Does Simile Comprehension Differ from Metaphor Comprehension?

-A functional MRI Study-

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Abstract

Since Aristotle, people have believed that metaphors and similes express the same type of figurative meaning, despite the fact that they are expressed with different sentence patterns. In contrast, recent psycholinguistic models have suggested that metaphors and similes may promote different comprehension processes. In this study, we investigated the neural substrates involved in the comprehension of metaphor and simile using functional magnetic resonance imaging (fMRI) to evaluate whether simile comprehension differs from metaphor comprehension or not. In the metaphor and simile sentence conditions, higher activation was seen in the left inferior frontal gyrus. This result suggests that the activation in both metaphor and simile conditions indicates similar patterns in the left frontal region. The results also suggest that similes elicit higher levels of activation in the medial frontal region which might be related to inference processes, whereas metaphors elicit more right-sided prefrontal activation which might be related to figurative language comprehension.

Keywords: metaphor; simile; literal sentence; fMRI; inferior frontal gyrus

1. Introduction

A metaphor is a figurative statement expressed by means of a copula sentence (An X is a Y), whereas a simile is a figurative statement using a hedge word such as "like" or "as" (An X is like a Y). With these explicit remarks, simile is literally true assertion. Though metaphor and simile use different sentence patterns, it has traditionally been considered that they express almost the same figurative meaning and that a metaphor can be paraphrased as a simile. Aristotle stated in Rhetoric, "The Simile is also a metaphor, the difference is but slight". According to his theory, metaphors are abbreviated similes. For example, "My lawyer is a shark" is an abbreviation of "My lawyer is like a shark".

In contrast, recent psycholinguistic models have suggested that metaphors are not abbreviated similes and that human understanding of the two figures of speech may rely on different comprehension processes. The class-inclusion model (Glucksberg & Keysar, 1990; Glucksberg, 2003) argues that simile can be understood as a process of comparison involving explicit remarks, while metaphor can be understood as a categorization process. In the sentence "My lawyer is like a shark", "shark" refers to the marine creature, whereas in the sentence "My lawyer is a shark", “shark” does not refer to the literal creature. In the latter case, the lawyer is categorized as a predator, and the shark is used to represent predators. Thus, the class-inclusion model argues that the comprehension processes used in understanding metaphor and simile differ.

Other experimental studies indicate that metaphors and similes differ in other respects. Chiappe and his colleagues (Chiappe & Kennedy 2000, 2001; Chiappe, Kennedy, & Smykowski, 2003) investigated whether properties of topic and vehicle affect subjects’ preference for the metaphor form. These studies demonstrated that where preference for metaphor exists, it can be explained by the similarity between a topic and a vehicle or by the aptness of the comparison. In cases in which the topic and the vehicle of the comparison are highly similar or in which the comparison is highly apt, the metaphor form is preferred over the simile form, while the simile form is preferred when the topic-vehicle similarity or the aptness of comparison is low. The authors also found that the degree of aptness of the topic-vehicle pairing influences the mental process used in understanding the metaphor. These experimental studies show that aptness and conventionality may impact metaphor and simile comprehension processes.

The results of these behavioral studies emphasize two issues. First, Glucksberg and his colleagues propose that the mental processes used in understanding metaphor and simile are different; simile can be understood as a comparison process with explicit remarks, while metaphor can be understood as a categorization process. Second, Chiappe and his colleagues presented data indicating that the properties of words (e.g., similarity or aptness between a topic and a vehicle) affect preference and comprehension processes.

Here, we focus on the sentence patterns of metaphor and simile, which, as described above, differ. Metaphor is expressed by means of a copula sentence, whereas a simile is expressed using a hedge word such as "like" or "as". Usually, a copula sentence expresses a class inclusion relation ("the dog is a mammal") or an attribute relation ("Socrates is wise"). In some instances, we can understand the meaning of a copula sentence, while in other instances we cannot. Even if we can understand the meaning, there are two cases. One is a case that we can understand literally ("the dog is a mammal"); another is the case that we can understand figuratively ("My lawyer is a shark"). The latter case is a metaphor. Thus, a copula sentence is understood as a metaphor only in specific cases. Further, how do copula sentences differ from simile sentences? These two sentences differ in sentence pattern. As with copula sentences, when we are presented with a simile sentence, in some cases we can understand the meaning ("An education is like stairs"), while in other cases we cannot ("Time is like a strawberry"). Considering the relationships between copula sentences, metaphors and similes, we can classify sentence patterns that use these figures of speech into five types (literal sentence, metaphor, simile, anomalous sentence and anomalous simile). In this study, we investigated cortical activation patterns using five types of experimental sentences, and evaluated whether or not differences exist in the comprehension processes used in understanding metaphor and simile.

During the last ten years, many researchers have investigated the neural mechanisms of metaphor processing in normal participants (Ahrens et al., 2007; Bottini et al., 1994; Eviatar & Just, 2006; Lee & Dapretto, 2006; Rapp, Leube, Erb, Grodd, & Kircher, 2004). In the first neuroimaging study on metaphor processing, Bottini et al. (1994) investigated cerebral activity using positron emission tomography (PET) in six healthy participants and concluded that the right hemisphere (RH) plays a role in metaphor comprehension. Based on the results of Bottini et al. (1994), Rapp et al. (2004) conducted another imaging study using event-related functional magnetic resonance imaging (fMRI) in healthy participants. Their stimuli consisted of 60 novel short German sentence pairs with either metaphorical or literal meanings. The participants read the literal and metaphorical statements and judged whether the statements had positive or negative connotations. Their results showed that metaphorical sentences elicited greater activation in the left lateral inferior frontal gyrus (IFG: BA 45/47), inferior temporal cortex (BA 20) and posterior middle/inferior temporal (BA 37) cortex than literal sentences. They concluded that activation of the left IFG might reflect semantic inference processes that occur during the understanding of a metaphor. Shibata, Abe, Terao, and Miyamoto (2007a,b) similarly investigated neural substrates involved in the comprehension of novel metaphor sentences using event-related fMRI and evaluated the involvement of the right hemisphere in metaphor comprehension. The material consisted of 21 literal sentences (e.g., "The dolphin is an animal"), 21 novel metaphor sentences (e.g., "Memory is a warehouse"), and 21 anomalous sentences (e.g., "Time is a strawberry") that were simple and short Japanese copula sentences of the form "An A is a B" that did not include any contextual information. Participants read these sentences and responded as to whether or not they could understand the meaning (semantic judgment task). The results showed that the metaphor sentences elicited higher activation in the left IFG (BA 45) and medial prefrontal cortex (MPFC: BA9/10) than the literal sentences (Shibata et al. 2007a). Using a metaphoricity judgment task, Shibata et al. (2007b) showed that metaphor sentences elicited higher activation in the right IFG (BA 47), MPFC (BA 10), left IFG (BA 45) and left precentral and left superior temporal gyrus (STG: BA 38) than did literal sentences. Higher activation in the right IFG (BA 47) with metaphor sentences compared with literal sentences revealed that the right hemisphere is involved in comprehension of metaphors.

On the basis of two previous experiments performed in our laboratory, we evaluated whether comprehension processes differ for metaphor and simile by comparing literal and anomalous sentence conditions using the same materials as Shibata et al. (2007a, b). If the comprehension processes involved in understanding these two figures of speech are mainly affected by differences in sentence pattern, the neural substrates involved in the comprehension of metaphor and simile would be expected to show different patterns of activation; on the other hand, if the comprehension processes are affected by the properties of words, the neural substrates studied would be expected to show similar patterns of activation.

2. Results

2.1. Behavioral results

Reaction time was defined as the time that passed between the onset of sentence presentation and the time at which the participant pressed the button. The mean reaction times for each type of sentence were 1308.7 ms for the literal sentence condition, 1924.0 ms for the metaphor sentence condition, 1782.4 ms for the simile sentence condition, 1586.6 ms for the anomalous sentence condition, and 1686.1 ms for the anomalous simile sentence condition. A one-way ANOVA correlating the reaction time to the sentence type revealed a significant main effect ($F(4, 115) = 53.07$, $p < .0001$). Tukey-Kramer post-hoc tests yielded significant differences in the reaction times among the five types of sentences ($p < .05$). The mean reaction time for metaphor sentences was significantly longer than those for simile, literal, anomalous and anomalous simile sentences. The mean rate of “Yes” responses was 99.2% for literal sentences, 90.2% for simile sentences and 79.8% for metaphor sentences. The mean rate of “No” responses was 97.3% for anomalous sentences and 98.5% for anomalous simile sentences. Only the mean rate of “Yes” responses for metaphor sentences was significantly lower than for other sentence types.

2.2. Imaging results

The imaging results indicated following findings. First, the left IFG (BA 45/47) and temporal regions were activated in metaphor and simile sentence conditions (Table 1 and Figure 1). In the anomalous and anomalous simile conditions, the left IFG (BA 45) was also activated. In the literal sentence condition, the left STG (BA 42) and left parahippocampal (PHG) regions were activated ($p < .05$, FDR). Second, we analyzed the differences between the metaphor sentence condition and the literal sentence condition. In the metaphor sentence condition minus the literal sentence condition, this contrast revealed higher activation in the bilateral IFG (BA 45/47), left STG (BA 38), and left MTG (BA 21). We also analyzed the differences between the simile sentence condition and the literal sentence condition. In the simile sentence condition minus the literal sentence condition, this contrast revealed higher activation in the bilateral IFG (BA 45/47), left SFG (BA 6/8/10), left MPFC (BA 10), right STG (BA 38), left MTG (BA 21) and left PHG. In the metaphor sentence condition minus the simile sentence condition, this contrast revealed higher activation in the right IFG (BA 47), MTG (BA 21) and caudate. In the simile sentence condition minus the metaphor sentence condition, this contrast revealed higher activation in the right IFG (BA9), left MPFC (BA 10), left STG (BA 38), right MTG (BA 22/42), right precentral, bilateral postcentral, thalamus and left PHG ($p < .001$, uncorrected; Table 2). Third, we delineated the regions activated during both metaphor and simile sentence conditions relative to the literal sentence condition (M+S－2L). This contrast revealed higher activation in the bilateral IFG (BA 45/47), left SFG (BA 8), left MPFC (BA 9),the left MTG and STG ($p < .05$, FDR , Figure 1, and Table 3).

To ensure that the activation obtained did not depend on differential task difficulty, a parametric modulation analysis was performed. We examined the correlation between reaction times and the amplitude of cortical activations for each stimulus. If this was the case, the results of the parametric modulation analysis should show a significant positive correlation between the reaction times and the amplitude of the cortical responses. The results showed that such a significant correlation ($p < .001$, uncorrected, with an extent threshold of 10 voxels) was not observed in all conditions.

3. Discussion

The purpose of the present study was to investigate neural substrates involved in the comprehension of metaphor and simile and to evaluate whether simile comprehension differs from metaphor comprehension. The mean reaction time for metaphor sentences was significantly longer than for simile, literal and anomalous sentences. A parametric modulation analysis was performed to ensure that the activation obtained did not depend on differential task difficulty. The results showed that such a significant correlation was not observed in all conditions at this threshold level ($p < .001$, uncorrected, with an extent threshold of 10 voxels). This indicates that the activation pattern in metaphor sentence condition not depends on task difficulty but depends on other comprehension processes. This result suggests that more neural processing is required for subjects to attain a coherent semantic interpretation of metaphor sentences than of simile and literal sentences. Moreover, the mean rate of “Yes” responses for metaphor sentences was significantly lower than for other sentence types (the mean rate of "Yes" responses was 79.8% and that of "No" responses was 20.2% for metaphor sentences). Regarding the "No" response for metaphor sentence, we examined this issue in our previous experiments.

Our previous study (Shibata et al. 2007a) indicated that both "Yes" and "No" responses in the metaphoric sentences elicited a positive curve in the left IFG. This result showed that the activation patterns of "No" judgments were the same as those for metaphoric sentences, and differed from those for anomalous sentences. This finding implies that, despite their "No" judgments, the participants were also engaged in metaphor comprehension processing.

The sentence pattern or the properties of words?

The imaging results showed that when subjects were tested using metaphor and simile sentences, activation was seen in the left IFG (BA 45/47) (Table 1 and Figure 1). Previous neuroimaging studies (Ahrens et al., 2007; Eviatar & Just, 2006; Kircher et al. 2007; Rapp et al., 2004; Stringaris et al., 2007) indicated that novel metaphor comprehension induced activation in the left IFG. Rapp et al. (2004), Kircher et al. (2007) and Stringaris et al. (2007) used simple novel sentences similar to our stimuli, and showed similar activation patterns in the left IFG. Based on previous and present results, activation in the left IFG may play a key role in the processes of metaphor and simile comprehension. In both the anomalous and anomalous simile sentence condition, mainly the left IFG was activated. Anomalous sentences (also anomalous simile sentence) contained a semantic violation and could not be comprehended. For example, in the study by Kiehl et al. (2002), the participants read sentences with endings that were either congruent (e.g., the dog caught the ball in his MOUTH) or incongruent (e.g., they called the police to stop the SOUP) with the sentence context. Incongruent sentence endings, like those in the anomalous sentences employed in our study, strongly induced activation in the left IFG. On the other hand, literal sentences induced higher activation in the left PHG as well as the left STG at this threshold level. Here, we recount our imaging results and experimental materials. In this study, we selected the materials based on these mean comprehensibility ratings (metaphor: 6.70, SD = 1.11, simile: 6.73, SD = 1.02, literal: 8.95, SD = 1.60, anomalous: 1.22, SD = 1.11, anomalous similes: 1.21, SD = 1.02). There were obviously qualitative differences among the three sentence types (metaphor/simile, literal, and anomalous/anomalous simile). The degree of the comprehensibility or similarity between a topic and a vehicle (the properties of words) might affect activation patterns. In the metaphor and simile sentence condition, sentences do not literally express a class inclusion relation or an attribute relation as well as in the anomalous and anomalous simile sentence condition. To understand the meanings of these sentences, semantic processes such as detection of semantic deviation are needed (Hagoort, Hald, Bastiaansen, & Petersson, 2004; Ni et al., 2000). Regarding the activation of the left IFG, previous functional neuroimaging studies have reported an increased BOLD response in the IFG during the following: sentence and discourse comprehension (bilateral IFG; Dapretto & Bookheimer, 1999; Kuperberg, Lakshmanan, Caplan, & Holcomb, 2006; Rodd, Davis, & Johnsrude, 2005; Zempleni, Haverkort, et al., 2007), detection of semantic anomalies (left IFG; Hagoort, Hald, Bastiaansen, & Petersson, 2004; Ni et al., 2000), following presentation of an ambiguous statement (bilateral IFG; Rodd et al., 2005; Zempleni, Renken, Hoeks, Hoogduin, & Stowe, 2007), during the construction of a situation model (bilateral IFG; Ferstl, Rinck, & von Cramon, 2005; Menenti, Petersson, Scheeringa, & Hagoort, 2009) or also idioms (selection of semantic knowledge among competing alternatives; Romero Lauro et al., 2008). On the basis of these previous studies and our results, the left IFG may play a key role in the processes of metaphor and simile comprehension, and semantic processing (detection of semantic deviation and selection of semantic information) is related to the left IFG activation.

Does simile comprehension differ from metaphor comprehension?

To examine activation patterns under metaphor and simile sentence conditions more closely, we delineated the regions activated during both metaphor and simile sentence conditions relative to the literal sentence condition (M+S-2L), and condition-specific parameter estimates (Figure 1 and Table 3). This contrast revealed higher activation in the bilateral IFG (BA 45/47), left SFG (BA 8), left MPFC (BA 9), the left MTG and STG ($p < .05$, FDR , Figure 1, and Table 3). This also showed that similes elicit more activation in fronto-medial regions, whereas metaphors induce more right-sided prefrontal activation. Several neuroimaging studies have indicated that the medial frontal region is important for coherence processes in language comprehension and for coherence building (Goel et al., 1997; Ferstl & von Cramon 2001, 2002; Zysset et al., 2002, 2003). Thus, activation in the medial frontal region in the simile sentence condition might reflect the inference process necessary to establish semantic coherence.

The contrast of both metaphor and simile sentence conditions relative to the literal sentence condition (M+S-2L; Figure 1) also indicated that metaphors elicit more activation in the right IFG than do similes. Relating to the activation of RH in the metaphor sentence condition, previous studies have indicated RH involvement in metaphor comprehension while searching for a wider range of semantic relationships, or for novel, non-salient metaphoric meanings (Mashal et al., 2005; Mashal et al., 2007; Stringaris et al., 2006). On the other hand, two previous experiments performed in our laboratory (Shibata et al. 2007a,b) concluded that the metaphoricity judgment task elicited higher activation in the right IFG with metaphor sentences, compared with literal sentences, while a semantic judgment task did not elicit activation in RH. In the metaphoricity judgment task, participants read the sentences and responded as to whether or not they could understand the sentence as a metaphor. This task makes participants more aware of metaphorical interpretation. On the basis of these results, one possibility indicated that activation in the right IFG may be influenced by metaphorical comprehension processes (i.e., extraction of features from topic and vehicle and integration). The difference of the mean reaction time between metaphor and simile sentence condition might be reflected in these processes. As for this point, Glucksberg and Haught (2006) also indicated that "the difference in reference – simile referring to "the literal concept" and metaphor to "an abstract (metaphorical) category" – results in it being "possible for metaphor and simile to differ in (a) interpretability and (b) in meaning" (2006: *p. 360*). Our result might reflect these differences.

In this study, we investigated the neural substrates involved in the comprehension of metaphor and simile, using the same materials as used in the study of Shibata et al. (2007a, b). Our result showed similar cortical activation patterns in the left IFG under metaphor and simile sentence conditions, despite the different sentence patterns employed in these two figures of speech. On the other hand, condition-specific parameter estimates showed that similes elicit more activation in the medial frontal region (Table 2) which might be related to inference process, whereas metaphors elicit more RH prefrontal activation which might be affected by metaphorical comprehension processes.

One serious limitation of this study involves the temporal processes associated with metaphor and simile comprehension. The behavioral results indicated that the subjects' mean reaction time for interpretation of metaphor sentences was significantly longer than that for interpretation of simile sentences. Parametric modulation analysis revealed no significant correlation between reaction times and cortical activation. Nevertheless, this result indicates that the processing of metaphor sentences requires more time to attain coherent semantic interpretation than the processing of simile sentences. Due to temporal resolution problems with fMRI, it is not clear whether specific processes influence the need for longer processing time. Further research on temporal processes is needed to clarify the relationship between metaphor and simile comprehension.

Furthermore, in this study, we evaluated comprehension processes between metaphor and simile using the novel metaphor (simile) as a factor in the materials. Recent psycholinguistic studies indicated that conventional and novel metaphors may be processed differently (Bowdle & Gentner, 2005), and that the degree of aptness of the topic-vehicle pairing influences the mental process used in understanding the metaphor. Further studies are needed to clarify the activation pattern between conventional and novel metaphor (simile) comprehension via well-designed experiments.

4. Method

4.1. Participants

Twenty-four healthy graduate and undergraduate students (fourteen men and ten women; mean age 25.9 years, range 21-47 years) participated in this experiment. The participants were all native Japanese speakers. Handedness was assessed by the Edinburgh Handedness Survey (Oldfield, 1971) and all participants were found to be right-handed. This experiment was conducted under a protocol that was approved by the Ethics Committee of Hokkaido University Graduate School of Medicine. All participants gave their written informed consent prior to participation in this experiment.

4.2. Materials

The experimental design included five conditions of sentence type (literal, metaphor, simile, anomalous simile, and anomalous sentence). The sentences consisted of 20 literal sentences (e.g., “A dolphin is an animal.”), 20 metaphor sentences (e.g., “Memory is a warehouse.”), 20 simile sentences (e.g., “An education is like stairs.”), 20 anomalous sentences (e.g., “Scissors are dogs.”) and 20 anomalous simile sentences (e.g., “Time is like a strawberry.”). Prior to this experiment, 100 novel metaphor sentences were extracted from Nakamoto and Kusumi (2004) or Shibata and Abe (2005). All words in these sentences were checked word frequency, familiarity and word length by the NTT database: “Lexical Properties of Japanese” (Amano & Kondo, 2000). Another 20 participants rated the comprehensibility of each sentence as a metaphor on a scale of 1 to 9. We selected the 40 metaphor sentences with the highest comprehensibility. Based on the comprehensibility rating of the behavioral experiments, we divided these sentences into 20 metaphors and 20 similes to ensure the homogeneity of the material (mean comprehensibility of metaphor sentences: 6.70, SD = 1.11, mean comprehensibility of simile sentences: 6.73, SD = 1.02). Using these materials, we created two counterbalanced lists (we presented the list 1 to the half of the participants, and presented list 2 to the remaining half of the participants). Each list contained 20 metaphors and 20 similes on which each pair of topic and vehicle was presented only once in each list. In addition to these metaphor and simile sentences, 20 literal meaning sentences (category inclusion statements) and 40 anomalous sentences with the lowest comprehensibility (semantic violation statements) were extracted from Shibata and Abe (2005). All words of the sentences in Shibata and Abe (2005) were selected from the NTT database to address lexical properties of Japanese (Amano & Kondo, 2000), and were matched by familiarity, frequency and word length using this database. We divided 20 anomalous sentences and 20 anomalous similes sentences (mean comprehensibility of anomalous sentences: 1.22, SD = 1.11, mean comprehensibility of anomalous similes sentences: 1.21, SD = 1.02). In each counterbalanced list, 20 anomalous and 20 anomalous similes sentences were contained as well as 20 literal sentences. Based on these mean comprehensibility ratings, there were obviously qualitative differences among the three sentence types (metaphor, literal, anomalous) and there were not qualitative differences between metaphor and simile sentences (see Supplementary materials).

4.3. Procedure

The fMRI scanning phase consisted of two sessions (120 functional image volumes per session with 4 initial volumes to avoid transient non-saturation effects) with 50 sentences (10 literal sentences, 10 metaphor sentences, 10 simile sentences, 10 anomalous sentences and 10 anomalous simile sentences) per session. The trials were pseudo-randomly ordered. Each stimulus sentence was displayed at the center of a rear projection screen for 3 s and was immediately followed by the presentation of a cross-hair that varied between 3 s and 5 s (on average, 4 s). The participants viewed the screen through a mirror system mounted at the head coil. The participants were asked to read each sentence carefully in order to understand the content of the sentences and to press one of two buttons with their left index finger if they understood the meaning of the sentence and with their middle finger if they did not, regardless of whether the meaning was literal or metaphorical. The participants literally determined the meaning of the literal sentence and metaphorically determined the meaning of the metaphor and simile sentences. They were tested individually and their comprehension time and Yes/No judgments were recorded. The experimental stimuli and the recording of the participants' responses were controlled by E-prime (Psychology Software Tools, Inc.).

4.4. fMRI data acquisition and data analysis

A whole-body 1.5 T Signa Echo-Speed scanner (General Electric, Inc.) was used to acquire high-resolution T1-weighted anatomical images and gradient echo echo-planar T2*-weighted images with blood oxygenation level-dependent (BOLD) contrast of 20 axial slices. The parameters of the sequence were set as follows: TR = 3000 ms, TE = 40 ms, Flip angle = 90°, FOV = 240 x 240 mm, Matrix = 64 x 64, slice thickness = 4 mm, slice gap = 0.8 mm. The data were analyzed by statistical parametric mapping (SPM5, Wellcome Department of Cognitive Neurology, London, UK: http://www.fil.ion.ucl.ac.uk/spm). All functional volumes were corrected for slice acquisition timing, realigned to the first volume of each participant to correct for head motion, spatially normalized to the Montreal Neurological Institute (MNI) brain template, resampled to 2 x 2 x 2 mm^3 voxels, and smoothed using an 8-mm full-width-at-half-maximum Gaussian kernel. Functional data were analyzed in an event-related design. Statistical analyses was performed on single participants with a fixed-effects statistical model including the hemodynamic response function (HRF). A high-pass filter with a cutoff period of 80 s was used to remove low-frequency noise. A design matrix was specified using the general linear model (GLM) for single subject analysis that specified a individual vector of onsets for each sentence. For each of the five conditions (Metaphor, Simile, Literal, Anomalous and Anomalous simile sentence condition), separate regressors were created with zero determined by the implicit baseline. We analyzed the image data based on the sentence conditions that we initially prepared, rather than on how the participants responded. The relevant contrast parameter images generated at the single subject level were submitted to the second-level analysis. For the group analysis, random effect analysis was conducted, based on the GLM, with each of the five conditions modeled by the canonical hemodynamic response function. Statistical parametric maps were generated for each contrast of the t statistic on a voxel-by-voxel basis. For the resulting statistical threshold, a false discovery rate [FDR] correction ($p < .05$) and statistical threshold of $p < .001$, uncorrected, with an extent threshold of 10 voxel for multiple spatial comparisons across the whole brain were used. The complete data set was transformed into Talairach space (Talairach and Tournoux,1988).

In the whole brain analysis, we delineated the activated regions related to each condition. We also analyzed the differences between each condition (metaphor vs. literal, simile vs. literal, metaphor vs. simile, and simile vs. metaphor), and the regions activated during both metaphor and simile conditions relative to the literal condition (metaphor + simile - 2 literal), with condition-specific parameter estimates.

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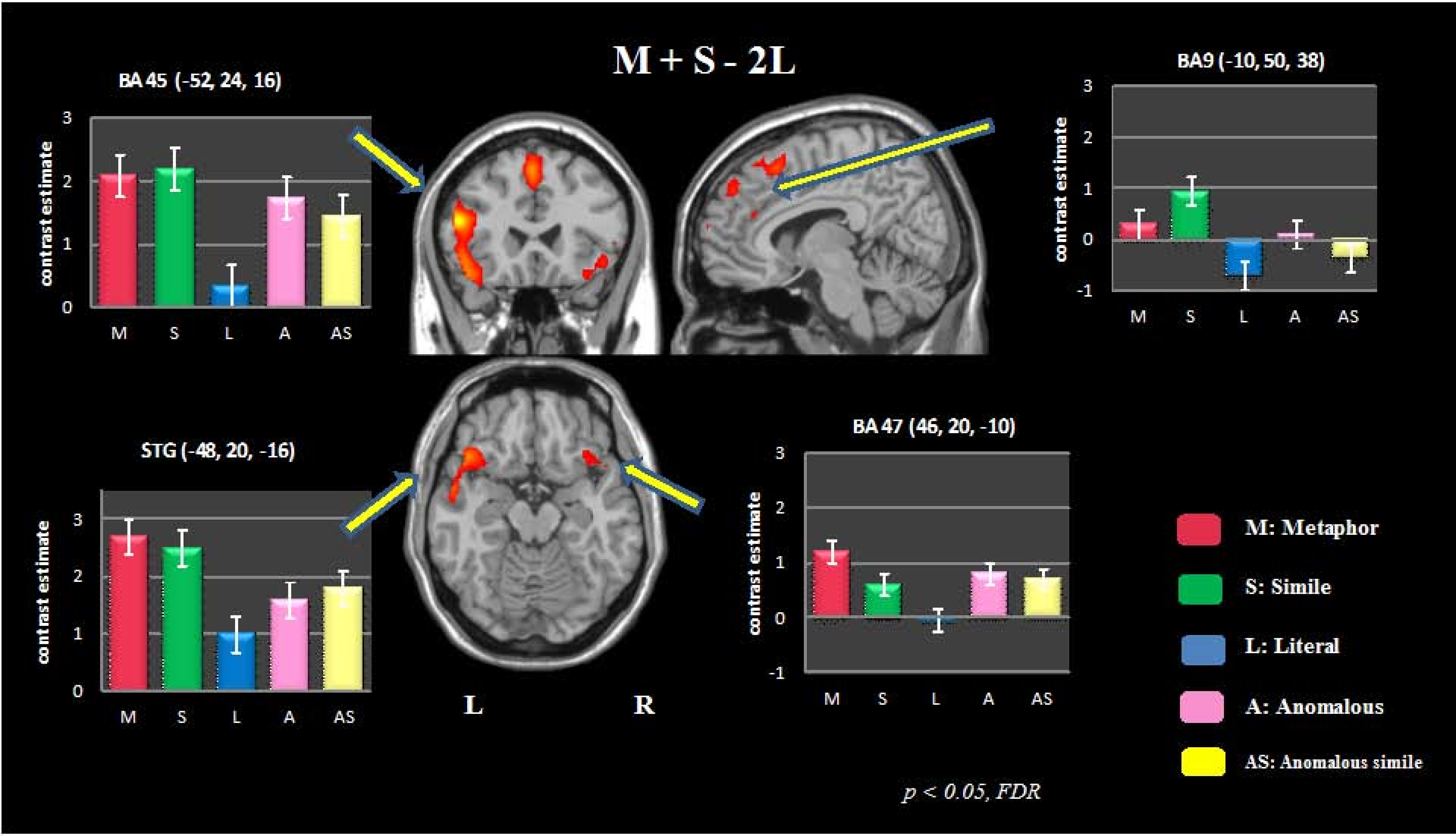
Figure legends

Figure 1. Regions activated during both metaphor and simile sentence conditions relative to the literal sentence condition (M+S-2L; $p < .05$, FDR).



M + S - 2L
BA 45 (-52, 24, 16)
contrast estimate
3
2
1
0
M
S
L
A
AS
BA9 (-10, 50, 38)
contrast estimate
3
2
1
0
-1
M
S
L
A
AS
STG (-48, 20, -16)
contrast estimate
3
2
1
0
M
S
L
A
AS
L
R
BA 47 (46, 20, -10)
contrast estimate
3
2
1
0
-1
M
S
L
A
AS
M: Metaphor
S: Simile
L: Literal
A: Anomalous
AS: Anomalous simile
p < 0.05, FDR

Table 1

Brain regions showing significant BOLD signal increases during each sentence versus the baseline.

Region of activation	Left/Right	Brodmann area	Cluster size	MNI cordinates			T value
				X	Y	Z	
Metaphor							
Inferior Frontal	L	45/47	159	-50	24	22	6.03
Superior Temporal	L	38	278	-48	24	-18	4.82
Parahippocampal	L	58		-16	-40	-6	5.86
Simile							
Inferior Frontal	L	45/47	137	-52	22	16	6.76
Superior Temporal	L	38	400	-52	14	-14	6.54
Parahippocampal	L	27	66	-14	-38	-4	6.05
Posterior Cingulate	R	31	199	10	-70	12	5.68
Thalamus	L	21		-14	-8	16	5.66
Literal sentence							
Superior Temporal	L	42	13	-60	-22	12	4.87
Parahippocampal	L	30	53	-16	-38	-4	7.32
Anomalous sentence							
Inferior Frontal	L	45/46	144	-54	22	16	5.32
Cuneus	R	18	128	16	-80	18	5.53
Parahippocampal	L		42	-16	-40	-4	5.85
Anomalous simile							
Inferior Frontal	L	45/47	115	-56	16	0	5.75
Superior Temporal	L	38		-52	14	-14	5.43
Superior Temporal	R	22	20	58	14	-2	5.17
Middle Temporal	R	21	15	60	-38	-2	5.10
Parahippocampal	L		104	-14	-40	-2	8.38
Posterior Cingulate	L	31	39	-12	-70	12	5.75
Cuneus	R	18	67	16	-78	16	5.34

$p < .05$, FDR

Table 2

Cerebral regions showing significant BOLD signal increases of the metaphor sentence condition versus the literal sentence condition, the simile sentence condition versus the literal sentence condition, the metaphor sentence condition versus the simile sentence condition and the simile sentence condition versus the metaphor sentence condition.

Region of activation	Left/Right	Brodmann area	Cluster size	MNI cordinates			T value
				X	Y	Z	
Metaphor sentence condition>Literal sentence condition							
Inferior Frontal	L	45/47	414	-52	24	18	5.72
Inferior Frontal	R	47	24	34	20	-20	3.80
Superior Frontal	L	8	245	-2	20	52	4.51
Middle Temporal	L	21	40	-54	0	-20	4.05
Superior Temporal	L	38		-46	22	-18	4.36
Simile sentence condition>Literal sentence condition							
Inferior Frontal	L	45/47	665	-52	22	16	6.09
Inferior Frontal	R	47	54	44	20	-10	4.07
Superior Frontal	L	6/8/10	349	-2	20	52	4.54
Middle Frontal	L	6	72	-42	12	48	3.99
Medial Frontal	L	10	33	-8	64	14	3.77
Superior Temporal	R	38	11	52	10	-22	3.76
Middle Temporal	L	21	41	-56	-4	-20	3.62
Parahippocampal	L	34	34	-18	-10	-14	4.10
Anterior Cingulate	R	32	28	8	34	28	3.50
Metaphor sentence condition>Simile sentence condition							
Inferior Frontal	R	46	30	44	30	8	3.84
Middle Temporal	R	21	10	54	-32	-8	3.55
Caudate	L		32	-5	6	12	3.78
Simile sentence condition>Metaphor sentence condition							
Inferior Frontal	R	9	51	52	12	28	4.14
Medial Frontal	L	10	13	-10	51	16	3.61
Superior Temporal	L	38	52	-36	12	-22	4.09
Middle Temporal	R	22	14	64	-38	6	3.17
Precentral	R	4	28	30	-22	64	3.63
Postcentral	L	1	12	-54	-18	44	3.47
Postcentral	R	43	31	54	-18	18	3.67
Thalamus	R		12	20	-22	18	3.71
Parahippocampal	L		33	-16	-12	-14	3.49

$p < .001$, uncorrected

Table 3

Brain regions activated during both the metaphor and simile conditions versus literal sentence condition (Metaphor + Simile - 2 Literal sentence).

Region of activation	Left/Right	Brodmann area	Cluster size	MNI cordinates			T value
				X	Y	Z	
Metaphor + Simile - 2 Literal sentence							
Inferior Frontal	L	45/47	489	-52	24	16	6.47
Inferior Frontal	R	47	13	46	20	-10	4.05
Superior Frontal	L	8	283	-2	20	52	5.09
Medial Frontal	L	9	14	-10	50	26	3.54
Middle Temporal	L	21	40	-54	0	-20	4.22
Superior Temporal	L	38		-48	20	-16	4.65

$p < .05$, FDR