3) unfamiliar + easy, and (4) unfamiliar + difficult Metaphors	No task (press response key)	Metaphoric vs. literal: activation in right insula, left temporal pole and right IFG. Familiar vs. unfamiliar metaphors: right MFG Easy vs. difficult metaphors: greater activation in left MFG Difficult vs. easy metaphors: left IFG

References

Ahrens, K., Liu, H., Lee, C., Gong, S., Fang, S., & Hsu, Y. (2007). Functional MRI of conventional and anomalous metaphors in Mandarin Chinese. *Brain and Language, 100*, 163–171.

Anaki, D., Faust, M., & Kravetz, S. (1998). Cerebral hemispheric asymmetries in processing lexical metaphors. *Neuropsychologia, 36*(4), 353–362.

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, 99*(3), 223–236.

Arzouan, Y., Goldstein, A., & Faust, M. (2007). Dynamics of hemispheric activity during metaphor comprehension: electrophysiological measures. *Neuroimage, 36*, 222–231.

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

Blasko, D. G., & Connine, C. M. (1993). Effects of familiarity and aptness on metaphor processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*(2), 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*(6), 1241.

Bowdle, B. F., & Gentner, D. (2005). The career of metaphor. *Psychological Review, 112*, 193–216.

Brownell, H. H., Potter, H. H., Michelow, D., & Gardner, H. (1984). Sensitivity to lexical denotation and connotation in brain-damaged patients: a double dissociation? *Brain & Language, 22*, 253.

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

Burgess, C., Tanenhaus, M. K., & Hoffman, M. (1994). Parafoveal and semantic effects on syntactic ambiguity resolution. In *Proceedings of the Cognitive Science Society* (pp. 96–99). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Cacciari, C., & Glucksberg, S. (1991). Understanding idiomatic expressions: the contribution of word meanings. In G. Simpson (Ed.), *Understanding word and sentence* (pp. 217–240). Amsterdam: North- Holland.

Chen, E., Widick, P., & Chatterjee, A. (2008). Functional-anatomical organization of predicate metaphor processing. *Brain and Language, 107*, 194–202.

Chiarello, C. (1991). Meanings by cerebral hemispheres: one is not enough. In P. J. Schwanenflugel (Ed.), *The psychology of word meanings* (pp. 251–271). Hillsdale: Laurence.

Chiarello, C., Burgess, C., Richards, L., & Pollock, A. (1990). Semantic and associative priming in the cerebral hemispheres: some words do, some words don't sometimes, some places. *Brain and Language, 38*, 75–104.

Eviatar, Z., & Just, M. A. (2006). Brain correlates of discourse processing: an fMRI investigation of irony and conventional metaphor comprehension. *Neuropsychologia, 44*, 2348–2359.

Faust, M., & Chiarello, C. (1988). Sentence context and lexical ambiguity resolution by the two hemispheres. *Neuropsychologia, 36*(9), 827–835.

Faust, M., & Lavidor, M. (2003). Semantically convergent and semantically divergent priming in the cerebral hemispheres: lexical decision and semantic judgment. *Cognitive Brain Research, 17*, 585–597.

Faust, M., & Mashal, N. (2007). RH advantage in processing novel metaphor expressions: a DVF study. *Neuropsychologia, 45*, 860–870.

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

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.

Gibbs, R. W. (1999). Figurative language. In R. A. Wilson (Ed.), *The MIT encyclopedia of the cognitive sciences* (pp. 314–315). Cambridge, MA: MIT Press.

Gibbs, R. W., & Beitel, D. (1995). What proverb understanding reveals about how people think. *Psychological Bulletin, 118*, 133–154.

Gibbs, R. W., & Nayak, N. P. (1989). Psycholinguistic studies on the syntactic behavior of idioms. *Cognitive Psychology, 21*, 100–138.

Gibbs, R. W., Nayak, N. P., & Cutting, C. (1989). How to kick the bucket and not decompose: analyzability and idiom processing. *Journal of Memory and Language, 28*, 576.

Giora, R. (1997). Understanding figurative and literal language: the graded salience hypothesis. *Cognitive Linguistics, 7*, 183–206.

Giora, R. (2003). *On our mind: Salience, context and figurative language*. New York: Oxford University Press.

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 & Symbol, 15*(1–2), 63–83.

Glucksberg, S. (2001). *Understanding figurative language*. Oxford: Oxford University Press.

Glucksberg, S., & Keysar, B. (1990). Understanding metaphoric comparisons: beyond similarity. *Psychological Review, 97*, 3–18.

Kacinik, N. A., & Chiarello, C. (2007). Understanding metaphors: is the right hemisphere uniquely involved? *Brain and Language, 100*, 188–207.

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 Activity, 3*, 191–214.

Lakoff, G., & Johnson, M. (1980). *Metaphors we Live by*. Chicago: University of Chicago Press.

Lee, S. S., & Dapretto, M. (2006). Metaphorical vs. literal word meanings: fMRI evidence against a selective role of the right hemisphere. *Neuroimage, 29*, 536–544.

Libben, M., & Titone, D. (2008). The multidetermined nature of idiom processing. *Memory and Cognition, 36*(6), 1103–1121.

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

Mashal, N., Faust, M., Hendler, T., & Jung-Beeman, M. (2007). An fMRI investigation of the neural correlates underlying the processing of novel metaphoric expressions. *Brain and Language, 100*(2), 115–126.

Oliveri, M., Romero, L., & Papagno, C. (2004). Left but not right temporal involvement in opaque idiom comprehension: a repetitive transcranial magnetic stimulation study. *Journal of Cognitive Neuroscience, 16*, 848–855.

Papagno, C., Oliveri, M., & Romero, L. (2002). Neural correlates of idiom comprehension. *Cortex, 38*, 895–898.

Pobric, G., Mashal, N., Faust, M., & Lavidor, M. (2008). The role of the right cerebral hemisphere in processing metaphoric expressions: a transcranial magnetic stimulation study. *Journal of Cognitive Neuroscience, 20*, 170–181.

Proverbio, A. M., Crotti, N., Zani, A., & Adorni, R. (2009). The role of left and right hemispheres in the comprehension of idiomatic language: an electrical neuroimaging study. *BMC Neuroscience, 10*, 116–132.

Rapp, A. M., Leube, D. T., Erb, M., Grodd, W., & Kircher, T. 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.

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

Schmidt, G. L., Kranjec, A., Cardillo, E. R., & Chatterjee, A. (2009). Beyond laterality: a critical assessment of research on the neural basis of metaphor. *Journal of the International Neuropsychological Society, 16*, 1–5.

Schmidt, G. L., & Seger, C. A. (2009). Neural correlates of metaphor processing: the roles of figurativeness, familiarity and difficulty. *Brain and Cognition, 71*(3), 375–386.

Schweigert, W. A. (1986). The comprehension of familiar and less familiar idioms. *Journal of Psycholinguistic Research, 15*(1), 33–45.

Sotillo, M., Carretié, L., Hinojosa, J. A., Tapia, M., Mercado, F., Lopez-Martin, S., et al. (2005). Neural activity associated with metaphor comprehension: spatial analysis. *Neuroscience Letters, 373*, 5–9.

Stringaris, A. K., Medford, N. C., Giampetro, V., Brammer, M. J., & David, A. S. (2007). Deriving meaning: distinct neural mechanisms for metaphoric, literal, and non-meaningful sentences. *Brain and Language, 100*(2), 150–162.

Thoma, P., & Daum, I. (2006). Neurocognitive mechanisms of figurative language processing: evidence from clinical dysfunctions. *Neuroscience and Biobehavioral Reviews, 30*, 1182–1205.

Titone, D. A., & Connine, C. M. (1994). Comprehension of idiomatic expressions: effects of predictability and literality. *Journal of Experimental Psychology: Learning, Memory and Cognition, 20*(5), 1126–1138.

Titone, D. A., & Connine, C. M. (1999). On the compositional and non-compositional nature of idiomatic expressions. *Journal of Pragmatics, 31*, 1655–1674.

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

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