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Abstract

Metaphor comprehension involves the generation of novel semantic attributes, especially when a metaphor emphasizes a shared but atypical characteristic of the relevant concepts. The present functional magnetic resonance imaging (fMRI) study explores neural activation during the process of attribute generation known as feature emergence. The participants judged whether a presented semantic feature was an appropriate interpretation of a primed metaphor sentence. Two types of features were evaluated: emergent features that are not applicable to the respective concepts and only become salient in a metaphorical context and non-emergent features which are typical characteristics. In contrast to non-emergent features, processing of emergent features mainly involved prefrontal regions of the right hemisphere, including the precentral gyrus. The present results suggest that feature emergence necessitates a shift of semantic attention that drives a novel metaphor interpretation beyond the semantic elaboration implicated within the left prefrontal cortex.

Keywords: Metaphor comprehension; Feature Emergence; functional MRI.

Introduction

It is widely accepted that the comprehension of metaphorical expressions entails greater semantic elaboration than for literal sentences, because the relevant concepts are not directly connected in terms of literal similarity, even though an expression is understandable (Ortony, 1979). Reflecting this salient nature of metaphors, it is also known that metaphor usage enhances recognition memory performance within reading tasks (Reynolds & Schwartz, 1983) and that it is more persuasive when logical reasoning is less effective (Sopory & Dillard, 2002).

The primary form for metaphors consists of two concepts combined by the "*be*" verb, such as "*A is B*", where (*A*) and (*B*) are known as the *topic* and the *vehicle*, respectively. This type of metaphor is believed to be interpreted through four types of features depending on whether the feature represents a typical characteristic of the concepts. In the first type of "common feature", the topic and vehicle share a typical feature. For example, in the metaphor of "*ideas are fireworks*", "*brilliant*" is a common feature, because both *ideas* and *fireworks* can be regarded as being brilliant. In the second type of "vehicle feature", the feature is only typical of the vehicle concept. Taking the same metaphor example again, "*momentary*" would be a vehicle feature because it is only relevant to "*fireworks*". In contrast to a vehicle feature, a topic feature is only a typical characteristic of the topic concept. "*Flash*" would be a topic feature in this example. Although these three feature types minimally involve a typical characteristic of either the topic or the vehicle concepts, the last type of "emergent feature" does not involve a typical characteristic of neither the topic nor the vehicle. However, non-emergent features only appear for interpretations of metaphorical context. The feature "*sudden*" is interpretable within the metaphor example, but it is not a typical characteristic of either the "*ideas*" topic or the "*fireworks*" vehicle. Gineste and colleagues (2000) claim that more than 60% of metaphoric interpretations involve emergent features, which suggests that emergent features play a major role within metaphor comprehension.

Although previous cognitive neuroscience studies have explored the neural regions involved in metaphor comprehension, they have failed to distinguish between the interpretations of emergent and non-emergent features (*e.g.*, Rapp et al. 2004; Shibata et al. 2007a, 2007b; Stringaris et al. 2007). Some studies indicate that literal and metaphorical sentence comprehension activates multiple cortical regions, including the ventro lateral prefrontal cortex near Brodmann areas (BA) 47 and 44/45, mainly in the left hemisphere (LH), and probably reflects normal semantic processing. In contrast, some other studies have reported fronto-temporal activation within the right hemisphere (RH) during the processing of verbally presented figurative expressions compared to literal expressions (*e.g.*, Marshal et al. 2007; Stringaris et al. 2006). In particular, Marshal and colleagues (2007) found that the processing of word pairs forming novel metaphors, compared to conventional ones, elicited stronger activation within the posterior superior temporal sulcus and the right inferior frontal gyrus mainly in the RH, and Stringaris and colleagues (2006) found right-lateralized prefrontal activation when participants search for a wider range of semantic relationships between a metaphoric sentence and a word. However, others have reported the opposite pattern of lateralization (*e.g.*, Rapp et al. 2004, Stringaris et al. 2007, Shibata et al. 2007b). Rapp and colleagues (2004) report that recognition of metaphors only elicits prominent brain activity in the LH–inferior frontal (BA45/47), inferior temporal (BA20) areas, and the posterior medial/inferior temporal (BA37) gyrus–with no RH activation.

The present study investigates the pattern of cortical involvement during metaphor comprehension. One possibility is, as Marshal and colleagues (2007) suggest, that the processing of novel metaphors involves the right hemisphere. Another possibility is that RH activation reflects some decision criteria processing of presented expressions. Shibata and colleagues (2007a, 2007b) suggest that right frontal regions are more activated when the metaphorical aspect is emphasized for judgments. Thus, they argue that metaphor comprehension requires association search over a wide range which involves RH activation.

The present study hypothesizes that feature emergence activates RH frontal regions during metaphor comprehension. In our previous studies, we have argued that feature emergence is enhanced with longer comprehension times, which suggests that feature emergence may involve interaction spreading out over the semantic network (Terai & Goldstone 2011). We apply the same paradigm within this fMRI study to explore the neural regions activated in feature emergence. We first develop a set of metaphors with features for which feature emergence occurs. In addition to non-emergent features, this set of metaphors was judged by participants while fMRI imaging was conducted.

Materials and Method

Participants

All participants ($N = 10$; mean age = 23.3 years; range 21-29 years; 5 male, 5 female) were healthy, right-handed, native Japanese speakers. The current study was approved by the ethical committee of Tokyo Institute of Technology. All participants gave their informed consent before the experiment, and they were compensated for their participation (2000 JPY/hour).

Materials

Ten metaphorical Japanese sentences of the style "*topic* is *vehicle*" (*e.g.*, "Ideas are fireworks") were created based on a behavioral experiment. The behavioral experiment used three feature types (emergent, non-emergent, and filler features). For each metaphor, an emergent (*e.g.*, "sudden"), a non-emergent (*e.g.*, "sparkle") and a filler feature (*e.g.*, "pray") were created based on results of a behavioral study. One hundred and fifty five participants evaluated 16 metaphors and six features for each metaphor. The metaphors and participants were divided into four groups. Each participant evaluated the relationship between four metaphors and their features on a 7-point scale. They also evaluated the relationships between eight concepts (the topics and vehicles of the four metaphors) and the features of the metaphors, and rated the characteristics of metaphors (*e.g.*, comprehensibility and novelty). Ten metaphors with higher mean ratings for comprehensibility (above 4) were selected as metaphors that can be easily interpreted. Each metaphor was then assigned with the three types of features, based on comprehensibility ratings of more than 5 (slightly comprehensible) from participants who could interpret a metaphor[1]. Features that fulfilled the following two criteria were classified as emergent features; 1) the mean adequacy rating was greater than three (neutral) and 2) the mean typicality rating was lower than that for the metaphor[2] [mean ratings (*SD*) for metaphor, 5.01 (1.80), topic, 4.60 (2.10), and vehicle, 4.38 (1.99)]. In contrast, features with mean ratings for the metaphor of more than 3 and with higher mean ratings for the vehicle that for the metaphor were classified as non-emergent features [mean ratings (*SD*) with the metaphor, 5.18 (1.81), topic, 4.85 (1.89), and vehicle, 5.88 (1.67)]. If the mean rating for a feature's relationship with the metaphor was less than 3, the feature was classified as a filler feature [mean ratings (*SD*) with metaphor, 1.80 (1.29), topic, 1.95 (1.43), vehicle, 2.05 (1.66)].

[1]The average proportion of participants who could interpret a metaphor was 33.0%.

[2]We expect that the relationships of an emergent feature with both the vehicle and with the topic are less than that with the metaphor. However, generally, metaphor interpretations can be regarded as a topic characteristic if it is not a typical characteristic. Participants tend to rate vehicles' relationships with the metaphor highly. Thus, we consider the difference between the relationships with the vehicle and with the metaphor as being important.

Procedures

fMRI scanning consisted of two sessions. For the first session (concept term condition), at the beginning of each trial, a fixation point "+" was presented for 900 msec on the computer screen. Then, participants were presented with a concept term, which was either a vehicle or a topic, for 3900 msec. They were asked to read the term covertly. Next, the fixation point "+" was presented for 900 msec again. Then, a feature (either an emergent, a non-emergent or a filler feature) was displayed on the screen for 4000 msec. The participants were instructed to respond concerning whether the feature is a typical characteristic of the concept (the vehicle or the topic) term during the presentation period. They held a response box in each hand and responded by pressing the right button ("Yes") or the left button ("No"). The trials were pseudo-randomly ordered. Fixation trials were also intermixed pseudo-randomly.

In the second, metaphor session, the procedure was as follows: At the beginning of each trial, the participants were presented with a metaphorical sentence on the computer screen for 3900 msec. They were asked to silently read and interpret the metaphor. Then, the metaphor disappeared and a fixation point "+" was presented for 900 msec, followed by the presentation of a feature for 4000 msec. The participants were asked to respond "Yes" or "No" depending on whether the feature represented an adequate interpretation of the metaphor by pressing the right button ("Yes") or the left button ("No") during the presentation period. The trials were presented pseudo-randomly, such that the same metaphor never appeared in succession. Fixation trials were intermixed pseudo-randomly.

Participants were given instructions prior to performing the tasks. They were asked to think of nothing during presentation of the fixation point. We conducted a follow-up survey with a questionnaire. The participants were asked to evaluate the characteristics of the metaphors (comprehensibility, novelty, etc.) on 7-point scales.

Imaging procedures

fMRI scans were conducted with the 3T GE SignaHDxt scanner (General Electric, Milwaukee, WI) at Tokyo Institute of Technology, Japan. High-resolution anatomical images were obtained using an FSPGR T1-weighted sequence [repetition time (TR) = 7.712 msec; echo time (TE) = 2.88 msec, flip angle (FA) = 11 deg, slice thickness = 1 mm; in-plane resolution = 1 x 1 mm^2]. Functional images were obtained using a GE-EPI sequence [TR = 2.0 sec, TE = 30 msec, FA = 90 deg, slice thickness = 3.0 mm, in-plane resolution = 3.75 x 3.75 mm^2, slice gap = 1.0 mm].

Imaging analysis procedures

Imaging analysis was performed using SPM8 (`http://fil.ion.ucl.ac.uk/spm/`). All the functional images were temporally aligned across the brain volumes, spatially registered to a MNI template, resampled into 2-mm isotropic voxels, and then spatially smoothed with an 8-mm FWHM Gaussian kernel.

The present imaging analysis focused on the metaphor condition. For each participant, a voxel-wise GLM analysis was first performed to estimate parameter values for the MR signal magnitudes. The trial period for the metaphor condition was modeled by two independent regressors, one coding metaphor-sentence presentation, and the other coding feature-word presentation that involved a feature judgment, convolved with a canonical HRF (together with time and dispersion derivatives). The metaphor regressor lasted from presentation onset to offset of the sentence, while the judgment regressor lasted for 1000 msec, which was determined based on the mean RTs for each condition for each participant. The estimated parameters during feature judgment were then contrasted between the emergent and non-emergent conditions.

Parameter estimates for each participant were submitted to a group analysis using a voxel-wise random-effect model. Whole-brain exploratory analysis was performed to identify the brain regions showing activity during feature judgment in the emergent condition relative to the non-emergent condition. Due to the small size of the sample in the present study, significance was assessed by a relatively liberal threshold of ten or more continuous voxels above $p < .001$ ($Z = 3.3$) uncorrected.

Results

Behavioral results

The mean reaction times in the concept term condition are shown in Figure 1. A two-way ANOVA with reaction times for the feature conditions and concept types as factors showed a significant main effect for feature types [$F(2,18) = 46.35$, $p < .01$]. A post-hoc t-test showed that reaction times for the emergent features were longer than reaction times for non-emergent features [$t(9) = 4.99$, $p < .01$]. These results suggest that emergent features are more involved in evaluation-related processes, which is consistent with previous studies (Gineste et al. 2000).

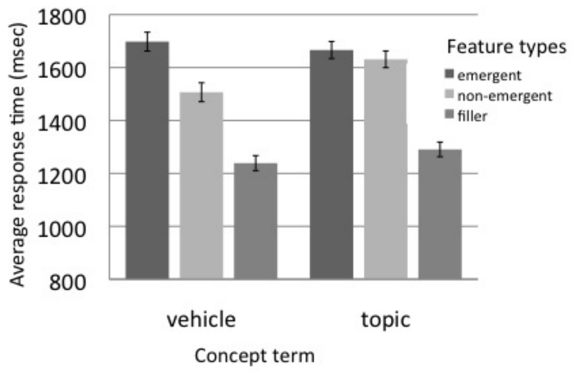

Figure 1: Mean reaction times ($\pm SEs$) for emergent, non-emergent and filler features (in concept term condition)

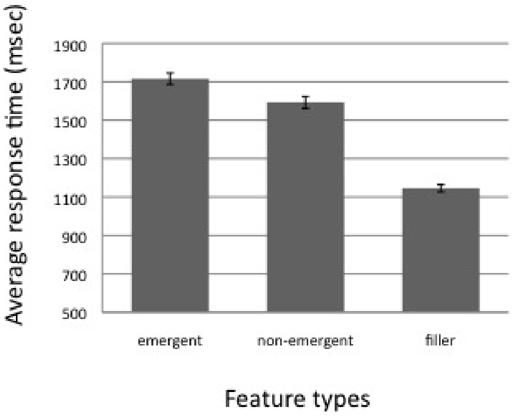

Figure 2: Mean reaction times ($\pm SEs$) for emergent, non-emergent and filler features (in the metaphor condition)

Figure 2 shows the mean reaction times for the metaphor condition. A one-way ANOVA for reaction times in the feature condition revealed that significant main effect of feature type [$F(2,18) = 29.20,\ p < .01$]. The reaction times for the emergent and the non-emergent features were significantly longer than those for the filler features at the 1% level. However, there was no significant difference between reaction times for emergent features and for non-emergent features (p=.19). These results indicate that emergent features are activated within metaphor processing as much as non-emergent features.

The average proportions of "Yes" responses are shown in Table1. All participants responded "No" for almost all the filler features. The proportions of "Yes" responses for emergent features in the metaphor condition (51.0%) were significantly lower than for the non-emergent features (67.0%) [$F(1,9) = 12.5,\ p < .01$]. In the concept term condition, when the target was the vehicle, the average proportion for non-emergent features (85.0%) was higher than that for emergent features (34.0%) [$F(1,9) = 157.1,\ p < .01$]. When the target was the topic, the average proportion for emergent features was 45.0%, while for non-emergent features, it was 30.0% [$F(1,9) = 5.55,\ p < .05$]. Collectively, these findings suggest that emergent features were not easily understood compared to non-emergent features, which is consistent with previous studies (Terai, Goldstone 2011).

These behavioral results suggest that there are distinct differences between the processing of emergent and non-emergent features. In particular, the results indicate that non-emergent features are recognized as a typical characteristic of the vehicle but emergent features are not.

Post-scan evaluations of the metaphor characteristics revealed that the mean rating of the metaphors' comprehensibility was 4.00 on the 7-point scale (1: incomprehensible - 7: comprehensible), suggesting that the participants understood the presented metaphors. The mean rating for the metaphors' novelty was 4.29, suggesting that the participants did not regard the metaphors as being very conventional.

Table 1: Mean proportions for emergent and non-emergent (%). For almost all of the filler features, the proportions were almost 0%.

	Concept Term Condition		Metaphor Condition
	Vehicle	Topic	Metaphor
Emergent	34.0	45.0	51.0
Non-emergent	85.0	30.0	67.1

Imaging results

In order to investigate the difference between the processing of emergent and non-emergent features within metaphor comprehension, we analyzed the differential contrast between the activation of emergent features and for non-emergent features in the metaphor condition (Figure 3 and Table 2). The emergent feature condition showed significant activation in the precentral gyrus (BA6) in the RH and the cingulate gyrus. In contrast, in the concept term condition, no activation was observed in the emergent condition compared to the non-emergent condition.

Discussion

The present study has explored the pattern of neural activation during feature emergence within metaphor comprehension. Emergent features elicited higher levels of activations in the right precentral gyrus (BA6) and the cingulate gyrus in contrast to non-emergent features in the metaphor condition.

Higher levels of activation have been observed in the right precentral gyrus and the cingulated gyrus during the reading of anomalous metaphors compared to literal sentences and in the right precentral gyrus compared to conventional metaphors (Ahrens et al. 2007). The metaphors were presented as a sentence (*e.g.* "The theory framework of this theory is very loose") and the participants were asked to read the sentence and press a button when they finished. In such a situation, participants may search for the relationships between the topic (*e.g.* "the theory framework") and the feature (*e.g.* "loose") presented in the sentence. In particular, in the anomalous metaphor sentence condition (*e.g.* "Their capital has rhythm"), they may search for a wider range of associations between the topic (*e.g.* "their capital") and the feature (*e.g.* "have rhythm"). One may speculate that the precentral gyrus is more activated when participants search for a relationship between a metaphor and a novel feature. Accordingly, emergent features may require additional cognitive processing in searching for a wider range of semantic relationships for the metaphor.

Furthermore, these right frontal regions have been associated with stimulus-driven attentional reorientation (Corbetta & Shulman 2002). It is thus feasible to assume that the presentation of emergent features shifts the participants' seman-

Table 2: Activation contrasts obtained for emergent features versus non-emergent features in the metaphor condition. (Activations listed here were obtained at a voxel level of two-tailed $p < .001$, uncorrected, clusters of 10 or more)

Z value	Cluster size	MNI(x)	MNI(y)	MNI(z)	BA	Side	Cerebral Region
4.40	10	52	-2	52	6	R	precentral gyrus
4.10	54	-2	-24	24	24	L/R	cingulate gyrus

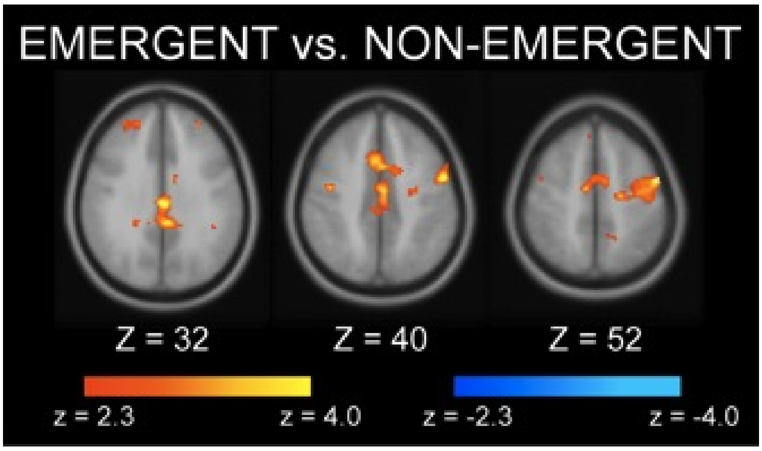

Figure 3: Activation patterns for the differential contrasts between emergent features versus non-emergent features in the metaphor condition (two-tailed $p < .001$, uncorrected, clusters of 10 or more)

tic attention to words that are triggered by the presentation of an emergent feature. In other words, these results suggest that the presentation of an emergent feature prompts participants to modify their comprehension processes to incorporate interaction between the topic and the vehicle. That would be consistent with experimental results (Gineste et al. 2000) which indicate that the processing of emergent features is facilitated by interaction between the target and the vehicle concepts.

Previous studies have suggested that searching for a wider range of semantic relationships within metaphor comprehension elicits activation of the right inferior frontal gyrus (Stringaris et al. 2006, Shibata et al. 2007a). However, the results from the present study failed to demonstrate that searching for a wider range of semantic relationships led to activation of this area. In Stringaris et al. (2006), the word was presented with the metaphor and the participants judged the relationship. In contrast, in the present study, the feature was presented after the metaphor had disappeared and we have analyzed data obtained during the interval between feature presentation onset and the participants' responses. Thus, the results from the present experiment only reflect the recognition processing of the feature. The present study's result observed no significant activation differences for the right inferior frontal gyrus.

Moreover, in the present study, emergent features were not spontaneously generated within the interpretative processing of the metaphors. Accordingly, the results only represent a part of the mechanisms of feature emergence within metaphor comprehension. It should also be noted that only ten individuals participated in the present study which only consisted of ten stimulus item for each condition. In order to obtain more robust results, further experiments are needed with more participants and more items.

Nonetheless, the present results indicate that that the right frontal area is involved in the processing of emergent features. Accordingly, it is not possible to account for the involvement of the RH merely in terms of metaphor novelty (Marshal et al. 2007, Ahrens et al. 2007), for it may rather reflect feature emergence. If RH involvement can explain differences between the cognitive processing of figurative and literal sentences, feature emergence may be related to metaphor recognition when reading sentences.

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