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Functional MRI of conventional and anomalous metaphors in Mandarin Chinese

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Abstract

This study looks at whether conventional and anomalous metaphors are processed in different locations in the brain while being read when compared with a literal condition in Mandarin Chinese. We find that conventional metaphors differ from the literal condition with a slight amount of increased activation in the right inferior temporal gyrus. In addition, when the anomalous metaphor condition is compared with the literal condition, increased activation occurs bilaterally in the frontal and temporal gyri. Lastly, the comparison between the anomalous and conventional metaphor conditions shows bilateral activation in the middle frontal gyrus and the precentral gyrus, and right-hemisphere activation in the superior frontal gyrus. Left hemisphere activation is found in the inferior frontal gyrus and fusiform gyrus. The left hemisphere activation in the frontal and temporal gyri point to the recruitment of traditional language-based areas for anomalous metaphor sentences, while the right-hemisphere activation found suggests that remote associations are being formed. In short, our study supports the idea that metaphors are not a homogenous type of figurative language and that distinguishing between different types of metaphors will advance theories of language comprehension.

Keywords: Functional MRI; Conventional metaphors; Novel metaphors; Anomalous metaphors; Mandarin Chinese; Graded salience hypothesis

1. Introduction

The involvement of the left hemisphere in language processing is well-established, but the role of the right hemisphere is less well-understood. Studies of aphasic patients suggest that the right hemisphere plays a role in generating lexical items that are remotely associated from a target (Joanette, Goulet, & Le Dorze, 1998), as well as in discourse comprehension (Benowitz, Moy, & Levine, 1990), and humour (Shammi & Stuss, 1999). Right-hemisphere-damaged patients also have difficulties suppressing ambiguous meanings (Tompkins, Baumgaertner, Lehman, & Fossett, 1997), understanding connotative meanings of words (Brownell, Potter, & Michelow, 1984), and comprehending metaphors (Brownell, Simpson, Bihrle, Potter, & Gardner, 1990; Winner & Gardner, 1977; for an overview see Burgess & Chiarello, 1996). All these studies involve accessing and understanding meaning, and suggest that the right hemisphere is used, when necessary, to comprehend novel or distant semantic relationships.

Conceptual metaphors are one type of linguistic phenomenon (similes and analogies are two others) that makes use of relationships between semantic domains to process information at a higher level. When we comprehend a conceptual metaphor, we use information from a concrete semantic domain to understand concepts in another, more abstract semantic domain. For example, productive conceptual metaphors have a set of mappings between a concrete source domain (i.e., JOURNEY) and an abstract target (i.e., LOVE) domain, as in the example "Their relationship hit a dead-end" (Lakoff, 1993; Lakoff & Johnson, 1980).

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Conceptual metaphors can be conventional, and encoded in the lexicon. For example, "foundation" thus has two conventionalized meanings: one is the literal meaning of a base for a building, and the second is the metaphorical meaning of a base for a concept, as in the following example from the IDEA IS A BUILDING metaphor, "She doesn't think his theory has any foundation." However, conceptual metaphors can also be so novel as to be anomalous, as in "The two sides are digesting natural resources." In this example, the source domain of FOOD is paired with the target domain of ECONOMY, a pairing which never occurs in English (cf. ECONOMY IS WAR, as in "The two sides are battling for natural resources" and IDEA IS FOOD, as in "The two sides are digesting the terms of the accord").

Giora and colleagues have proposed a theory of language processing, the graded salience hypothesis, which claims that salient and non-salient language will involve different brain regions (Giora, 2003; Giora, Zaidel, Soroker, & Kasher, 2000). In particular, salient meanings (i.e., meanings that are encoded in the mental lexical lexicon), will primarily involve the left hemisphere. Conventional metaphorical meanings are considered salient. However, meanings that are non-salient (i.e., not encoded in the lexicon or are constructed on the fly) are postulated to involve primarily right-hemisphere processing, because the right hemisphere specializes in reinterpreting linguistic information that was not able to be processed on the first pass. Anomalous metaphors fall in this category. The graded salience hypothesis contrasts with the standard pragmatic model which proposes that any type of metaphorical language is processed with different mechanisms than that of literal language.

Giora et al. (2000) found that left brain-damaged patients had significantly more difficulty than right brain-damaged patients and age-matched controls in explaining four metaphorical phrases in Hebrew. In addition, there was a significant negative correlation between test scores and lesion extent in the left middle temporal gyrus and surrounding areas. This finding was surprising given that a previous PET neuro-imaging study by Bottini et al. (1994) found right-hemisphere activation when participants decided on the plausibility of metaphorical sentences as compared with the plausibility of literal sentences.

In that study, Bottini et al. found significant activation in the right hemisphere in the frontal region (BA 8 and 46), middle temporal gyrus (BA 21), precuneus (BA 31), anterior, and posterior cingulate (BA 32 and 31), when deciding on the plausibility of metaphorical versus literal sentences. They postulated that the frontal lobe was used to retrieve information from episodic memory when completing the plausibility task or perhaps was used to comprehend metaphors through mental imagery. The precuneus was also suggested to have a role in long-term memory function, while the middle temporal gyrus was related to processing complex tasks. In short, they proposed that their findings argued for a role of the right hemisphere in performing complex language operations, such as interpreting connotative meaning.

Bottini et al.'s study, while important for its contribution to understanding the right hemisphere's role in language processing, has methodological issues that need to be addressed. One issue is that the level of plausibility for the metaphorical sentences is lower overall than that of the literal sentences (i.e., 79% versus 95%). Thus, it was harder for participants to decide if the metaphorical sentences were plausible or not, which was reflected in the hit rate between the two groups (Bookheimer, 2002). This could mean that the right-hemisphere activation was not a result of processing metaphors, it was instead a result of the difference in difficulty to making a plausibility decision. Newman, Just, and Carpenter (2002) and Stowe et al. (1998), for example, argue that the right frontal gyrus is recruited for problem-solving.

In addition, in a recent study on metaphor processing in German, Rapp, Leube, Erb, Grodd, and Kircher (2004) suggested that the right-hemisphere activation that Bottini et al. found might be a result of the complexity of the stimuli used. They followed up on Bottini et al.'s study by asking participants to judge whether literal and metaphorical sentences had positive or negative connotations in an event-related fMRI experiment. The stimuli consisted of 60 novel metaphors and 60 literal sentences with a simple predicating 'X is/are Y' structure. They found that reading metaphorical sentences activated signal changes in the left lateral inferior frontal (BA 45 and 47), inferior temporal (BA 19 and 20), and posterior middle/inferior temporal (BA 37) gyri. They suggested that the left inferior frontal gyrus, in particular, has been associated with semantic comprehension (see Bookheimer, 2002 for an overview).

Rapp et al. (2004), following up on Winner and Gardner's (1977) point that the manner of presentation or the response asked for in aphasic studies could influence results, postulated that their lack of a RH activation might be a result of the design used (event-related versus block), or the different task instructions given (determining positive or negative connotation versus determining plausibility). Rapp et al. also suggested that another critical difference might have to do with the fact that different types of stimuli were used (i.e., simple predicate metaphors in Rapp et al. versus more structurally complex metaphors such as "Tim had been poured into his clothes and forgotten to say when" in Bottini et al.), since evidence suggests that the right superior and middle temporal gyri are involved in complex syntactic and semantic processing at the sentence level (Kaan & Swaab, 2002; Kircher, Brammer, Tous-Andreu, Williams, & McGuire, 2001). If any of the above explanations are correct, such that Bottini's results have to do with making a plausibility decision or with complexity in sentence processing, then their long-standing finding that metaphors are processed in the right hemisphere will be called into doubt. On the other hand, if Rapp et al.'s interpretation of their findings holds up, then Giora's et al.'s hypothesis that novel metaphors (i.e., non-salient language) will be primarily processed in the right hemisphere will be called into question, since Rapp et al. considered their metaphors novel, yet only left hemisphere activation was found.

In this study, we use a block design with silent reading and sentential stimuli that are 11–12 characters in length and have varied syntactic structure. Our study will examine the issue of the localization of metaphor processing in terms of degree of novelty by looking at three conditions: a literal sentence condition, a conventional conceptual metaphor condition, and an anomalous metaphor condition. We examine these two metaphor types to investigate the different predictions made by the graded salience hypothesis: in particular, conventional metaphors and literal sentences should not differ to a large extent in their processing location, while anomalous metaphors should show right-hemisphere activation when compared with both conventional metaphors and literal sentences.

2. Method

2.1. Participants

Participants were eight right-handed, neurologically normal males students from Chang Gung University (mean age = 21 years, ranging from 20 to 22 years). They were all native speakers of Mandarin Chinese and right-handed by self-report. All gave informed consent using a form approved by Chang Gung University Hospital and were paid for their participation.

2.2. Materials and procedures

Three types of sentential stimuli were created: conventional metaphor sentences (1), anomalous metaphor sentences (2), and literal sentences (3). The conventional metaphors were all created from source–target domain pairings that were determined by a group of native speakers to be conventional target domain pairings in Mandarin Chinese as spoken in Taiwan (i.e., IDEA and FOOD). The anomalous metaphors were created out of source and target domain pairings that were determined by a group of native speakers to never occur in Mandarin Chinese as spoken in Taiwan (i.e., BUSINESS IS A SONG and TIME IS A PLAY) (Ahrens, 2002).

Each condition had 36 sentences, for a total of 108 sentences. A pre-test was run to select these 108 sentences. In this pre-test, 15 college-age participants determined the interpretability level for 300 sentences (100 sentences for each type) on a scale of 1 'not understandable to 7 'understandable.' Thirty-six sentences were then selected from each group based on their interpretability ratings. Each sentence in the conventional metaphor group and the literal sentence group received an interpretability rating of 7.0, while the sentences in the anomalous metaphor condition had an average rating of 1.76 (range between 1.13 and 2.33). We ran this pretest to ensure that the conventional metaphor sentences and literal sentences were equally understandable, so that any differences found between these two conditions could not be attributed to the fact that conventional metaphor sentences are less comprehensible than the literal sentences.

In addition, all sentences were approximately the same length (average length = 11.4 characters, ranging between 11 and 12 characters) and the different types of syntactic structures used (subject–verb–object, subject–verb, predicating, and complex sentences including subordinate clause constructions, serial verb constructions, and passive verb constructions) were evenly distributed across the three groups of stimuli. A further pre-test was run on 11 participants to determine the approximate amount of time need to read sentences of these lengths and types, to give the participants enough time to complete reading each sentence when in the scanner. The pre-test showed that the average amount of time needed to read these sentences was 1216 ms ($SD = 561$ ms). Conventional metaphor sentences averaged 1122 ms ($SD = 504$ ms), anomalous metaphors sentences averaged 1421 ms ($SD = 662$ ms) and literal sentences averaged 1096 ms ($SD = 517$ ms). A Bonferroni post hoc test shows that the anomalous metaphors are read more slowly than both conventional metaphors ($p < .05$) and literal sentences ($p < .05$). Furthermore, there is no significant difference in reaction times between the conventional metaphors and literal sentences ($p = 1$).

Participants were instructed to read each sentence and press a button when they finished. They were also given a

(1) Conventional metaphor sentence

Zhe ge	lilun	de	jiagou	feichang	songsan
This CL	theory	POSS	framework	very	loose

"The framework of this theory is very loose." (IDEA IS A BUILDING)

(2) Anomalous metaphor sentence

ta-men	de	ziben	feichang	you	jiezhougan
Their	POSS	capital	very	has	rhythm

Their (financial) capital has a lot of rhythm. (BUSINESS IS A SONG)

(3) Literal sentence

ta	zhengtian	zai	tushuguan	limian	kanshu
He	whole day	in	library	inside	study

He studied in the library the whole day

block of stimuli (including a fixation block, a conventional metaphor block, an anomalous metaphor block, and a literal sentence block) to practice on a computer outside the scanner. The sentences in the practice block were different from the sentences that they saw later in the scanner.

Eighteen blocks of stimuli were run in total, with six blocks for each of the three sentential conditions (conventional metaphor (C), anomalous metaphor (A), and literal sentence (L)). These sentential conditions are presented in random order and interleaved with a fixation condition (F).

The fixation condition lasted 12 s. Each sentential condition lasted 21 s. In the sentential condition, each sentence was displayed for 3.5 s (above a cross) and then the sentence went off and the cross remained on the screen for 500 ms before the next sentence was presented. The experiment started with the fixation condition and lasted for 9 min and 54 s.

2.3. Image acquisition and analysis

The fMRI experiment was performed using a 1.5 T Siemens Vision MRI scanner (Erlangen, Germany). Prior to the MRI scan, the subject was visually familiarized with the procedures and the experimental conditions to minimize anxiety and enhance task performance. Following this familiarization, the subject lay supine on the scanning table and was fitted with plastic ear-canal molds. The subject's head was immobilized by a tightly fitting, thermally molded, plastic facial mask that extended from the hairline to the chin.

A single shot, T_2^*-weighted gradient-echo echo planar imaging (EPI) sequence was used for the fMRI scans, with the slice thickness = 5 mm, in-plane resolution = 3×3 mm, and TR/TE/θ = 3000 ms/60 ms/90°. The field of view was 192×192 mm, and the acquisition matrix was 64×64. Twenty-four contiguous axial slices were acquired to cover the whole brain. For each slice, 198 images were acquired. The anatomical MRI was acquired using a T_1-weighted, three-dimensional, gradient-echo pulse-sequence. This sequence provided high resolution ($1 \times 1 \times 1$ mm) images of the entire brain.

We used Matlab Version 6.5 (The Math Works, Natick, MA) and in-house software for image data processing (Xiong, Gao, Lancaster, & Fox, 1995). Each subject's raw EPI images were spatially smoothed by convolution with a 3D Gaussian kernel (FWHM = 8 mm), and motion was corrected with a six-parameter, rigid-body algorithm using MEDx (Sensor System, Sterling, VA, USA). Skull stripping of the 3D MRI T1-weighted images was carried out using Alice (Perceptive Systems, Boulder, CO, USA) and MEDx. These images were then spatially normalized to the Talairach brain atlas (Talairach & Tournoux, 1988) using the Convex Hull algorithm (Lancaster et al., 1997, 1999).

Functional images were grouped into fixation, conventional metaphor, anomalous metaphor, and literal sentence groups. Images from the first 6 s of each block were excluded from further functional data processing to minimize the transit effects of hemodynamic responses. Activation maps were calculated by comparing images acquired during different conditions using a students' group t test. Like the T_1-weighted anatomical images, the activation maps were also spatially normalized into Talairach space using the Convex Hull algorithm. Activation maps were calculated by comparing images acquired during different conditions using a students' group t test, and then the t scores were transferred into Z values. Like the T_1-weighted anatomical images, the activation maps were also spatially normalized into Talairach space using the Convex Hull algorithm. The averaged activation maps across the eight subjects with a Z value threshold of 3.1 ($p < .001$) on the single voxel level and an extent threshold of at least 400 mm^3 voxels were then overlaid on the corresponding T_1 images. For each condition, Talairach coordinates of the local maxima of the activation clusters were determined based on the averaged activation maps. Anatomical labels (lobes, gyri) and Brodmann area (BA) designations were applied automatically using a 3D electronic brain atlas (Lancaster et al., 1997).

3. Results

3.1. Behavioral performance

The average reaction time to the literal condition was1484 ms, to the conventional metaphor condition was 1540 ms and to the anomalous metaphor condition was 1657 ms. Reaction times were tested by one-way ANOVA. The statistical results shows that there is a significant difference among groups ($F(2, 841) = 8.016$, $p < .05$). A Bonferroni post hoc test also shows that the anomalous metaphors are read more slowly than both conventional metaphors ($p < .05$) and literal sentences ($p < .05$). Furthermore, there is no significant difference in reaction times between the conventional metaphors and literal sentences ($p = .622$).

3.2. Brain activations

3.2.1. Conventional metaphors—literal sentences condition

As shown in Table 1 and Fig. 1 (Row A) there was slightly greater activation in the right inferior temporal gyrus (BA 20) when the conventional metaphor condition was compared with the literal sentences condition.

3.2.2. Anomalous metaphors—literal sentences condition

As shown in Table 2 and Fig. 1 (Row B) there was activation in the right hemisphere, in the superior, middle, inferior, and medial frontal gyrus (BA 8, 9, 11, 45, 46, and 47), precentral gyrus (BA 6 and 9) temporal gyrus (BA 20, 21, and 22), inferior occipital gyrus (BA 18 and 19), and insula (BA 13). There was also activation in the left hemisphere, in the superior, middle, inferior and medial frontal gyrus

Table 1
Regions of significant activation for conventional metaphor sentences as compared with literal sentences

Regions	Side	BA	Coordinates			
			x	*y*	*z*	*Z* max
Temporal						
Inferior temporal G	R	20	54	−24	−16	3.89

Note. BA, Brodmann's areas; *x*, *y*, and *z*, Talairach coordinates; G, gyrus; $p < .001$, uncorrected.

(BA 6, 8, 9, 11, 32, 45, and 46), precentral gyrus (BA 4), temporal gyrus (BA 21 and 38), fusiform gyrus (BA 37), inferior occipital gyrus (BA 18), cingulate gyrus (BA 24), and insula (BA 13).

3.2.3. Anomalous metaphors—conventional metaphor condition

As shown in Table 3 and Fig. 1 (Row C) there was activation in the right hemisphere in the superior and middle frontal gyrus (BA 6, 8, and 9), precentral gyrus (BA 6), and inferior occipital gyrus (BA 19). There was also activation found in the left hemisphere, notably in the middle and inferior frontal gyrus (BA 8, 9, 13, 44, 45, 46, and 47), precentral gyrus (BA 4 and 6), and fusiform gyrus (BA 37).

4. Discussion

The results from the behavioral data indicate that there was no difference in reading time for the conventional metaphor stimuli and the literal sentences. This was predicted and similar to what was found in our pre-test. In addition, the anomalous metaphors were read more slowly than either conventional metaphor or literal sentences. This increase in reaction time indicates that the participants were actually reading the anomalous sentences and not just pressing the button upon seeing a sentence presented.

In terms of neuro-imaging results, our study demonstrates that conventional metaphors are recruiting a small amount of right-hemisphere resources in the inferior temporal gyrus as compared with literal sentences. Bottini et al. (1994) found activation in the right middle temporal gyrus and attributed it to either complex semantic judgments or metaphor appreciation; however, no judgment was involved in our task as this was a straightforward reading paradigm. St. George, Kutas, Martinez, and Sereno, (1999) found right middle temporal sulcus activation when participants read untitled paragraphs (as compared to reading titled paragraphs), and Nichelli et al. (1995) also found greater activation in the right middle temporal gyrus when participants monitored Aesop's fables for their moral as compared with monitoring it for a semantics feature of the main character. While Nicelli et al. discussed their findings in terms of the right hemisphere's role in thematic processing, St. George et al. (1999) argued for it being involved in an attempt to build a coherent model of discourse.

However, the underlying reason for the slight right temporal activation that we found in the conventional versus literal condition is less clear. It could simply be an artifact of the block design, since it is the nature of the block design to emphasize the sameness of the stimuli under study. In a block design, participants see sentences from the same condition (in our case, six sentences of the same type). It is possible that participants are adopting different cognitive strategies when reading these sentences one after another than they would if they were not aware (or less aware) that the sentences they were reading involved conceptual metaphors. Thus, it might be the case that when participants are not aware they are processing conventional metaphor sentences, no additional cortical resources will be used. This might be done in an event-related functional MRI experiment where equally intepretable literal and metaphorical sentences are inter-mixed. An alternate possibility is that conventional metaphors do recruit additional resources to

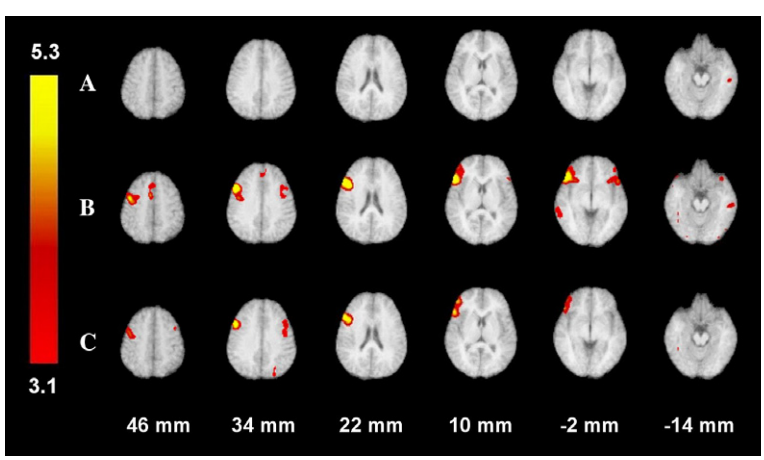

Fig. 1. Areas of activation for conventional metaphor sentences as compared with literal sentences (A), areas of activation for anomalous metaphor sentences as compared with literal sentences (B), areas of activation for anomalous metaphor sentences as compared with conventional metaphor sentences (C). The right hemisphere is projected to the right-hand side of the figure.

Table 2
Regions of significant activation for anomalous metaphor sentences as compared with literal sentences

Regions	Side	BA	Coordinates x	y	z	Z max
Frontal						
Superior frontal G	L	6	−4	6	50	5.11
	R	8	2	26	50	4.19
Middle frontal G	L	6	−44	2	48	5.09
	L	8	−50	14	36	6.33
	L	9	−50	18	32	6.76
	L	11	−42	34	−10	4.20
	L	46	−48	20	26	6.82
	R	8	50	14	38	3.26
	R	11	40	34	−10	3.83
	R	46	46	18	26	3.39
Inferior frontal G	L	45	−52	28	4	6.99
	R	45	52	24	4	4.04
	R	47	50	20	−2	4.43
Precentral G	L	4	−34	−18	56	3.47
	R	6	42	0	36	3.99
	R	9	40	16	36	3.76
Medial frontal G	L	8	0	38	38	4.25
	L	32	−4	6	46	4.42
	R	9	8	50	34	3.18
Temporal						
Superior temporal G	L	38	−56	12	−10	3.53
	R	22	52	14	−4	3.18
Middle temporal G	L	21	−58	−44	0	3.41
	R	21	56	−24	−14	3.68
Inferior temporal G	R	20	52	−26	−14	3.47
Fusiform G	L	37	−44	−46	−20	4.80
Occipital						
Inferior occipital G	L	18	−28	−88	−20	3.68
	R	18	34	−84	−16	3.31
	R	19	46	−72	−16	3.39
Other areas						
Cingulate G	L	24	−4	2	46	3.64
Insula	L	13	−44	28	4	5.25
	R	13	34	22	−2	4.20

Note. BA, Brodmann's areas; *x*, *y*, and *z*, Talairach coordinates; G, gyrus; $p < .001$, uncorrected.

Table 3
Regions of significant activation for anomalous metaphor sentences as compared with conventional metaphor sentences

Regions	Side	BA	Coordinates x	y	z	Z max
Frontal						
Superior frontal G	R	6	4	24	56	3.53
	R	8	6	24	50	3.53
Middle frontal G	L	8	−48	12	36	5.12
	L	46	−48	22	24	5.83
	R	8	48	10	38	3.54
	R	9	46	16	34	3.96
Inferior frontal G	L	9	−50	20	26	6.20
	L	13	−44	28	6	3.76
	L	44	−48	10	20	3.98
	L	45	−52	28	6	5.46
	L	47	−50	30	0	5.09
Precentral G	L	4	−36	−12	54	3.28
	L	6	−44	0	48	4.54
	R	6	44	−2	36	3.85
Temporal						
Fusiform G	L	37	−46	−48	−20	4.59
Occipital						
Inferior occipital G	R	19	22	−76	38	3.96

Note. BA, Brodmann's areas; *x*, *y*, and *z*, Talairach coordinates; G, gyrus; $p < .001$, uncorrected.

interpret the metaphor's meaning. In either case, Giora's graded salience hypothesis, which predicts that salient meanings are processed primarily in the left hemisphere, received support from our study since only a small amount of right-hemisphere resources were used when reading conventional metaphors.

Additional findings in our study showed that the resources recruited for the conventional metaphor versus literal condition differed from the areas recruited in the anomalous metaphor versus literal condition, where increased activation occurs bilaterally in the frontal gyri, temporal gyri, inferior occipital gyrus, and insula. Although it has been suggested that the right frontal lobe is involved in active responses or judgments (Bookheimer, 2002) and problem-solving in relation to working memory constraints (Newman et al., 2002; Stowe et al., 1998), and the right temporal lobe is involved in generating sentence completions (Kircher et al., 2001), the task here was simply a reading task. Since no overt problem solving or judgments were involved, the right-hemisphere activation found cannot be directly attributed to task demands. However, the right hemisphere has been shown to be involved in the processing of unusual semantic relationships (Seger, Desmond, Glover, & Garbrieli, 2000), distant meaning associations (Beeman, 1998; Beeman et al., 1994), and semantic anomalies (Kang, Constable, Gore, & Avrutin, 1999).

In addition, to comprehend the anomalous metaphor sentences, participants need to hold the semantic attributes of both the source and target domain in memory to ascertain if there is a viable interpretation, which could lead to an increase in the working memory load. Rypma, Prabhakaran, Desmond, Glover, and Garbrieli (1999), for example, found that activation of the left caudal inferior gyrus was observed for a mild increase in working memory load, but bilateral activation occurred in the middle and superior frontal gyri when there was a substantial increase in memory load. Noesselt, Shah, and Jäncke (2003) also found that their semantic categorization condition activated the inferior frontal gyrus and middle frontal gyrus bilaterally when compared to a passive listening condition and attribute this finding to the increase in working memory for the semantic categorization condition.

In addition, the left inferior frontal gyrus activation may involve the activation of an executive system for semantic tasks (Gabrieli, Poldrack, & Desmond, 1998), or controlled semantic retrieval (Wagner, Paré-Blagoev, Clark, & Poldrack, 2001). Baumgaetner, Weiller, and Buchel (2002), moreover, found in a region-of-interest analysis for the left inferior frontal and left posterior middle temporal areas that both unexpected and anomalous completions activated these areas when compared to expected completions. The left temporal activation, moreover, may be attributed to semantic integration. For example, when Ni et al. (2000) looked at violation of semantic selectional restriction rules, they found activation in the left superior temporal areas, and Kuperberg et al. (2000) had a similar finding for pragmatic violations as compared with syntactic/semantic violations. Moreover, Kuperberg et al. (2003) also found increased activation in both left temporal and left inferior frontal regions for pragmatic anomalies as compared with non-violated sentences.

In addition, the left fusiform gyrus activation found in this study is noteworthy because it has been argued to be a visual word form area (Cohen et al., 2002), based on lesions sites of patients with alexia. Price and Devlin (2003) reviewed studies demonstrating that this area is also activated in tasks that do not involve any visual word components. Thus, while our study was a reading study, the left fusiform gyrus activation we found here cannot be attributed to reading, since all three conditions were read. Instead, as Price and Devlin (2003) discuss, the left midfusiform is activated in response to visual, auditory, and tactile input, and is a possible "convergence zone" for neural loops (Damasio & Damasio, 1994), which interact with other brain regions.

Furthermore, the comparison between the anomalous and conventional metaphor conditions shows activation in the left fusiform gyrus and left inferior frontal gyrus, as well as bilateral activation in the middle frontal gyrus and precentral gyrus. Right-hemisphere activation is found in the superior frontal gyrus and the inferior occipital gyrus. This difference in activation area for anomalous metaphors as compared with conventional metaphors may be further evidence against the standard pragmatic view, but further evidence for theories of metaphor processing that allow for differences among metaphor types, such as the graded salience hypothesis (Giora et al., 2000). However, it may also be argued that the extensive right-hemisphere activation was a result of the fact that the anomalous metaphor interpretability levels were much lower than that the literal sentences (1.76 versus 7 on a scale of 1 to 7), because although we could control for interpretability levels in the conventional metaphor condition, it is the nature of anomalous metaphorical sentences to have very low interpretability levels, as Rapp et al. (2004) points out.

In fact, when we compare the three studies, we find that the Rapp study suggests that the only the left hemisphere resources are recruited when comprehending semantically novel metaphorical sentences, and the Bottini et al. (1994) study suggests that only the right hemisphere is recruited, while our study suggests that *both* hemispheres play a role in comprehending novel metaphors. Our finding is in line with several recent studies. For example, in a lesion study, Gagnon, Goulet, Giroux, and Joanette (2003) found that both left-hemisphere- and right-hemisphere-damaged patients had a semantic deficit for processing metaphoric meaning of words. Faust and Weisper (2000), using visual field priming study, found that target word responses to metaphoric sentences were slower and less accurate as compared with false sentences for both the right and left visual fields. In addition, Zaidel, Kasher, Soroker, and Batory (2002) adapted the Right Hemisphere Communication Battery (Gardner & Brownell, 1986) for Hebrew and tested it on both right brain-damaged and left brain-damaged patients and found that, with respect to metaphors (as well as other pragmatic uses of language), both the left and right hemisphere contributes to their language performance.

Thus, in light of the fact that there is evidence for bi-hemisphere comprehension of metaphors, it is necessary to compare the differences in activation areas and tasks used in the three neuro-imaging studies on metaphor to date. Bottini et al. (1994) find right-hemisphere activation when participants made plausibility decisions to long metaphorical sentences as compared with literal sentences in English. Rapp et al. (2004) found left frontal and temporal activation when participants made positive or negative connotation decisions to short "X is Y" types of metaphors in German as compared with literal sentences. In our study, we found bilateral frontal and temporal activation when participants read anomalous medium-length metaphorical sentences as compared to literal sentences in Chinese. In short, language, task, and sentence type all varied. Other differences included the fact that this study and Bottini's were both block designs (as compared to Rapp et al.'s which was an event-related design), and the number of participants in each study varied (i.e., Bottini's study involved six male participants, our study involved eight male participants and Rapp et al.'s involved 15 participants (six female and nine male)).

Assuming that languages are processed similarly in terms of sentence-length reading-based tasks, and that design and number of participants was appropriately chosen (although this point is open to interpretation), this leaves the possibility of experimental task and sentence type influencing the results. It is possible that Rapp et al.'s short sentence structures did not require any additional resources outside the traditional language areas of the brain. In addition, the predicating structure for both the literal and metaphorical sentences could have led the participants to treat the sentences as simple categorizing statements. Another possibility is that the given task of deciding whether the sentence had a positive or negative connotation could also have been treated by participants as a type of category test. Thus, the confluence of both the task (categorizing) and sentence type (simple predicating structures) might only recruit left hemisphere resources. Hugdahl et al. (1999), for example, found that the left middle frontal gyrus was activated when subjects were required to silently generate words related to a specific semantic category. If this is the case, then we postulate that using more complex sentence structures in a reading task involving anomalous metaphor sentences versus literal sentences will show both left and right-hemisphere activation.

Another possibility has to do with the level of anomalousness in Rapp et al.'s study as compared with our own. In our study, it might be the case that right-hemisphere resources were recruited because our source-target domain pairs for anomalous metaphors were more distant than in Rapp's study. (We rule out syntactic structure as a factor because in our study different syntactic structures occurred evenly among the three different groups.) For example, when we compare the interpretability rating for our anomalous sentences versus Rapp et al.'s we find that ours were rated 1.76 on a scale of one (not understandable) to seven (understandable) while his were rated 4.56 on a scale of one (not understandable) to six (understandable). One way to get around this question in the future is to select novel metaphor sentences that are not anomalous, but are still novel.

In short, recent linguistically based theories on metaphor have focused on the differences in degree in different types of metaphor and found support in experimental studies for such differences. For example, Giora's Graded Salience Hypothesis found support in a study of aphasic patients (Giora et al., 2000); Fauconnier's Conceptual Blending Theory found support in an ERP study (Coulson & Van Petten, 2002) and Ahrens' Conceptual Mapping Model found support in off-line rating studies (Ahrens, 2002). The slicing of metaphors into operationally defined semantic categories is clearly the area where further discoveries are to be made. No longer can conventional and novel metaphors be grouped together into a 'metaphor' group as compared with literal expressions. Instead, using finer-grained distinctions to categorize metaphors into different groups will improve our overall understanding of sentence-level semantic processing. In sum, out study demonstrates that the area of activation associated with metaphor processing is dependent upon the degree of conventionality of the metaphor, with highly conventional metaphors recruiting only a small amount of right temporal resources, and anomalous metaphors recruiting a larger amount of bilateral frontal and temporal cortex as compared with literal sentences.

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