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Research report

Distinction between the literal and intended meanings of sentences: A functional magnetic resonance imaging study of metaphor and sarcasm

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ABSTRACT

To comprehend figurative utterances such as metaphor or sarcasm, a listener must both judge the literal meaning of the statement and infer the speaker's intended meaning (mentalizing; Amodio and Frith, 2006). To delineate the neural substrates of pragmatic comprehension, we conducted functional magnetic resonance imaging (fMRI) with 20 normal adult volunteers. Participants read short stories followed by a target sentence. Depending on the context provided by the preceding stories, the target sentences were classified as follows: (1) metaphor versus literally coherent; (2) metaphor versus literally incoherent; (3) sarcasm versus literally coherent; and (4) sarcasm versus literally incoherent. For each task pair, we directly compared the activations evoked by the same target sentences in the different contexts. The contrast images were incorporated into a 2 (metaphor and sarcasm) $\times$ 2 (literal coherency and incoherency) design. Metaphor-specific activation was found in the head of the caudate, which might be involved in associating statements with potential meanings, and restricting sentence meanings within a set of possible candidates for what the speaker intended. Sarcasm-specific activation was found in the left amygdala, which is an important component of the neural substrates of social behavior. Conjunction analysis revealed that both metaphor and sarcasm activated the anterior rostral medial frontal cortex (arMFC), which is a key node of mentalizing. A distinct literal coherency effect was found in the orbital MFC, which is thought to be involved in monitoring. These mesial frontal areas are jointly involved in monitoring literal coherency and mentalizing within social contexts in order to comprehend the pragmatic meanings of utterances.

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1. Introduction

The understanding of an utterance cannot be based solely on the meanings of individual words (semantics) or grammar (syntax). Comprehension also requires the understanding of the speaker's intention within a social context (pragmatics). Irony is one form of pragmatics that is used to convey feelings in an indirect way (Shamay-Tsoory et al., 2005). Irony is characterized by an opposition between the literal meaning of the sentence and the speaker's intended meaning (Haverkate, 1990; Winner, 1988). Sarcasm is a form of irony that is used in a hurtful or critical way (McDonald and Pearce, 1996). Sarcasm is generally used to communicate implicit criticism about the listener or a situation to provoke a negative effect, and is accompanied by disapproval, contempt, and scorn (Sperber and Wilson, 1995). Metaphor is another form of pragmatic language, which is used to express meaning that is otherwise difficult to conceptualize. Understanding a metaphor requires the mental linkage of different category domains that are normally not related to each other (Rapp et al., 2004).

According to the standard pragmatic model (Grice, 1975; Searle, 1979), there must be some shared strategies by which the hearer is able to recognize that the utterance is not intended literally. As sarcastic or metaphorical statements usually do not make sense if taken literally (Searle, 1979), the judgment of literal coherence (i.e., whether there was a literal connection between the two sentences) is generally involved in the comprehension of pragmatic language. The position of the standard pragmatic model is that the literal interpretation of the utterance is processed first, followed by re-processing to extract the correct meaning (serial processing). However, this model cannot account for the finding that participants do not respond more slowly to conventional metaphors and ironies than to literal statements (Giora, 1997).

More recent models have proposed that both types of meaning—literal and non-literal—may be processed concurrently (Gernsbacher et al., 2001; Gibbs, 2001; Giora, 1999). They propose that a common mechanism is used to comprehend both literal and non-literal language, in which sarcasm and metaphors are seen as a source of polysemy in a language (e.g., Cacciari and Glucksberg, 1994). Thus, similar to the process of lexical access for ambiguous words (e.g., Swinney, 1979), both the literal and the non-literal meanings are initially activated, and the inappropriate meaning is inhibited as a result of context effects (parallel processing).

It has been proposed that successful understanding of a pragmatic utterance depends on perceiving the intention of the speaker within a social context (Grice, 1975). In sarcasm, the speaker's thoughts must be taken into account in order to reject the incorrect literal interpretation. Metaphor also involves understanding that the literal meaning is not the intended one and extracting the implicit meaning (Fine et al., 2001). Thus, theory of mind (ToM) or mentalizing—the ability to infer other people's mental states, thoughts, and feelings—is key to understanding figurative utterances (Frith and Frith, 2003).

However, there are also important differences between metaphor and sarcasm. First, several theorists argue that metaphors function to describe and clarify by making us see similarities that are not typically noticed (Dews and Winner, 1997). Thus, using a default value of literalness will not work. Instead, the understanding of metaphor can be achieved by grasping the intentions of the speaker; it thus requires first-order ToM (Happe, 1993). By contrast, the primary function of ironic utterances is not to reveal what things are like, but instead to reveal the speaker's evaluative attitude to an attributed thought (Colston and Gibbs, 2002). Thus, the comprehension of an ironic statement requires the ability to appreciate both the thoughts of the speaker and the speaker's evaluative attitude toward those attributed thoughts—i.e., the ability to form a second-order metarepresentation, exemplified by second-order ToM (Happe, 1993). Second, metaphor is a descriptive use of language that indicates the relationship between the propositional form of an utterance and the thought that it is representing. Metaphor comprehension requires the sentence meaning (vehicle) to be associated with a set of possible candidates for what the speaker intended (target), and the restriction of the range of possible candidates to the target—in other words, ambiguity resolution (Searle, 1979). In sarcasm comprehension, these two processes—association formation with ambiguity resolution—are less complex than in metaphor, because the speaker usually means the opposite of what is said (Searle, 1979). Thus, ToM and association formation with ambiguity resolution make differential contributions to the comprehension of metaphor and sarcasm, both of which involve the judgment of literal coherence.

Previous lesion and neuroimaging studies have shown that the mentalizing network is involved in processing sarcasm. Prefrontal brain damage has been associated with impairments in both empathic ability and the interpretation of ironic utterances (Shamay et al., 2002; Shamay-Tsoory et al., 2005). Using functional magnetic resonance imaging (fMRI) during a sarcasm detection task with written vignettes, Uchiyama et al. (2006) found activation of the mentalizing network, including the medial frontal cortex (MFC), left lateral orbitofrontal cortex, temporal pole, and superior temporal sulcus (STS). They utilized scenario-reading tasks, in which sentences describing a certain situation (S1) were presented, followed by the protagonist's comments regarding that situation (S2, target sentence). These areas were activated when the participants tried to discriminate whether the S2 conveyed sarcastic information, in contrast to unrelated sentences that indicated only which button to press (Uchiyama et al., 2006). In this task setting, during both sarcastic and non-sarcastic conditions, sarcasm comprehension of the S2 was necessary to determine which button should be pressed, whereas the unconnected sentence condition did not require the understanding of sarcasm. As these mentalizing-related areas did not show activation specific to sarcasm, the neural substrates of sarcasm comprehension have yet to be elucidated.

The proposed neural substrates of metaphor comprehension are highly controversial (Giora, 2007). Behavioral data with the divided visual-field paradigm have shown that the right hemisphere (RH) might be critically involved in at least one important component of novel metaphor comprehension: the integration of the individual meanings of two seemingly unrelated concepts into a meaningful metaphoric expression (Faust and Mashal, 2007). Some neuroimaging studies have indicated that the RH has a unique role in the comprehension of the figurative meaning of metaphors (Ahrens et al., 2007; Bottini et al., 1994; Mashal et al., 2005, 2007; Stringaris et al., 2006), whereas the results of other studies do not support a selective role for the RH in accessing metaphorical meanings (Lee and Dapretto, 2006; Rapp et al., 2004, 2007; Shibata et al., 2007). Eviatar and Just (2006) directly compared sarcasm and metaphor, and showed that metaphoric utterances caused higher levels of activation in the left inferior frontal gyrus and the bilateral temporal cortex than did sarcasm. Conversely, sarcasm led to prominent activation in the right superior and middle temporal gyri. The authors attributed this differential hemispheric sensitivity to the need to understand the speaker's communicative intent as dissociated from the informative intent in sarcasm (Eviatar and Just, 2006).

Involvement of the basal ganglia in figurative language processing has been reported in lesion studies (for a review see Thoma and Daum, 2006). Basal ganglia patients are unable to provide adequate explanations of idiom meanings (Wallesch et al., 1983). Patients with Huntington's disease and a group of patients with stroke-induced focal lesions of non-thalamic subcortical structures tended to stick to the literal meaning of figurative utterances, regardless of the contextual information provided (Chenery et al., 2002). Based on lesion studies, Wallesch and Papagno (1988) concluded that the basal ganglia support the recognition of a possible, most appropriate meaning, and hence contribute to ambiguity resolution.

These discrepant findings might reflect the divergence of metaphor with respect to the meaning salience, remoteness of semantic relationships, open-endedness, transparency of the meaning of stimuli, and speaker's intention (Giora, 2007). Despite these extensive theoretical and neuroimaging studies, the roles of literal coherence judgment and mentalizing processes in the pragmatic comprehension of sarcasm and metaphor have not been explicitly tested, and their neural correlates have not been clarified.

In the present study, we used fMRI to determine the neural substrates of pragmatic language. We hypothesized that although the neural substrates of metaphor and sarcasm are shared with those of literal coherence judgment (Searle, 1979), metaphor and sarcasm comprehension differ in the requirement for ambiguity resolution and the need to infer the speaker's mental status. To segregate the judgment of literal coherence in addition to the pragmatic-specific processes, we manipulated the contexts such that the same target sentences either did or did not convey pragmatic information, and were either literally coherent or not.

In the case of sarcasm, subjects determined whether there was a sarcastic component, and thus the neural substrates of sarcasm comprehension should be activated (Uchiyama et al., 2006). However, in the sarcastic context, compared with the non-sarcastic context, the sentence should convey feelings or emotion-laden criticism that might activate emotion-related areas, whereas metaphor processing usually would not activate such regions.

By contrast, metaphor places greater demands on ambiguity resolution than sarcasm. Thus, we hypothesized that sarcasm and metaphor should differentially activate limbic areas, and areas involved in ambiguity resolution such as the striatum (Thoma and Daum, 2006) or the thalamus (Stringaris et al., 2006).

2. Methods

2.1. Participants

Twenty participants (10 females and 10 males; mean age, 25.6 years; range, 21–30 years) were recruited as paid volunteers for the fMRI experiment. All participants were right-handed, educated beyond college level[1], and had normal or corrected-to-normal visual acuity. Handedness was determined using the Edinburgh handedness inventory (Oldfield, 1971). None of the participants had any history of neurological or psychiatric illness. Written informed consent to take part in the study was obtained following procedures approved by the Ethical Committee of the National Institute for Physiological Sciences, Japan.

2.2. Preparation of task materials

The discourse task consisted of two parts: the first (S1) was a story that explained the situation of one protagonist, whereas the second (S2) gave the comment of another protagonist. S2 was the target sentence. The target sentences could be interpreted differently depending on the context given by the S1 (Mano et al., 2009).

We manipulated the context in which sentences were presented such that the same sentences either did or did not convey pragmatic information. During fMRI scanning, participants read short stories followed by a target sentence. Depending on the context provided by the preceding stories, the target sentence involved one of the following: (1) a metaphor or a literally coherent meaning; (2) a metaphor or a literally incoherent meaning; (3) sarcasm or a literally coherent meaning; and (4) sarcasm or a literally incoherent meaning. The task was to judge whether the target sentences represented metaphor, sarcasm, were literally coherent, or were literally incoherent. In each task pair, we directly compared the activations evoked by the same target sentences in the different contexts. The contrast images highlighted the neural activation of the context effect in the pragmatic conditions compared with the non-pragmatic sentences with or without literal coherency. The contrast images were incorporated into a 2×2 design to delineate the effects of pragmatics (metaphor *vs* sarcasm) and coherency (literally coherent *vs* literally incoherent). Examples are given below.

2.2.1. Metaphor–literally coherent pairs (Mc–Cm) (Fig. 1)

The target sentence S2 was "*It was bone-breaking*" (in Japanese "*hone ga ore-ru*"). This S2 could follow an S1 sentence such as:

> "The senior colleague tried hard to explain the history of the martial art to a foreigner who knew nothing about it. The senior said to his junior:"

In this case, the S2 metaphorically indicates that the task requires a large effort. By contrast, it could follow an S1 such as:

[1] Japanese education involves the following: 6 years in elementary school, 3 years in junior-high school, 3 years in high school, 4 years in college or university, 2 years in master's courses, and 3 or 4 years in doctoral courses.

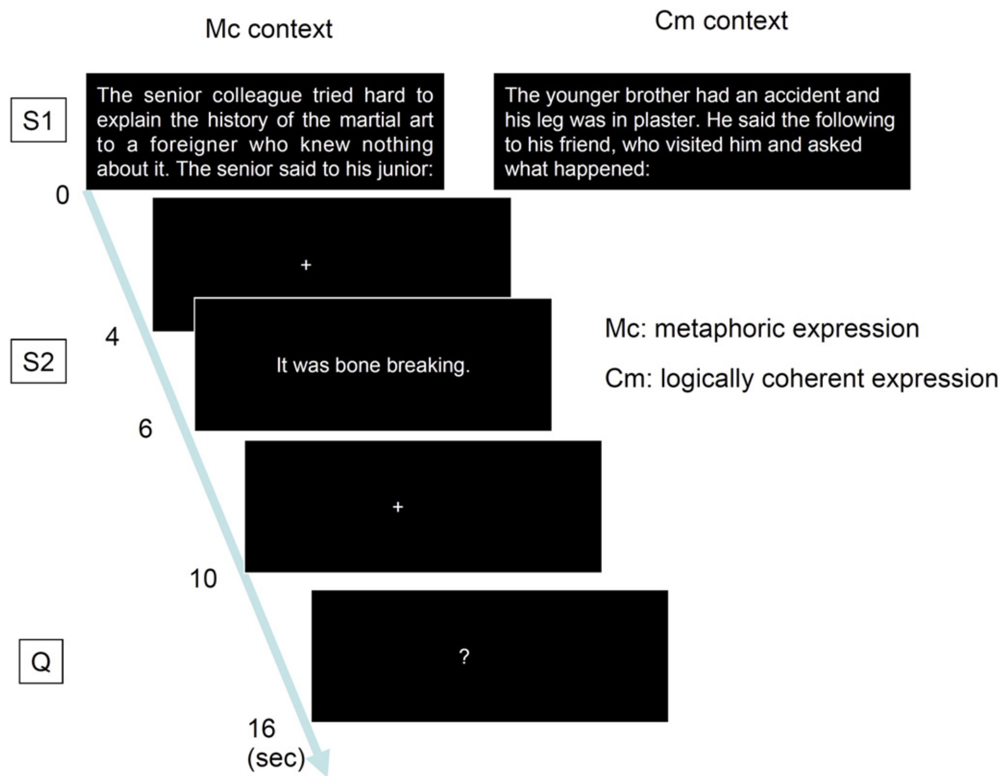

Fig. 1 – Examples of stimuli and the time course of the experiment. S1 explained the situation of a character, and S2 was the comment of another protagonist. By modifying S1 while keeping S2 constant, the target sentence S2 represented either a metaphor (Mc) or a literally coherent expression (Cm). The same format was adopted for other pairs, such as Mi and Im, Sc and Cs, and Si and Is. Once the question mark "?" was presented, the participant was required to indicate whether the S2 represented metaphor, sarcasm, a literally coherent statement, or a literally incoherent statement by pressing a button.

"The younger brother had an accident and his leg was in plaster. He said the following to his friend, who visited him and asked what happened:"

In this case, the S2 literally indicates that the injury was bone-breaking. Thus, the comparison between the context-dependent metaphoric response (Mc) of the S2 that was paired with a literally coherent response (Cm) should reflect the process of metaphor inference relative to the comprehension of a literally coherent sentence.

2.2.2. *Metaphor–literally incoherent pairs (Mi–Im)*

The target sentence S2 was "*He has been running all the time*" (in Japanese "*hashiri tsuduke-ru*"). This could follow an S1 such as:

"During the past 10 years, the man had always been at the forefront of the IT industry. A friend who knew the man well commented on him:"

In this case, the S2 metaphorically indicates that the protagonist has been at the forefront of the field. By contrast, it could follow an S1 such as:

"The father thought he saw his elder sister and was about to call out to her, but it proved to be someone else. The father told the mother, who was next to him:"

In this case, the S2 is literally incoherent. Hence, the target sentence is processed as an anomalous (incoherent) sentence. Thus, the comparison between the context-dependent metaphoric response of the S2 (Mi) that was paired with the literally incoherent response (Im) should reflect the activity related to metaphor inference relative to the literally incoherent inference.

2.2.3. *Sarcasm–literally coherent pairs (Sc–Cs)*

The target sentence S2 was "*You're very skillful!*"

Following an S1 such as:

"The woman was not a good cook and was taking up to an hour just preparing the ingredients. Her mother-in-law, who was watching how she was doing, said to her:"

S2 indicates sarcasm. In reality, the comment of the speaker (mother-in-law) means the opposite of what she says. On the other hand, following an S1 such as:

"The woman was a good cook and was preparing dinner efficiently. Her mother-in-law, who was watching how she was doing, said to her:"

S2 is logically coherent, and thus there was no sarcasm.

In this paradigm, the comparison between the context-dependent sarcastic response of the S2 (Sc) that was paired with the logically incoherent response (Cs) should reflect sarcastic inference relative to literally coherent inference.

2.2.4. *Sarcasm–literally incoherent pairs (Si–Is)*

In this example, the target sentence S2 was "*What a lovely dress you have!*"

Following an S1 such as:

"The elder sister went to the party in a shabby dress, because she had nothing else to wear for the occasion. Her acquaintance, who was on bad terms with her, said:"

S2 indicates sarcasm. On the other hand, following an S1 such as:

"The elder sister worked as a secretary at the father's company after finishing junior college. She told the president that the scheduled meeting was about the following:"

S2 is logically incoherent, without a sarcastic component.

Thus, the comparison between the context-dependent sarcastic response of the S2 (Si) that was paired with the logically incoherent response (Is) should reflect activity related to sarcastic inference relative to the inference of literal coherence.

The target sentences (S2) were obtained through searches of the Japanese dictionary and the Internet by Google (http://www.google.com) to find frequently-used pragmatic expressions (collocation). For each of the 37 metaphor and 34 sarcastic sentences, S1s were created to generate the four types of scenario pairs: 23 Mc–Cm, 14 Mi–Im, 16 Sc–Cs, and 18 Si–Is. From the total pool, we selected 10 scenario pairs for each condition.

To evaluate the comprehensibility of these materials, 27 normal volunteers (10 men and 17 women; mean age, 21.0 years $\pm$ 3.36 standard deviations – SD) participated in a preliminary experiment. All participants were educated beyond college level. They correctly discriminated each category at an accuracy greater than 90% (Mc, 91.1 $\pm$ 10.9%; Cm, 98.9 $\pm$ 3.20%; Mi, 90.7 $\pm$ 11.4%; Im, 95.6 $\pm$ 6.41; Sc, 97.8 $\pm$ 5.06; Cs, 99.6 $\pm$ 1.92; Si, 98.9 $\pm$ 3.20; Is, 95.2 $\pm$ 7.00). They also rated each scenario using a five-level comprehensibility rating (1 = completely mismatched; 3 = average meaningfulness; 5 = highly meaningful). As expected, both pragmatic expressions (Mc, Mi, Sc, Si) and non-pragmatic literally coherent expressions (Cs, Cm) showed higher mean comprehensibility (Mc, 4.06 $\pm$ .55; Cm, 4.60 $\pm$ .50; Mi, 4.34 $\pm$ .53; Sc, 3.54 $\pm$ 1.09; Cs, 4.81 $\pm$ .48; Si, 3.67 $\pm$ .96) than non-pragmatic literally incoherent scenarios (Im, 1.29 $\pm$ .61; Is, 1.39 $\pm$ .96; $p < .001$, one-way analysis of variance – ANOVA). All of the test materials are shown in Appendix, including the percentage (%) correct accuracy rates and comprehensibility rating results.

2.3. *fMRI procedures*

Prior to the fMRI session, the participants received detailed instructions and an explanation of the task procedure, and were trained with the stimuli that were not used during the fMRI session. All stimuli were prepared and presented using Presentation 9.20 software (Neurobehavioral Systems, Albany, CA) implemented on a personal computer (Dimension 9200; Dell Computer, Round Rock, TX). Using a liquid crystal display (LCD) projector (DLA-M200L, Victor, Yokohama, Japan), the visual stimuli were projected onto a half-transparent viewing screen located behind the head coil of the MRI scanner. Participants viewed the stimuli via a mirror attached to the head coil. The sentence stimuli were written in Japanese and presented as white letters against a black background. The maximum visual angle was 20.8° (width) by 9.5° (height).

Each S1 was presented on the screen for 4 sec followed by a cross-hair for 2 sec (Fig. 1). The S2 then appeared for 4 sec followed by the cross-hair for 5 sec. Then, the participant was required to press the button as quickly as possible after the question mark "?" was presented (Q condition). The question mark was presented for 1 sec followed by a cross-hair for 10 sec. The participants were given four choices to classify the target sentence (metaphor, sarcasm, literally coherent, and literally incoherent).

We used an event-related design to minimize habituation and learning effects. There were 20 scenarios for each condition, and the 80 total scenarios were presented in a random order. The same S2 comments were repeated twice in different sessions, but the interpretation differed in each session. Each condition was pseudo-randomly presented within the session and the session order was counterbalanced across participants. In total, four sessions, each with five trials of each condition, were run.

All images were acquired using a 3T MR scanner (Allegra; Siemens, Erlangen, Germany). For functional imaging during the sessions, an interleaved T2*-weighted gradient-echo echo-planar imaging (EPI) procedure was used to produce 34 continuous 4-mm thick transaxial slices covering the entire cerebrum and cerebellum (repetition time – TR, 2000 msec; echo time – TE, 30 msec; flip angle, 75°; field of view, 192 mm; 64×64 matrix; voxel dimensions, $3.0 \times 3.0 \times 4.0$ mm). Oblique scanning was used to exclude the eyeballs from the images. Each session consisted of a continuous series of 266 volume acquisitions with a total duration of 8 min 52 sec. The session was repeated four times. For anatomical imaging, T1-weighted magnetization-prepared rapid-acquisition gradient-echo (MP-RAGE) images were also obtained. The total duration of the experiment was ~60 min, including the acquisition of the structural MR images.

2.4. *Data analysis*

2.4.1. *Performance*

In the current study, we assumed that comprehension of pragmatic language such as metaphor and sarcasm includes the judgment of literal coherence in addition to the pragmatic-specific processes. We tried to segregate the process of literal coherence judgment by manipulating the context such that the same sentences either did or did not convey pragmatic information. For example, the Mc–Cm contrast reflects both metaphor-specific processing and literal incoherence judgment, because Cm is literally coherent whereas Mc is not. On the other hand, the Mi–Im contrast reflects metaphor-specific processing only, because Im is literally incoherent; thus, the process of literal coherence judgment is subtracted out. The same procedure was adopted for sarcasm comprehension, to yield a 2 (pragmatic effect) $\times$ 2 (coherence) factorial design.

Statistical analysis of performance was carried out using SPSS version 10.0J software (SPSS Japan Inc., Tokyo, Japan).

2.4.2. *Imaging data*

The preprocessing of the imaging data was performed as follows. The first six volumes of each session were eliminated to allow for the stabilization of the magnetization, and the remaining 260 volumes per session (a total of 1040 volumes per participant for four sessions) were used for the analysis. The data were analyzed using Statistical Parametric Mapping 5 (SPM5; Wellcome Department of Cognitive Neurology, London, UK; Friston et al., 2007). After being realigned for motion correction, all EPI volumes were normalized to the Montréal Neurological Institute EPI image template using a nonlinear basis function, and were spatially smoothed in three dimensions using an 8 mm full-width half-maximum Gaussian kernel.

The signal intensity of the images was scaled proportionally by setting the whole-brain mean value to 100 arbitrary units. The signal time course for each participant was modeled with a general linear model. Regressors of interest (trial effects) of the 10 conditions (S1, Mc, Cm, Mi, Im, Sc, Cs, Si, Is, and Q) were generated using a box-car function convolved with a hemodynamic-response function. Regressors that were of no interest, such as the session effect and high-pass filtering (128 sec), were also included. To depict the activations evoked by the same target sentences in the different contexts, each task pair was directly compared with the following contrasts: (1) metaphor versus literally coherent meaning (Mc–Cm); (2) metaphor versus literally incoherent meaning (Mi–Im); (3) sarcasm versus literally coherent meaning (Sc–Cs); and (4) sarcasm versus literally incoherent meaning (Si–Is).

The weighted sum of the parameter estimates in the individual analyses constituted the contrast images, which were used for the group analysis to make population-level inferences regarding the task-related activation. The contrast images obtained by the individual analyses represent the normalized task-related increment of the MR signal of each participant. In total, the data from 20 participants and four different contrasts (Mc–Cm, Mi–Im, Sc–Cs, and Si–Is) were incorporated into the 2 (pragmatics: metaphor *vs* sarcasm) $\times$ 2 (coherence: coherent *vs* incoherent) factorial design with a sphericity correction (Friston et al., 2007).

The statistical threshold was set at $p < .05$ with a correction for multiple comparisons at the cluster level for the entire brain.

3. Results

3.1. *Behavioral performance*

During the fMRI experiment, the mean (±SD) percentage of correct answers were as follows: 91.3 ± 8.83 for the metaphor scenarios, which consisted of Mc (92.5 ± 8.51) and Mi (90.0 ± 9.18); 98.0 ± 4.64 for the sarcasm scenarios, including Sc (97.5 ± 5.50) and Si (98.5 ± 3.66); 96.3 ± 6.67 for the literally coherent scenarios of Cm (97.5 ± 4.44) and Cs (95.0 ± 8.27); and 97.0 ± 5.64 for the literally incoherent scenarios of Im (97.0 ± 5.71) and Is (97.0 ± 5.71). Thus, the participants performed all conditions satisfactorily (>90% accuracy).

A two-way repeated-measures ANOVA showed a significant pragmatic effect [$F(1,128) = 13.005$, $p = .002$ with Greenhouse–Geisser correction]. Neither the coherence effect [$F(1,45) = .774$, $p = .39$] nor the pragmatic by coherence interaction [$F(1,5) = .049$, $p = .827$] was significant. Regarding the simple effects, Mc performance was significantly worse than Cm [$t(19) = -2.939$, $p = .008$], and Mi was significantly worse than Im [$t(19) = -3.04$, $p = .007$]. On the other hand, there were no significant differences between Sc and Cs [$t(19) = 1.157$, $p = .262$] or between Si and Is [$t(19) = .9$, $p = .379$]. Therefore, compared with the literally coherent control conditions, metaphor comprehension is more difficult than sarcasm comprehension (Fig. 2).

3.2. *Group analysis with a random-effects model*

Significant metaphor effects were found in the medial prefrontal cortices, caudate nucleus, anterior cingulate cortex (ACC), thalamus, piriform cortex, and ventral tegmental area (VTA), forming one large cluster (Fig. 3, Table 1). The bilateral caudate nuclei were specifically involved in the condition in which there was metaphor without sarcasm or coherence (Fig. 4, Table 1). The contrast of [(Sc–Cs)+(Si–Is)] showed an effect of sarcasm in two clusters located in the mPFC and left amygdala, extending to the temporal pole and putamen (Fig. 5, Table 1).

Post-hoc testing was performed with the weighted sum of the parameter estimates of the activation in the left amygdala at (−26, 0, −20). A repeated-measures ANOVA showed a more prominent effect of sarcasm than metaphor [$F(1,19) = 5.503$, $p = .03$] without a coherence effect [$F(1,19) = 2.1$, $p = .164$], and no interaction effect [$F(1,19) = .85$, $p = .374$] (Fig. 6).

Using the contrast of [(Mc–Cm)–(Mi–Im)+(Sc–Cs)–(Si–Is)], a significant main effect of coherence was found in the medial orbitofrontal cortex (Fig. 7, bottom; Table 1). The conjunction analysis revealed that both metaphor and sarcasm commonly activated the anterior rostral medial frontal cortex (arMFC), which cannot be explained by the coherence effect (Fig. 7, top; Table 2), because Mi–Im [$t(19) = 2.979$, $p = .008$, one sample *t*-test] and Si–Is [$t(19) = 2.319$, $p = .032$, one sample *t*-test] were both significantly positive.

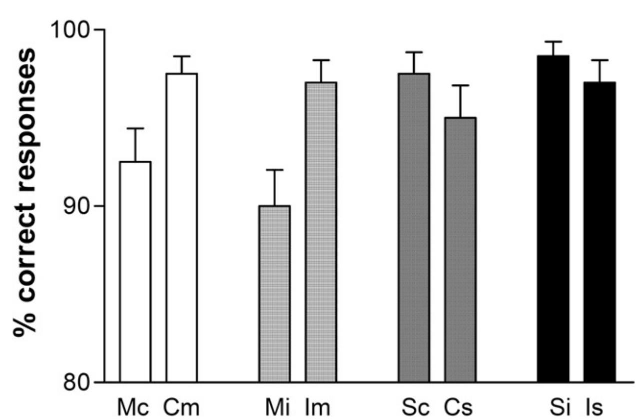

Fig. 2 – The percentage of correct responses in each condition (Mc, Cm, Mi, Im, Sc, Cs, Si, and Is) is shown. The error bar indicates the standard error of the mean.

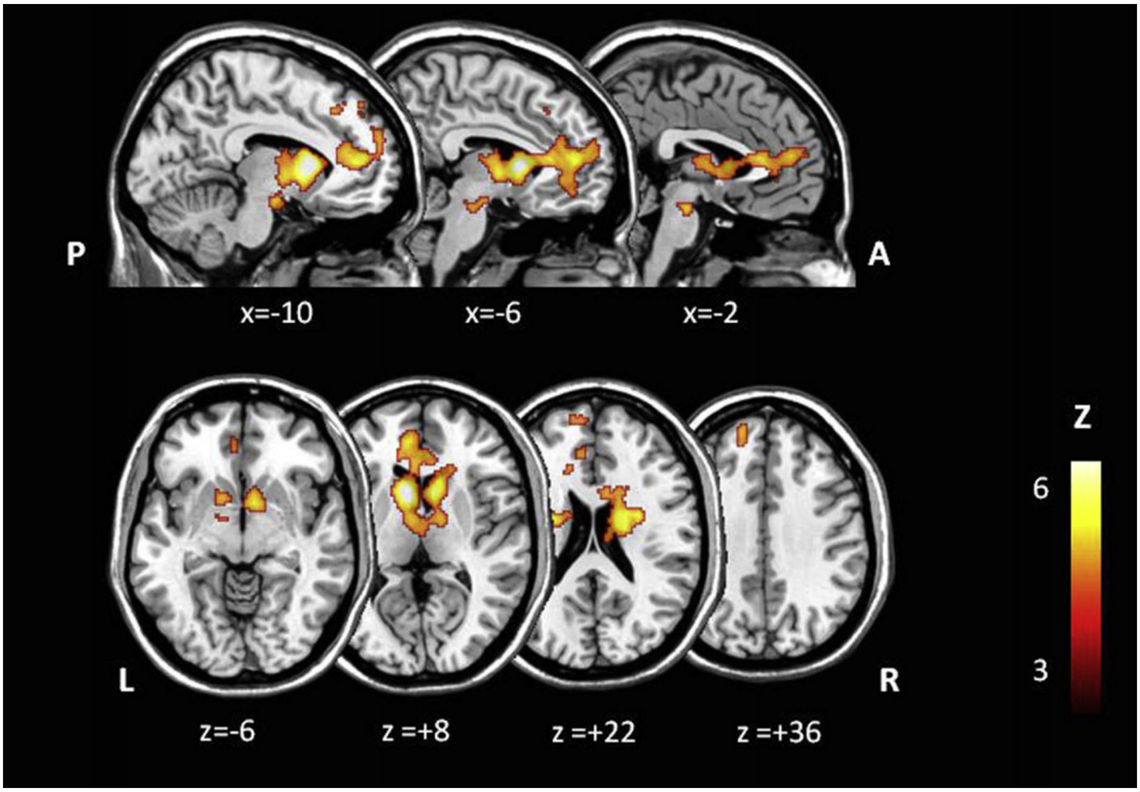

Fig. 3 – The metaphor effect as depicted by the contrast of [(Mc−Cm) + (Mi−Im)] superimposed on the T1-weighted high-resolution MRI of a participant unrelated to the study. A, anterior; P, posterior; L, left; R, right. The color scale shows Z values.

4. Discussion

4.1. *Performance*

Relative to the non-pragmatic control sentences, performance was similar during sarcasm comprehension, but worse during metaphor comprehension (Fig. 2). This is consistent with a parallel processing model, because in the serial model the processing of non-literal pragmatic sentences follows literal coherence judgment, and thus should be more difficult.

As comprehension of the non-pragmatic control sentences was equivalent in the metaphor and sarcasm sessions, the performance difference suggests that metaphor comprehension is more difficult than sarcasm comprehension. This seems to be contrary to the notion that sarcasm is more complex and difficult to understand than metaphor, because sarcasm reflects the speaker's second-order, meta-representational thoughts (Colston and Gibbs, 2002). It should be considered that, in addition to ToM, association formation with ambiguity resolution is essential to the comprehension of metaphor. Therefore, metaphor and sarcasm comprehension reflect both processes.

This might be particularly true in this study because we did not use dead metaphors, thus placing greater demands on association formation with ambiguity resolution. In the case of dead metaphors, the vehicle–target relationship is fixed, and thus they are easy to understand. If the metaphor is not dead, association formation with ambiguity resolution is necessary. Thus, the poorer performance on metaphor comprehension compared to sarcasm comprehension may reflect the more difficult process of association formation with ambiguity resolution.

4.2. *Neural activation*

The present study revealed that subcortical structures such as the caudate nuclei are specifically involved in metaphor comprehension, and the amygdala is related to sarcasm comprehension. We also showed that comprehension of metaphor and sarcasm commonly activated the arMFC, as both processes involve monitoring literal coherency and mentalizing within social contexts. Thus, the neural substrates of pragmatic comprehension are shown to extend well beyond the classical language areas.

4.2.1. *Metaphor-related activation of subcortical structures*

The present study revealed that metaphor comprehension led to more prominent activation of the head of the caudate bilaterally than did sarcasm. There was no coherency effect (Fig. 4), and thus the caudate involvement was metaphor-specific.

According to Searle (1979), metaphor comprehension (the ability to understand that "S is R" when one hears that "S is P") includes three steps. First, there must be some shared strategies on the basis of which the hearer can recognize that what the speaker means differs from what he says. Second, there must be some shared principles that associate the P term with a set of possible values of R. Third, there must be some shared strategies that enable the speaker and the hearer to restrict the

Table 1 – Task-related activation.

Cluster p	Cluster size	Z-value	Coordinates			Side	Location	BA
			x	y	z			
Metaphor effect [(Mc−Cm)+(Mi−Im)]								
<.001	4099	3.73	−12	34	46	L	prMFC	8
		4.32	−14	56	30	L	arMFC	8/9
		4.73	−8	46	12	L	ACC	32
		4.3	−4	28	12	L	ACC	24
		3.97	10	−4	12	R	Thalamus	
		4.35	−8	−4	2	L	Thalamus	
		5.15	10	16	10	R	Caudate nucleus	
		6.39	−8	12	8	L	Caudate nucleus	
		4.29	−16	6	−12	L	Putamen	
		4.08	−18	−2	−12	L	Piriform cortex	
		3.92	−2	−18	−20	L	VTA	
Metaphor-specific effect [(Mc−Cm)+(Mi−Im)]−[(Sc−Cs)−(Si−Is)] within the areas showing a metaphor effect								
.012	118	4.12	18	28	8	R	Caudate nucleus	
.009	135	4.06	−6	22	8	L	Caudate nucleus	
Sarcasm effect [(Sc−Cs)+(Si−Is)]								
<.001	2009	5.33	2	56	24	R	arMFC	10
		4.8	−10	52	16	L	arMFC	10
		4.3	−6	46	−6	L	oMFC	10
.04	231	3.96	−18	2	−10	L	Putamen	
		3.7	−26	0	−20	L	Amygdala	
		4.11	−28	14	−24	L	Temporal pole	38
Coherence effect [(Mc−Cm)−(Mi−Im)]+[(Sc−Cs)−(Si−Is)]								
.03	249	3.66	−8	48	−4	L	oMFC	10
		4	−2	52	−14	L	oMFC	10/11

Abbreviation: ACC, anterior cingulate cortex; arMFC, anterior rostral medial frontal cortex; oMFC, orbital medial frontal cortex; prMFC, posterior rostral medial frontal cortex; VTA, ventral tegmental area. All p values are corrected for multiple comparisons at the cluster level with a height threshold of $Z > 3.09$. L, left; R, right.

range of the possible values of R to the actual value of R based on their knowledge of the S term. According to Searle (1979), the second and the third steps are the more prominent components of metaphor comprehension in contrast to the understanding of sarcasm. Thus, the metaphor-specific activation of the caudate head is related to the active exploration of the candidates for R (the candidate values for the speaker's intention) and ambiguity resolution in terms of the possible value of R. These processes of association formation with ambiguity resolution require the manipulation of information. The caudate nucleus has been shown to be involved in manipulating items within working memory as opposed to the maintenance/retrieval of the same material (Lewis et al., 2004).

The present finding is consistent with previous neuroimaging studies showing the involvement of the basal ganglia in ambiguity resolution at both word (Ketteler et al., 2008) and sentence (Mummery et al., 1998; Price et al., 1997) levels. In reviewing imaging studies of bilingual language processing, Friederici (2006) suggested that the left caudate participates in the monitoring and processing of semantic decisions, and that its activity is enhanced when the language processing system cannot rely entirely on automatic mechanisms. In the present study, metaphor comprehension required non-automatic exploratory association formation followed by ambiguity resolution, as we did not use dead metaphors. Thus, it is possible that the activation in the head of the caudate is related to the metaphor-specific process of association formation with ambiguity resolution at a discourse level.

The finding of metaphor-related activation in the thalamus was also striking. Using fMRI, Stringaris et al. (2007) showed that the left thalamus is related to deriving meaning from metaphoric sentences. They argued that the thalamus is related to the non-compositional associations that are essential to metaphor comprehension.

Although the basal ganglia are not directly involved in primary language or semantic functions, the closed basal ganglia-thalamo-cortical circuit (Alexander and Crutcher, 1990; Haber and Calzavara, 2009) might contribute to the enhancement of selected cognition and the suppression of competing cognition (Crosson et al., 2007), which is an essential part of ambiguity resolution, and hence metaphor comprehension (Gernsbacher et al., 2001). Thus, the metaphor-related activation of the head of the caudate and the thalamus might represent the process of exploratory association formation with ambiguity resolution.

4.2.2. *Sarcasm-related activation of the left amygdala*

The left amygdala showed activation during sarcasm comprehension. This is consistent with a previous fMRI study using an irony task, which showed activation of the left amygdala in adults (Wang et al., 2006). The amygdala is known to be an important component of the neural substrates of

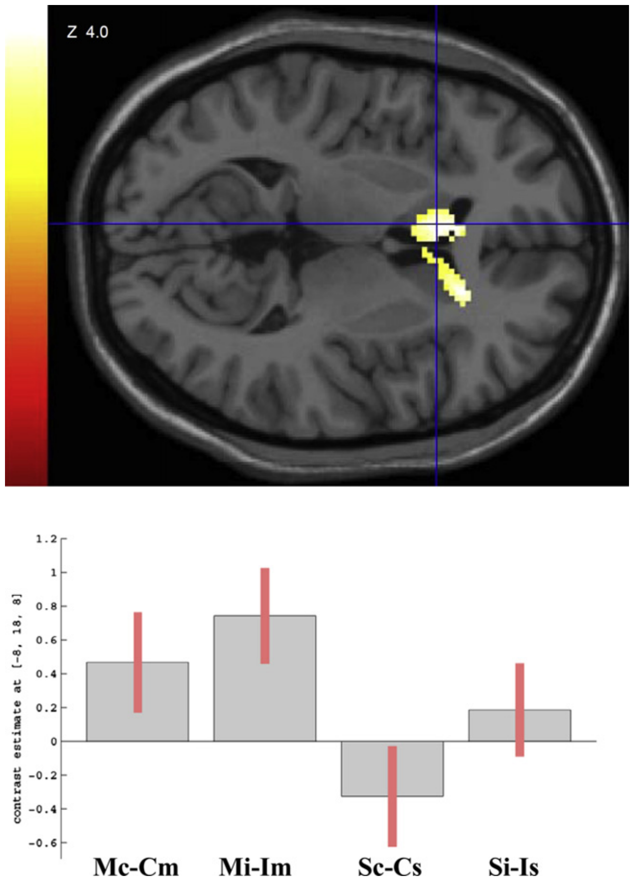

Fig. 4 – (Top) Metaphor-specific areas highlighted when [(Mc–Cm) + (Mi–Im)] – [(Sc–Cs) – (Si–Is)] was searched within the areas that revealed a significant metaphor effect. The blue lines cross at (−8, 18, 8). The color scale shows Z values. (Bottom) Percent signal change in the left caudate nucleus at (−8, 18, 8) for (Mc–Cm), (Mi–Im), (Sc–Cs), and (Si–Is). Error bars indicate the 90% confidence interval.

social behavior (Brothers et al., 1990). However, the role of the amygdala in ToM has been debated. The amygdala is responsible for a variety of social emotional information processes (Adolphs, 2003). Individuals with autism or Asperger's syndrome, who consistently fail the ToM task (Baron-Cohen, 1995), frequently show amygdala abnormalities (Baron-Cohen et al., 2000). By comparing patients with early and late damage to the amygdala, Shaw et al. (2004) concluded that it is not involved in on-line ToM processing, but rather has an important role in the neural systems supporting the normal development of ToM reasoning.

Sarcasm is a form of irony that is used in a hurtful or critical way (McDonald and Pearce, 1996), and is usually employed to communicate implicit criticism about the listener or the situation, provoking a negative effect, accompanied by disapproval, contempt, and scorn (Sperber and Wilson, 1995). Thus, the inference of the emotional status of another person is part of sarcasm comprehension. Baron-Cohen et al. (1999) showed that the left amygdala was activated by a task requiring the participant to infer the emotional state of an individual from the expression of their eyes. Thus, the left amygdala might be related to the detection of non-linguistic emotional cues. Considering that no non-linguistic (eye) or paralinguistic (prosodic) cues were presented in the current study, the left amygdala might also be involved in the detection of affective linguistic cues regarding the emotional status of another person.

4.2.3. *Coherence effect in the orbital MFC (oMFC)*

The oMFC showed a significant literal coherence effect. The literal coherence contrast was used to depict the areas where the activation during pragmatic comprehension with literally coherent control sentences (Mc–Cm and Sc–Cs) was larger than the activation with incoherent control sentences (Mi–Im and Si–Is). This comparison was motivated by the fact that the pragmatic sentences were literally incoherent. The oMFC shows almost no activation related to pragmatic comprehension when compared with the incoherent control sentences (Fig. 7), indicating that activation in this area is mainly related to the judgment of literal coherence during pragmatic comprehension.

The oMFC is known to be involved in monitoring the reward value of stimuli and responses. It represents and updates the value of possible future outcomes by which subsequent behaviors are guided (Amodio and Frith, 2006). This monitoring process might be necessary for sentence comprehension. A previous neuroimaging study showed that the oMFC is involved in making associations between the stimuli and the correct responses in sentence completion or story comprehension (Elliott et al., 2000). During a sentence completion task in which participants were required to generate the missing final word, anterior oMFC activation was associated with making an appropriate completion. This activation was enhanced in the lower constraint conditions, in which a greater number of possible candidates existed. Elliott et al. (2000) suggested that the oMFC is involved in the selection of stimuli and/or responses on the basis of their reward value. Participants were required to monitor the stimuli and/or responses, and to contrast the possible reward values of future responses. This monitoring process is also necessary in story comprehension. Furthermore, oMFC activation increases with the degree of guesswork needed to comprehend the meaning of stories (Elliott et al., 2000; Maguire et al., 1999). In the present study, both the metaphor and sarcasm contexts were literally incoherent. The literally incoherent contexts required more guesswork than the literally coherent contexts, and thus caused more prominent activation in the oMFC. It is conceivable that the oMFC is involved in pragmatic comprehension through monitoring the information provided by the preceding stories, which is in turn utilized to evaluate the literal coherency of the target sentences by referring to the common background assumption that is shared by the speaker and listener. This contrasts with metaphor comprehension, in which active exploratory association formation is necessary.

The monitoring function might not be limited to literal coherency. Wakusawa et al. (2007) showed activation of the oMFC during irony comprehension, when sentences depicting irony in certain social situations were compared with literally correct (and thus coherent), but situationally inappropriate, control sentences. Thus, the oMFC might also be involved in monitoring in general, including both situational and literal coherency.

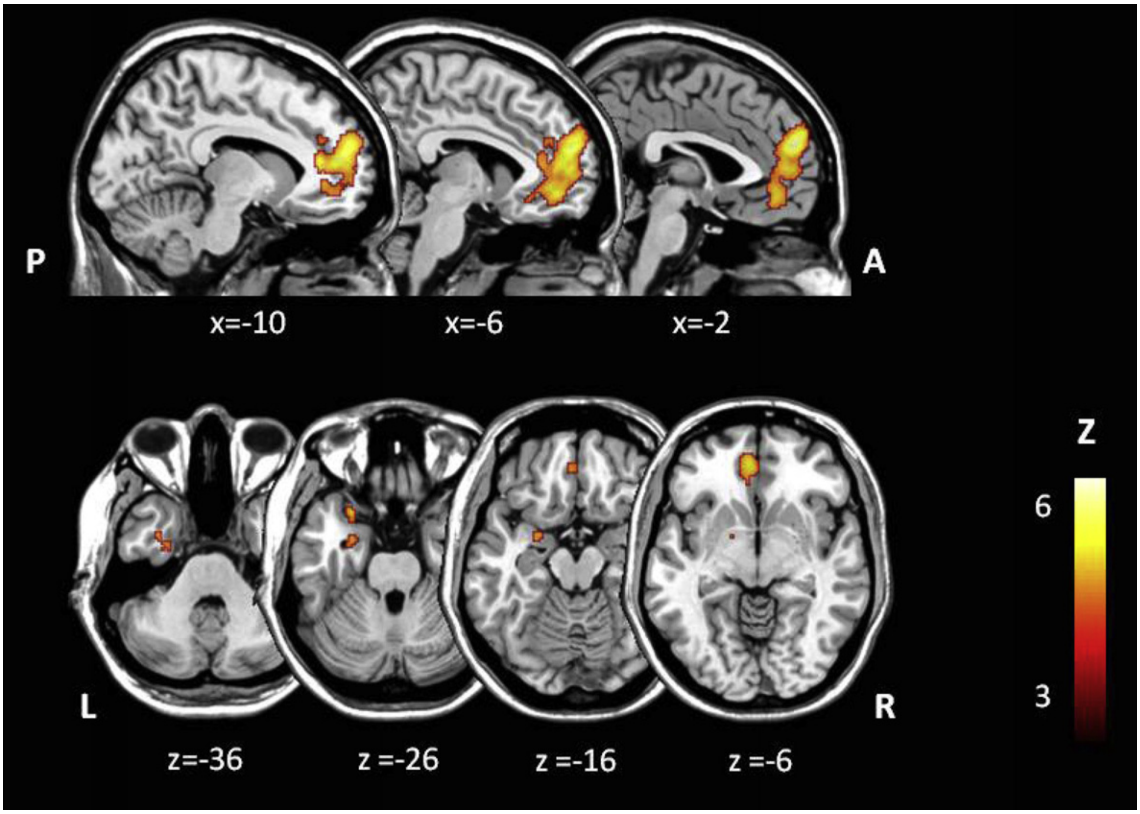

Fig. 5 – The sarcasm effect depicted by the contrast of [(Sc–Cs) + (Si–Is)] superimposed on the T1-weighted high-resolution MRI of a participant unrelated to the study. The color scale shows *Z* values.

4.2.4. *Sarcasm and metaphor both activate the arMFC*

Both metaphor and sarcasm activated the arMFC. This cannot be explained solely by the coherence effect. As successful understanding of both metaphor and sarcasm depends on perceiving the intention of the speaker within a social context (Grice, 1975), the common activation of the arMFC is in part related to the mentalizing process.

The arMFC was activated during mentalizing tasks in which participants were required to represent another person's mental state (for a review see Gallagher and Frith, 2003). The arMFC is also related to self-referential processing (for a review see Northoff and Bermpohl, 2004), in which participants judged whether a personality trait or a statement about attitudes accurately described them. The arMFC areas activated by self-reflection and mentalizing tasks largely overlapped at the individual participant level (Saxe et al., 2006). D'Argembeau et al. (2007) further showed that the same arMFC region was activated when participants judged whether other people would say that an adjective described them. Thus, the arMFC is generally related to thinking about "social" attributes, regardless of whether they pertain to the self or others, forming metacognitive representations (Amodio and Frith, 2006).

Activation in the MFC is elicited by a broad range of social tasks, such as social judgment about event knowledge, morality, social scripts, and ToM beliefs (Van Overwalle, 2009). To parsimoniously explain the involvement of the MFC in a broad range of social tasks, Krueger et al. (2009) proposed that the mPFC mediates social event knowledge by binding MFC representations with information from regions in the posterior cerebral cortex and limbic structures (the structural and temporal representation binding theory). Their theory assumes that the MFC represents event simulators (elators) that encompass a multi-modal representation of social event knowledge distributed throughout association and modality-specific areas. Elators, abstract dynamic structured summary representations, provide the underlying properties for social cognitive structures that are involved in planning and monitoring one's own behavior and understanding and predicting the behavior of others. They also proposed that elator function is segregated along the dorso-ventral axis: goal knowledge mediated by the dorsal MFC pathway supports inferences about the likely actions performed by agents for goal achievement, whereas outcome knowledge mediated by the oMFC pathway supports inferences about the likely reward value accompanying the achievement of goals. The most rostral parts of the MFC allow the integration of the information from both pathways.

This model suggests that coherence monitoring and the mentalizing process are integrated at the arMFC during pragmatic comprehension. In the present study, the arMFC (anterior rostral medial frontal cortex) region was activated by both sarcasm and metaphor comprehension, in addition to the coherence effect (Fig. 7). This notion is also supported by a previous study (Ferstl and von Cramon, 2002), in which the relationship between mentalizing and literal coherency was explicitly tested. They found that, within the mentalizing network, the arMFC plays a role in coherence processing during both mentalizing and logical stories (Ferstl and von Cramon, 2002). The authors postulated that these tasks

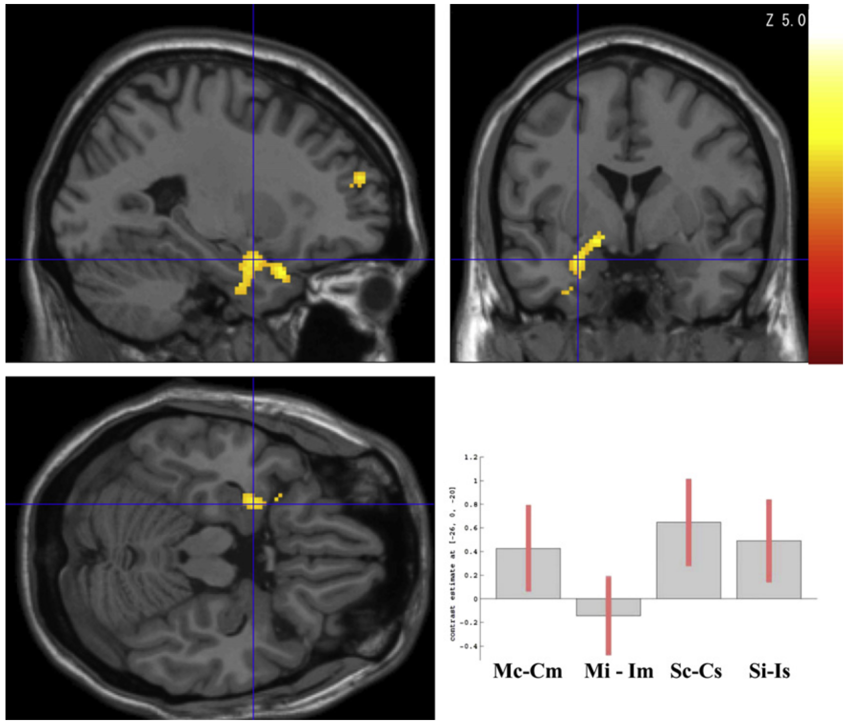

Fig. 6 – The sarcasm effect in the left amygdala superimposed on the T1-weighted high-resolution MRI of a participant unrelated to the study. The blue lines cross at (−26, 0, −20). The color scale shows Z values. (Bottom right) Percent signal change in the left amygdala at (−26, 0, −20) for the (Mc−Cm), (Mi−Im), (Sc−Cs), and (Si−Is) contrasts. Error bars indicate the 90% confidence interval.

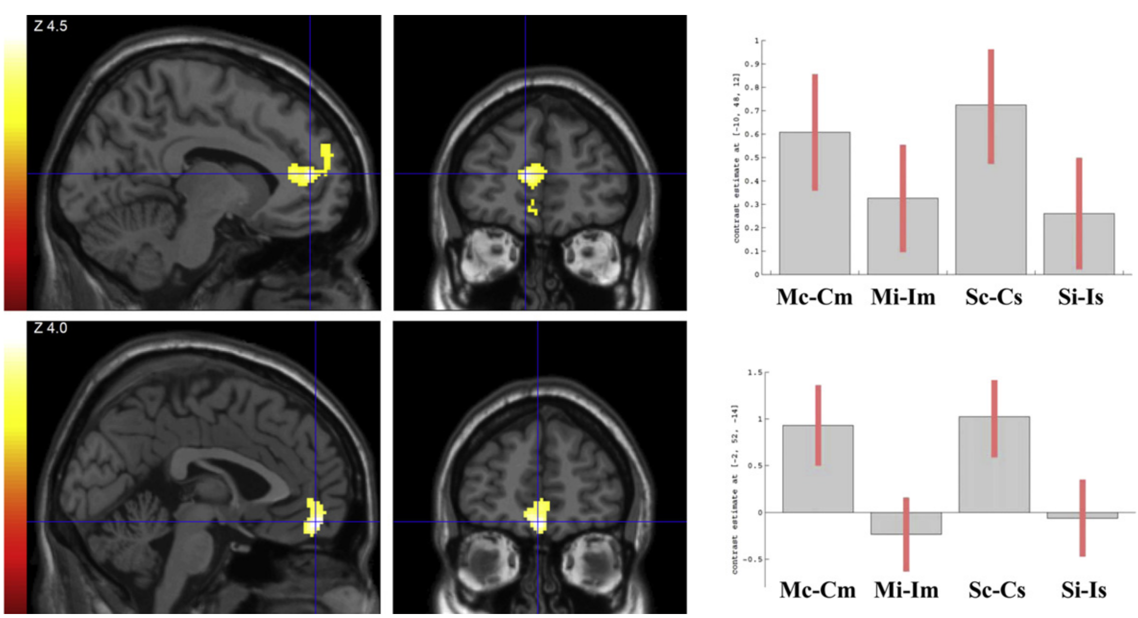

Fig. 7 – (Top left) The areas showing both metaphor and sarcasm effects depicted by the conjunction of [(Mc−Cm)+(Mi−Im)] and [(Sc−Cs)+(Si−Is)] superimposed on the T1-weighted high-resolution MRI of a participant unrelated to the study. The blue lines cross at (−10, 48, 12). The color scale shows Z values. (Top right) Percent signal change in the left arMFC at (−10, 48, 12) for (Mc−Cm), (Mi−Im), (Sc−Cs), and (Si−Is). Error bars indicate the 90% confidence interval. (Bottom left) The coherence effect depicted by the contrast of [(Mc−Cm)−(Mi−Im)]+[(Sc−Cs)−(Si−Is)]. The blue lines cross at (−2, 52, −14). The color scale shows Z values. (Bottom right) Percent signal change in the left oMFC at (−2, 52, −14) for (Mc−Cm), (Mi−Im), (Sc−Cs), and (Si−Is). Error bars indicate the 90% confidence interval. The coherence effect is more prominent in the ventral than the dorsal medial prefrontal areas.

Table 2 – Brain regions showing both sarcasm and metaphor effects by the conjunction analysis.

Cluster p	Cluster size	Z-value	Coordinates			Side	Location	BA
			x	y	z			
.001	522	4.17	−14	56	28	L	arMFC	9
		4.59	−10	48	12	L	arMFC	10/32
		3.5	−6	40	−4	L	oMFC	10/32

arMFC, anterior rostral medial frontal cortex; oMFC, orbital medial frontal cortex. All p values are corrected for multiple comparisons at the cluster level with a height threshold of $Z > 3.09$. L, left; R, right.

shared a common component: the initiation and maintenance of non-automatic cognitive processes. They speculated that this component is linked to the so-called self-model, "a transient computational module, episodically activated by the system in order to regulate its interaction with the environment" (Ferstl and von Cramon, 2002). The self-model is continuously updated by dynamically integrating internal and external information, and thus corresponds to the elator function of the rostral part of the mPFC. These previous studies, along with the present study, indicate that the arMFC is related to the integration of mentalizing and coherence monitoring during pragmatic comprehension.

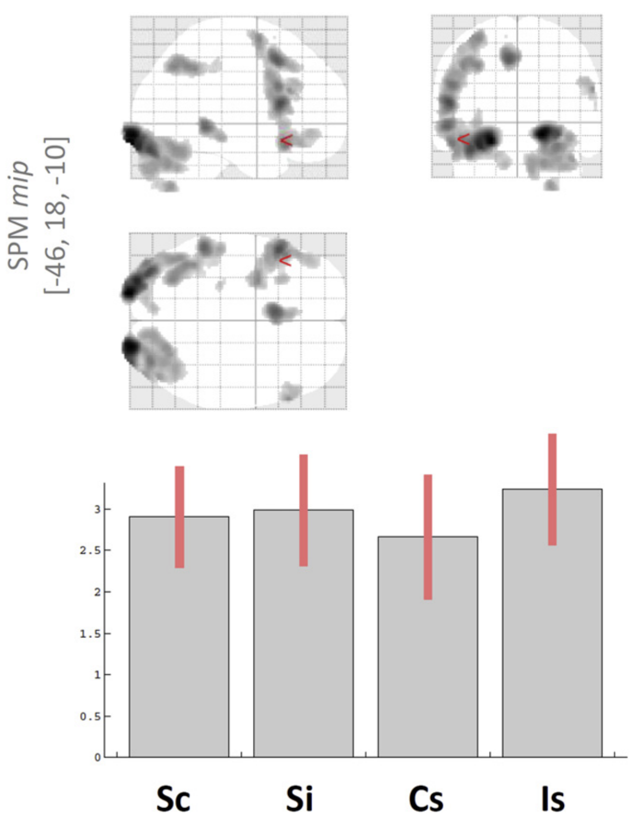

Fig. 8 – (Top) Statistical parametric maps of the areas activated by both Sc and Cs. The activated patterns were revealed with conjunction analysis in the group-level analysis using the random-effects model that incorporated the individual parameter estimates of Sc, Si, Cs, and Ci evoked by the S2 presentation. The three-dimensional information was collapsed into two-dimensional sagittal, coronal, and transverse images (i.e., maximum intensity projections viewed from the right, back, and top of the brain). Maps are thresholded at $p < .05$ with a family-wise error correction at the voxel level. (Bottom) Percent signal change in left BA 47 at (−46, 18, −10), the sarcasm-related region of activation that had been shown in a previous study (Uchiyama et al., 2006).

4.3. *Comparisons with previous findings*

The present study showed activation mostly in subcortical and limbic regions, in contrast to all previous studies, which reported mostly lateral fronto-temporal brain activation. This is likely due to the task, which was specifically designed to evaluate the context effect, in which identical sentences either did or did not convey pragmatic information. In fact, the conjunction analysis of Sc and Cs at the group level showed a left-lateralized activation pattern that is usually observed during reading tasks (Fig. 8), including Brodmann area (BA) 47, which was similar to the activation shown in a previous study by Uchiyama et al. (2006). The Sc and Cs activations were evoked by identical sentences, but with different contexts (sarcastic and non-sarcastic lexically coherent sentences); thus, the Sc–Cs contrast canceled out the both the lexical and the sarcasm comprehension processes that were common to both the Sc and Cs conditions (Uchiyama et al., 2006). The left amygdala activation highlighted by the Sc–Cs contrast in the present study might thus represent the feelings of the speaker that are indirectly conveyed by the Sc condition, but not by the Cs sentences. Similarly, the contrast of Mc–Cm represents the process of exploratory association formation with ambiguity resolution, because the Mc condition is more ambiguous than the Cm condition due to the different contexts given by S1.

5. Conclusion

The present results highlight both the shared and the unique neural substrates for the pragmatic language processes of sarcasm and metaphor. Metaphor-specific activation was found in the head of the caudate, which might have a role in making associations with potential meanings, and in restricting the sentence meaning to a set of possible candidates for what the speaker intended. Sarcasm-specific activation in the left amygdala is related to the representation of the emotional status of others. The mesial frontal areas, such as the oMFC and arMFC, are involved in monitoring the literal coherency of sentences and in the inductive reasoning needed to comprehend the pragmatic meanings. These findings indicate that pragmatic comprehension requires multiple neural substrates outside the classical language areas, particularly those that are part of the "social brain" (Skuse and Gallagher, 2009, for review).

Acknowledgments

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Appendix

Table A1 – Metaphor-logically coherent pairs. Results of the preliminary experiment (*n* = 27).

Label		S1_story	S2_comment [(nearest equivalent English metaphor satisfying both sentences)]	S2 sense of metaphor explained / S2 phonetic Japanese/literal translation	% Correct	Comprehensibility rating
1	Mc01	The senior colleague tried hard to explain the history of the martial art to a foreigner who knew nothing about it. The senior said to his junior:	(The effort) was bone-breaking	A laborious task	96.3	3.83
	Cm01	The younger brother had an accident and his leg was in plaster. He said the following to his friend, who visited him and asked what happened:	(The injury) was bone-breaking	Hone ga ore-ru/a bone is broken	96.3	4.74
2	Mc02	The man was thought too old to work anymore. Having learned of this, the president told the man's boss:	(His ability) is past its sell-by date	To have seen one's best days	85.2	3.68
	Cm02	The mother realized that the cake in the fridge was 3-month old. She told the elder brother:	(His cake) is past its sell-by date	Shomikigen ga kire-ru/past the sell-by date	100	4.46
3	Mc03	After failing his college entrance exam four times, the elder brother finally passed it. The mother learned the news and told him:	(His university career) is finally blooming	To pass an entrance examination	81.5	4.62
	Cm03	That year, the cherry blossom season started late all over Japan. The mother, who had eagerly awaited cherry blossoms, told the elder brother:	(The cherry tree) is finally blooming	Sakura ga sa-ku/cherry blossom is in bloom	100	4.88
4	Mc04	The elder brother alone had outstanding grades. The teacher saw this and said the following about the elder brother:	(The brother) is/are sharp	To be intelligent	85.2	4.3
	Cm04	The elder sister's scissors could cut up any clothes, no matter how thick they were. The teacher saw her scissors and said:	(The scissors) is/are sharp	Kire-ru/He's/it's sharp	96.3	4.33

(continued on next page)

Table A1 – (*continued*)

	Label	S1_story	S2_comment [(nearest equivalent English metaphor satisfying both sentences)]	S2 sense of metaphor explained / S2 phonetic Japanese/literal translation	% Correct	Comprehensibility rating
5	Mc05	The younger sister came home, looking enraged about something. Her father saw this and commented:	(The sister) is about to boil over	To be on the verge of losing one's temper	96.3	4.2
	Cm05	A girl had a kettle on the stove. Her elder brother saw the boiling kettle and said:	(The kettle) is about to boil over	Yuge ga ta-tsu/You are/it is giving off steam	100	4.72
6	Mc06	The plainclothes detective intended to let the suspect who was on the run remain at large, while keeping him under surveillance. He told his subordinates:	Keep a close eye on (the suspect)	To delay an arrest in order to monitor a suspect	96.3	4.48
	Cm06	The younger brother, who liked swimming, had been in the pool for a while. The father, who was with him, said to the mother:	Keep a close eye on (the younger brother swimming)	Oyogasete o-ku/let us leave him swimming for a while	100	4.44
7	Mc07	The elder brother's volleyball team kept winning matches, repeating their victory, until they finally lost. The younger brother, who saw their losing game, said:	You've muddied your (winning record)	To lose after a run of victories	88.9	3.26
	Cm07	The younger brother, who was running in the school yard, tripped and fell. The elder sister came to help and said:	You've muddied your (knees)	Tsuchi ga tsu-ku/You've been covered in mud	96.3	4.25
8	Mc08	The protagonist the scriptwriter had created was ordinary and boring. The director told the scriptwriter frankly:	(The character) needs spicing up	To be made more interesting	100	3.88
	Cm08	The dish that he cooked was good but something was missing. The chef tasted it and gave him a piece of advice:	(The dish) needs spicing up	Supaisu (spice) ga tarinai/It needs to be spiced up a bit	100	4.76
9	Mc09	Five people, each of whom had different musical talents, gathered together and gave a wonderful performance. The audience heard their concert and said:	(The performers had good) chemistry	Performers that complement each other well	96.3	4.29
	Cm09	In a science experiment, the water was separated by electrolysis to produce hydrogen and oxygen. The teacher demonstrated this and told the students:	(The experiment involved) chemistry	Kagakuhannou/A chemical reaction has occurred	100	4.72

(*continued on next page*)

Table A1 – (continued)

	Label	S1_story	S2_comment [(nearest equivalent English metaphor satisfying both sentences)]	S2 sense of metaphor explained / S2 phonetic Japanese/literal translation	% Correct	Comprehensibility rating
10	Mc10	The husband spent most of his salary on pachinko (a Japanese pinball game). The wife finally told her husband, who never seemed to stop playing:	To wash (his hands) of (pachinko)	To be reformed after past misdeeds	85.2	4.23
	Cm10	The younger brother, who had been playing outside, walked in with dirty feet. The mother saw this and told him:	To wash (his feet) of (dirt)	Ashi wo ara-u/Wash your feet	100	4.72

Table A2 – Metaphor-logically incoherent pairs.

	Label	S1_story	S2_comment [nearest equivalent English metaphor (satisfying both sentences)]	S2 sense of metaphor explained / S2 phonetic Japanese/literal translation	% Correct	Comprehensibility rating
1	Mi01	During the past 10 years, the man had always been at the forefront of the IT industry. A friend who knew the subject well commented on him:	He/she has been a workaholic	To continue with untiring perseverance	85.2	4.45
	Im01	The father thought he saw the elder sister and was about to call out to her, but it proved to be someone else. The father told the mother, who was next to him:		Hashiri tsuduke-ru/He has been running all the time	96.3	1.25
2	Mi02	He had been depressed for a while after being laid off from his job, but is now employed. His girlfriend, who had been worried about him, saw this and said:	He/she is back on his/her feet again	To recover from a setback	88.9	4.13
	Im02	The previous weekend, the elder sister had been to a much anticipated concert with a friend. The teacher learned about this and said the following about the elder sister:		Arukida-su/He has started walking again	100	1.28
3	Mi03	After some work experience, he became a university student at the age of 30. He told his classmates that:	I've been taking a career side step	To have been distracted from the main path	96.3	4.08
	Im03	The elder sister continued talking, without being aware that a customer had entered. The younger sister saw this and said:		Yorimichi wo su-ru/I have been on a detour for a while	96.3	1.25
4	Mi04	Opposing teams were glaring at each other with fierce intensity. The sports commentator said:	Sparks are flying	To have a heated confrontation	92.6	4.79
	Im04	The elder sister was having a shower in the bathroom while the mother was away. The mother came home and said upon seeing her:		Hibana ga chi-ru/Look at the bright sparks flying	100	1.36

(continued on next page)

Table A2 – (*continued*)

	Label	S1_story	S2_comment [nearest equivalent English metaphor (satisfying both sentences)]	S2 sense of metaphor explained / S2 phonetic Japanese/literal translation	% Correct	Comprehensibility rating
5	Mi05	A senior colleague in the company had been spending a considerable amount of time drinking coffee and wasting time at a café with his junior, even though he had not finished his work. A colleague said:	He/she has been messing around	To idle one's time away	96.3	4.28
	Im05	The younger sister turned 20 that year and attended a coming-of-age ceremony in her hometown. A middle-aged lady learned the news and told her:		Abura wo u-ru/ He is selling oil	100	1.32
6	Mi06	The mother, who was in hospital with cancer, had only a short while left to live. Conscious of the short time left to her, she told her daughter:	I will soon be passing away	To die	88.9	4.52
	Im06	The senior had finished his postgraduate studies and was working at a major company. The junior came to visit his company and told the senior:		Omukae ga ku-ru/I will be taken away soon	88.9	1.39
7	Mi07	To try and gain favor, the section supervisor flattered his departmental manager. Their boss found out and told everyone:	(He/she has been) toadying up to his department manager	To flatter	88.9	4.77
	Im07	The younger sister ate too much and had an upset stomach. She had been in the toilet since lunch. The mother saw this and said to her:		Goma wo su-ru/He is grinding sesame at the moment	100	1.23
8	Mi08	The elder brother's room was full of waste paper. It was so messy that there was no place even to sit down. The younger sister told her brother:	The room is a pigsty	A very messy room/dwellings	85.2	4.14
	Im08	The younger brother left school early and went to a hospital to have a work-up examination. The mother saw him and said:		Butagoya/It is a pigsty over there	88.9	1.35
9	Mi09	In the husband's company, there were no barriers between positions, and workers could freely express their professional opinions. A friend learned about this and said:	The company has an open-door policy	Able to have frank and open discussions	88.9	3.26
	Im09	The husband looked through a gift catalog and compared different products, but soon became fed up with it. He told his wife:		Kazetooshi ga ii/ There is a good breeze here	96.3	1.16
10	Mi10	The father roared at the younger brother, who had been mischievous. The elder sister saw this and told the mother quietly:	He is getting a tongue-lashing	To be fiercely admonished	96.3	4.72
	Im10	The grandfather took his grandchild for a leisurely walk with the dog by the sea. A middle-aged woman saw them and told the grandfather:		Kaminari ga ochi-ru/A thunderstorm has struck	88.9	1.43

Table A3 – Sarcasm-logically coherent pairs.

Label		S1_story	S2_comment	% Correct	Comprehensibility rating
1	Sc01	The woman was not a good cook and was taking up to an hour just preparing the ingredients. Her mother-in-law, who was watching how she was doing, said to her:	You're very skillful!	100	3.76
	Cs01	The woman was a good cook and was preparing dinner efficiently. Her mother-in-law, who was watching how she was doing, said to her:		100	4.81
2	Sc02	The younger brother had bad handwriting that he alone could read. The elder sister was amazed by his handwriting and said:	You've got great handwriting!	100	3.44
	Cs02	The younger brother was good at calligraphy and had received prizes for it. The elder sister was impressed upon seeing his handwriting and said:		100	4.85
3	Sc03	During office hours, the subordinate spent his time on trivial tasks and did not do any meaningful work. The boss saw this and said to him:	How diligent you are!	96.3	3.71
	Cs03	The senior colleague worked very hard during office hours without taking a break. The boss saw this and said to him:		100	4.73
4	Sc04	After graduating from university, the elder brother had no steady job. He idled away his time, having fun every day and spending his parents' money. The teacher learned about this and said:	You are magnificent!	96.3	3.46
	Cs04	After graduating from university, the elder brother worked hard to set up a company, and was now the president of a first-class enterprise. The teacher learned about this and said:		100	4.73
5	Sc05	The younger sister folded the laundry untidily, so it became messy in no time. The mother saw this and said to her:	You fold the laundry very carefully.	96.3	3.33
	Cs05	The younger sister folded the laundry neatly so that it was arranged tidily. The mother saw this and said to her:		100	4.76
6	Sc06	The younger sister was wearing old and tattered gloves with holes in them. A middle-aged lady saw them and said to her:	What lovely gloves you have!	100	3.36
	Cs06	The younger sister was wearing pretty gloves that she had just bought. A middle-aged lady saw them and said to her:		100	4.84
7	Sc07	The grandfather's garden was infested by weeds that were growing all over the place, as it was not well maintained. A middle-aged lady saw the garden and said to him:	What a lovely garden!	100	3.72
	Cs07	The grandfather's garden was tidy, as it is was carefully maintained. A middle-aged lady saw the garden and said to him:		100	4.76
8	Sc08	The younger brother's room was full of rubbish and there was no space left to sit down. The mother saw his room and told him:	You always keep it clean.	100	3.56
	Cs08	The younger brother's room was clean and tidy without any rubbish. The mother saw his room and told him:		96.3	4.88

(continued on next page)

Table A3 – (continued)

Label		S1_story	S2_comment	% Correct	Comprehensibility rating
9	Sc09	The elder brother undressed and left his clothes lying about, so his room was messy. The mother saw his room and told him:	It is always tidy.	96.3	3.71
	Cs09	The elder brother put his clothes away in the drawer, and kept his room tidy. The mother saw his room and told him:		100	4.84
10	Sc10	We did not understand what the senior's research presentation was about. The teacher, who was listening to the presentation, told the senior:	It was very well-organized.	92.6	3.39
	Cs10	The senior's research presentation addressed a difficult issue but was lucid and easy to follow. The teacher, who was listening to the presentation, told the senior:		100	4.84

Table A4 – Sarcasm-logically incoherent pairs.

Label		S1_story	S2_comment	% Correct	Comprehensibility rating
1	Si01	The elder sister went to the party in a shabby dress, because she had nothing else to wear for the occasion. Her acquaintance, who was on bad terms with her, said:	What a lovely dress you have!	100	3.86
	Is01	The elder sister worked as a secretary at the father's company after finishing junior college. She told the president that the scheduled meeting was about the following:		100	1.12
2	Si02	The younger sister's cooking was hopelessly bad. Her boyfriend, who had to eat it, told her:	You are a super cook.	96.3	3.83
	Is02	The younger sister bought an expensive wallet as a souvenir from her trip. When she presented the wallet to her boyfriend on returning home, he said:		100	1.16
3	Si03	The senior could not play the violin well and always made mistakes. The teacher listened to his performance and said:	That was a brilliant recital!	100	3.58
	Is03	The younger brother went to the racecourse and, after some contemplation, bought a ticket for the favorite. The elder brother, who was an expert on horse racing, was with him and said:		100	1.17
4	Si04	The younger brother finally woke up at 11 AM on Sunday. The mother told him, when he appeared looking drowsy:	You are an extremely early riser!	96.3	4.32
	Is04	The youngest of a family was tricked by his best friend into a debt of 10 million yen. Upon discovering the IOU, the mother said:		96.3	1.28

(continued on next page)

Table A4 – (*continued*)

Label		S1_story	S2_comment	% Correct	Comprehensibility rating
5	Si05	A child was creating a lot of noise on a train by running up and down the aisle. A middle-aged woman told the child's mother:	Your child is very well behaved!	100	3.88
	Is05	Due to illness, the younger daughter was paralyzed on the right side of her body and wrote slowly. A middle-aged woman saw this and said:		85.2	1.24
6	Si06	A young man, who was a baseball player, had been in a slump recently, and was unable to make any hits. His manager told him the following:	You are doing great these days.	100	3.36
	Is06	The senior worker went to work in his favorite suit. His boss saw him and said:		85.2	1.62
7	Si07	The day after she announced that she would go on a diet, she went to all-you-can-eat cake buffet. Her mother saw this and said to her:	You are trying hard to lose weight.	100	3.46
	Is07	The older daughter got severely burned because she touched a kettle containing boiling water. Her mother saw this and said to her:		96.3	1.24
8	Si08	The younger daughter had been lying around for a while, eating candy. Her father saw what she had been doing and said to her:	You look incredibly busy.	100	3.58
	Is08	The older of two sisters gave a skirt she had bought on sale to her younger sister. The younger sister was grateful and said to her older sister:		96.3	1.25
9	Si09	It was impossible to listen to the older boy in the family sing as he was out of tune and lacked rhythm. A friend's mother who heard him said:	You are a really good singer.	96.3	3.38
	Is09	Recently, the man's forehead had become considerably more visible due to hair loss. His daughter saw it and told him:		100	1.24
10	Si10	The junior worker arrived an hour after the scheduled time. His boss, who had been waiting all along, saw him and said:	You have arrived very early.	100	3.44
	Is10	A boy was talking loudly with his friend in the classroom after school. A teacher who saw them said:		92.6	1.42

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