Neural correlates of Japanese honorific agreement processing mediated by socio-pragmatic factors: An fMRI study

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ABSTRACT

Socio-pragmatic factors, such as social roles and language experience, could be key variables influencing language processing. However, little is known regarding the neural correlates of syntactic processing mediated by socio-pragmatic factors. Honorific agreement in Japanese is well-suited for the investigation of this issue. Japanese honorifics are governed by socio-pragmatic and syntactic rules. Lower social status speakers are expected to address higher social status counterparts in accordance with these rules. This linguistic skill is typically developed through language experience accrued in social contexts. The present functional magnetic resonance imaging study investigated the neural correlates of the honorific agreement processing mediated by socio-pragmatic factors. Thirty-three native Japanese speakers performed a socio-pragmatic judgment task containing sentence conditions manipulated by conventionality (i.e., conventional vs. unconventional) and speaker (lower-status vs. higher-status). The lower-status conditions elicited significantly more activation of the left inferior frontal gyrus (IFG), bilateral insula, and dorsal medial prefrontal cortex than the higher-status ones, irrespective of conventionality. This suggests that social cues (i.e., speaker social status) trigger computation of honorific agreement via the left IFG. Furthermore, the conventional conditions significantly enhanced activation of the bilateral anterior temporal lobes (ATLs), compared with the unconventional conditions. Finally, the listener’s experience with honorific use in the workplace was positively correlated with activation of the left inferior parietal lobule (IPL) during comprehension of conventional honorific utterances. Our findings demonstrate the importance of socio-pragmatic factors in Japanese honorific agreement processing, which involves the ATLs and IPL.

1. Introduction

Socio-pragmatic factors (e.g., social roles, interlocutor relationships, and language experience during social interactions) are key variables that constrain speakers’ linguistic expressions, to ensure appropriate interactions (Agha, 2006). These social and linguistic factors play a role in Japanese referent honorific expressions, known as honorifics. In Japan, speakers perceived to be of lower social status are expected to use syntactically formed honorifics (i.e., humble or respectful grammatical forms) when addressing individuals...
of higher social status, or when there is a significant social distance (Fernandes & Assunção, 2018; Okamoto, 1999). Honorifics are frequently used in the workplace and business contexts as a formal speech register that facilitates interactions with guests and superiors. Consequently, native Japanese speakers often begin to learn appropriate honorifics use until late adolescents through language experiences accrued during their professional careers (Dunn, 1999, 2011).

Many neuroimaging studies have investigated the brain mechanisms that underlie syntactic processing (e.g., Friederici, 2018; Friederici et al., 2006; Matchin & Hickok, 2020; Zaccarella & Friederici, 2017) and pragmatic processing (e.g., Baštánková et al., 2015; Hagoort & van Berkum, 2007; Jang et al., 2013; Tesink et al., 2009). However, little is known regarding the neural correlates of syntactic processing mediated by socio-pragmatic factors. Moreover, it remains unclear whether language experience in social contexts influences brain mechanisms. Here, we conducted a functional magnetic resonance imaging (fMRI) experiment to investigate the neural correlates of honorifics in Japanese, which is a language well-suited to the exploration of these issues.

1.1. Japanese honorifics: established socio-syntactic agreement dependencies

Honorific expressions are frequently practiced to acknowledge differences in social status and characteristics (e.g., social rank, age, etc.) between speakers and addressees, as a social norm/convention (Ide, 1989). Many languages include honorific expressions with certain lexical forms (e.g., personal pronoun-based honorific expressions in French and Chinese) (Morford, 1997; Pan & Kádár, 2011). However, in some languages, honorifics are governed by syntactic rules, such as Japanese and Korean (Boeckx, 2006; Kim & Kaiser, 2009). In Japan, speakers of lower social status (e.g., office workers) are expected to use expressions in which respectful or humble verb forms agree with the social status (e.g., higher or lower) of the subject noun when addressing individuals of higher social status (e.g., company presidents). When speakers of lower social status refer to an event in a sentence where the subject noun corresponds to an addressee of higher social status, the respectful verb form (o-verb-ninarimasu) is used to maintain agreement with the subject noun, as shown in example 1a. If the subject noun refers to the speaker of lower social status him/herself, the humble verb form (o-verb-itashimashita) is applied, as shown in Example 1b (Yoshimura & MacWhinney, 2010). In contrast, speakers of higher social status are not expected to use honorifics. They mainly use sentences with the polite verb form (verb-masu) when addressing those of lower social status (see examples 1c and 1d [non-honorific counterparts of 1a and 1b]).

Example 1a. Office worker: Shachoo-ga watashi-no posut-a o-hari-ninarimashita

   "The president pasted my poster."

Example 1b. Office worker: Watashi-ga shachoo-no posut-a o-hari-itashimashita

   "I pasted the president’s poster."

Example 1c. Company president: Watashi-ga kimi-no posut-a o harimashita

   "I pasted your poster."

Example 1d. Company president: Kimi-ga watashi-no posut-a o harimashita

   "You pasted my poster."

(NOM: nominative case; 1SG: first-person singular; 2SG: second-person singular; ACC: accusative case; POSS: possessive case; HON: honorific/respectful; HUM: humble).

Because the respectful and humble verb forms (1a and 1b) are associated with the social properties of a subject noun, Japanese honorifics are regarded as analogous to the syntactic agreement dependencies that exist in most Indo-European languages (Boeckx, 2006; Harada, 1976; Ivana & Sakai, 2007). Syntactic agreement in these languages involves indicating the relationship between a controller noun and its agreement-bearing target; the target is often a verb (Mancini, 2018). For example, the singular or plural form of a verb in English is controlled by the number property of a subject noun. Similarly, in languages such as Spanish and French, the morphosyntactic form of a verb is determined by the gender, personal, and number properties of a subject noun.

From sociolinguistic and pragmatic perspectives, Japanese honorific agreement differs from syntactic agreement (Hori, 1986; Ide, 1992). Violations of honorific agreement may not lead to grammatical errors, but they may cause an addressee to perceive that inappropriate social behavior is taking place or infer that a speaker has hidden intentions (e.g., speakers of higher social status use honorifics for the purpose of irony toward addressees of lower social status). To determine whether an honorific expression is obligatory or socio-conventionally appropriate, speakers should consider both syntactic rules and socio-pragmatic factors, such as the perceived social hierarchical relationships of interlocutors and the social contexts in which honorifics are used (Ide, 1992; Okamoto, 1999, 2011).

Based on the above, Japanese honorifics involve both socio-pragmatic and syntactic rules. Japanese honorific agreement is not purely constrained by the syntactic relationship between a verb form and the social properties of a subject noun. Notably, it is also governed by social norms and conventions. When speakers of lower social status use honorifics to address individuals of higher social status, humble or respectful verb forms must agree with the social property of the subject noun in a sentence. Thus, the social cue of a lower social status speaker is critical for processing honorific agreement. Because both syntactic information and speaker properties are rapidly recognized when processing Japanese honorifics, brain systems relevant to syntactic and pragmatic processing are
presumed to have essential roles in Japanese honorific agreement processing. In the following sections, we describe the potential cognitive mechanisms underlying Japanese honorifics, as well as the brain areas that may be involved, based on previous findings concerning syntactic/honorific agreement and pragmatic language processing.

1.2. Linguistic agreement cues for syntactic and honorific agreement processing

Many psycho- and neuro-linguistic studies have investigated the cognitive mechanisms that underlie obligatory syntactic agreement processing (e.g., subject-verb number and gender agreement) using the violation paradigm (e.g., a singular subject noun following a verb with a plural form) (Hammer et al., 2007; Momo et al., 2008; Moro et al., 2001; Newman et al., 2003). There is a general consensus in the current literature that syntactic agreement processing is triggered by agreement types and cues (e.g., the semantic properties of subject nouns, case markers, or morphosyntactic verb inflection) (Molnar et al., 2011; Tanner et al., 2014; Yoshimura & MacWhinney, 2010). For example, upon recognition of an agreement-bearing verb (e.g., the plural form of the verb ‘were’ in "the key to the cabinets were … “ [Bock & Miller, 1991]), listeners may use the verb as a cue to check or retrieve a controller noun with the matched property and evaluate the agreement. Alternatively, an agreement can be evaluated by cues relevant to the property of a controller noun (e.g., the plural of ‘keys’ in "the keys to the cabinets were … “), which allows listeners to anticipate the specific form of an agreement-bearing verb (e.g., Nevins et al., 2007).

Neuroimaging findings are increasingly indicating that various cues can trigger syntactic computation (e.g., Bonhage et al., 2015; Henderson et al., 2016; Jakusziet al., 2013; Matchin et al., 2017; Santi & Grodzinsky, 2012; Soderstrom et al., 2018); the left inferior frontal gyrus (IFG) has a critical role in syntactic agreement computation (e.g., Carreiras et al., 2015; Heim et al., 2006; Mancini et al., 2017; Momo et al., 2008; Moro et al., 2001; Newman et al., 2003; Quinones et al., 2018). These studies have reported consistent findings, whereby the left IFG is associated with various types of syntactic agreement in different languages: number agreement (e.g., singular-plural) in Italian (Moro et al., 2001); noun-verb syntactic agreement (e.g., the lady praises the artist and meets the artist in the night) in English (Newman et al., 2003); gender agreement, determiner–noun concordance, and subject-verb agreement in Spanish (Carreiras et al., 2015). For instance, Carreiras et al. (2015) observed that left IFG activation was more commonly involved in both determiner–noun concordance and subject-verb agreement mismatched conditions, compared with matched conditions (ella/*ellas corre, she/*they dances vs. el/*ellos anillo, the rrg/*the st ring). They also observed increased activation in the pars opercularis within the left IFG, depending on the difficulty of processing syntactic agreement.

To our knowledge, there have been few studies concerning the cognitive mechanisms involved in honorific agreement processing in Japanese and Korean (Kwon & Sturt, 2016; Momo et al., 2008). One key finding of these studies is that the mechanism underlying honorific processing is similar to that underlying syntactic agreement processing. An fMRI study conducted by Momo et al. (2008), which is the most relevant to the current study, examined the neural correlates of Japanese honorific agreement. They found activation in the left IFG when participants judged the grammaticality of sentences that consisted of morphosyntactic, semantic, spelling, and honorific agreement violations. Sentences violating both morphosyntactic and honorific agreement elicited stronger activation of the left IFG than sentences that contained spelling and semantic violations. Furthermore, activation of the IFG was modulated by the performance of grammatical judgment tasks involving honorific sentences. However, participants were asked to focus on sentence grammaticality. The honorific sentences did not include explicit social status information (e.g., a subject of the first-person pronoun ‘I’ used a humble expression but incorporated the “respectful” verb form). Therefore, the participants were likely to detect honorific violations and assess the agreement between the subject noun and honorific verb forms; they were less likely to consider socio-pragmatic factors.

Kwon and Sturt (2016) found that the social status property of a subject noun raises listeners’ expectations about retrieving a specific verb form during comprehension of subject-verb honorific agreement in Korean sentences presented online. Korean honorific agreement is similar to Japanese honorific agreement, in that a verb changes to its honorific form to agree with a subject noun that contains properties indicating higher social status (e.g., chairman or president), which also carries an honorific form (marked by the nominative particle kkeyse). Kwon and Sturt conducted self-reading and eye-tracking experiments that involved correct and incorrect (agreement violation) sentences, in which the main verb agreed with the main subject noun’s property. In contrast, the embedded verb retained its honorific form that matched or mismatched with the social properties of an embedded subject noun (e.g., the *inho/-chairman-HON closed the front door so that the president/*inho could start-HON the meeting). They observed that the main subject noun referring to higher social status facilitated processing of the embedded verb with honorific forms in both the correct and incorrect sentences (e.g., attraction effect or facilitatory interference). The attraction effects suggest, that upon reading the main subject noun with properties indicating higher social status, the listeners retrieved the specific form of the Korean honorific verb.

1.3. Roles of social cues in honorific and socio-pragmatic processing

The studies mentioned earlier demonstrate that honorific agreement is processed in a manner similar to the syntactic agreement used in other languages. However, little is known regarding how honorific agreement is processed under the constraints of social norms and conventions determined by social cues. A few event-related potential (ERP) studies have demonstrated that the social cues of interlocutor’s social status prompted listeners to establish a semantic-pragmatic expectation of honorific use in Chinese, manifested through the second-person pronouns (Jiang et al., 2013; Jiang & Zhou, 2015). Jiang et al. (2013) examined the effect of the social status of interlocutors on the neural processing of respectful Chinese expressions, which are constructed using second-person pronouns (you/your can be changed to the respectful forms nin/nin-de). N400-like effects, often related to semantic-pragmatic processing, were elicited when the listeners encountered unconventional uses of second-person pronouns in relation to the social status of the
interlocutors (e.g., Professor Li to Student Liu: I have finished reading your HON article; Student Liu to Professor Li: I have heard about your situation). This finding suggests that listeners formed expectations regarding the upcoming pronoun based on the social status of the interlocutors. Thus, the unexpected use of pronouns caused difficulties when integrating sentence meanings with pragmatic references. Although the Japanese and Chinese languages differ in terms of the expression of honorifics (i.e., through syntactic rules or lexiscon), the processing of Japanese honorifics may rely on cognitive mechanisms similar to those that underlie semantic-pragmatic expectations of honorific use.

Neuroimaging research has repeatedly shown that interlocutor-related social cues have critical roles in facilitating various types of pragmatic language processing, such as indirect (politeness), inferential, and affective speech expressions (Bašnákova et al., 2015; Feng et al., 2017; Hellbernd & Sammler, 2016, 2018; Jiang et al., 2013; Jiang et al., 2018; Rigoulot et al., 2014). In particular, these studies observed that brain regions sensitive to social, emotional, and salient information are coactivated with language areas to promote the comprehension of pragmatic meaning or speakers’ intentions. For example, Bašnákova et al. (2015) found that listeners considered an interlocutor’s role in a conversation, such as whether a person was a direct addressee or non-addressee, when analyzing the speech intentions of a speaker’s indirect face-saving reply (e.g., “I am planning to enroll in a language course this summer” in response to the job interview question: “Are you fluent in any foreign languages?”). Rigoulot et al. (2014) also reported that a speaker’s prosody characteristics were used as socially salient cues to interpret expressions that conveyed the pragmatic intentions of politeness (see Jiang et al., 2018 and Hellbernd & Sammler, 2018 for a similar finding). These socially salient cues induced brain activation associated with mentalizing (e.g., dorsal medial prefrontal cortex [dmPFC] and temporal-parietal junction activity) and the perception of salient socioemotional information (e.g., insula and amygdala activity) (see Jiang, 2018 for a review). In summary, existing research has suggested that interlocutor-related information is effectively used and perceived by listeners to promote successful language comprehension (Van Berkum et al., 2008).

### 1.4. The present study

In this study, we examined the neural correlates of Japanese honorifics to address two main research goals. Our first goal was to examine how socio-pragmatic factors (i.e., the social status of interlocutors) are applied when processing Japanese honorific

| **Table 1** | Example sentence stimuli from the four task conditions. |
|---|---|
| **LC** | a. 私が watashi-ga 'I pasted (the) professor’s poster.’ 1SG-NOM sensei-no HON-paste-HUM-PST 1. A professor pasted my poster. 2. A student pasted the professor’s poster. |
| **HC** | a. 私が watashi-ga 'I pasted your poster.’ 1SG-NOM kimi-no poster-ACC HON-verb-PST 1. (The) professor pasted my poster. 2. The professor pasted your poster. |
| **LU** | a. *私が watashi-ga 'I pasted (the) professor’s poster.’ 1SG-NOM sensei-no poster-ACC HON-verb-PST 1. A professor pasted my poster. 2. A student pasted the professor’s poster. |
| **HU** | a. *私が watashi-ga 'I pasted your poster.’ 1SG-NOM kimi-no poster-ACC HON-verb-PST 1. (The) professor pasted my poster. 2. The professor pasted your poster. |

Note. LC: speaker of lower social status, conventional expressions; HC: speaker of higher social status, conventional expressions; LU: speaker of lower social status, unconventional expressions; HU: speaker of higher social status, unconventional expressions. Asterisk (*) indicates sentences with unconventional conditions. The same sentences are shown in the table for the four conditions, but the sentences were counterbalanced across the conditions during the experiment.
agreement in the brain during utterance comprehension. To achieve this goal, we created a socio-pragmatic judgment task that consisted of auditory sentences categorized according to "social status" and "conventionality." Each factor had two levels: lower speaker (L) versus higher speaker (H) and conventional (C) versus unconventional (U). In the LC condition, conventional sentences by speakers of lower social status were created by matching different types of honorific verbs (humble and respectful) and the social properties of subject nouns (e.g., student and professor). In the LU condition, unconventional sentences by speakers of lower social status were created by mismatching respectful and humble verb forms in conventional sentences. In the HC condition, conventional sentences by speakers of higher social status had a polite verb form. In the HU condition, unconventional sentences of higher social status were created by replacing the polite verb form with a respectful and humble verb form (see Table 1). The speaker and addressee, with typical social status differences, were simultaneously presented visually along with the auditory sentences. Native speakers of Japanese were instructed to judge whether each sentence was socially conventional.

We established three hypotheses concerning the neurocognitive patterns that underlie sentence processing. First, we predicted increased brain activation in association with syntactic agreement processing (e.g., left IFG) of unconventional expressions, relative to the activation associated with conventional expressions \([U > C]\). This assumption was based on previous evidence that checking and evaluating agreement according to agreement-related cues is critical when processing honorific violations (e.g., Momo et al., 2008). Second, we predicted greater brain activation during the syntactic agreement processing associated with the comparison of expressions by speakers of lower versus higher social status \([L > H]\). This is because we assumed that the listeners expected to hear respectful or humble utterances from a speaker of lower social status toward an individual of higher social status. Therefore, the social cues (lower social status speakers) may cause listeners to check the agreement between subject nouns and honorific verb forms for sentences in both the LC and LU conditions. These assumptions were supported by previous evidence that information concerning the social status of interlocutors caused listeners to form an expectation of honorific use (e.g., Jiang et al., 2013), and to retrieve the honorific verb forms, and evaluate the agreement (Kwon & Sturt, 2016). Based on these considerations, we predicted that social cues of lower social status would be critical for processing honorific agreement. Third, recognition of conventionality in honorific and non-honorific sentences is associated with semantic-pragmatic-relevant brain activation (Jiang et al., 2013; Jiang & Zhou, 2015). Consequently, we predicted that brain areas involved in the perception of speaker-related social information (e.g., social cognition-related areas) and computation of syntactic agreement (e.g., left IFG) may interact during comprehension of Japanese honorifics.

The second goal of this study was to explore the effect of language experience on honorific processing. This goal was motivated by the observation that native Japanese speakers begin to learn appropriate honorifics use until late adolescents via language experience accrued during their career and professional activities (Dunn, 1999, 2011). To achieve this goal, we used a questionnaire that measured each participant’s experience of using honorifics in the workplace. As mentioned earlier, a previous fMRI study revealed interindividual differences among native speakers of Japanese in the left IFG activation associated with honorific agreement processing (Momo et al., 2008). Therefore, we predicted that activation of the left IFG would depend on a participant’s language experience accrued in the workplace, which may influence the ability to learn honorific syntactic rules. As an alternative, we predicted that experience in the use of honorifics would be associated with the activation of brain regions sensitive to perceived social status, such as the inferior parietal lobes (Chiao et al., 2009). This is because honorific use always occurs in combination with perceptions of the social hierarchy in the workplace context.

Fig. 1. fMRI task. Each visuo-auditory stimulus was presented for 6 s, with an inter-stimulus interval randomly varying from 2 to 6 s. English translations are provided in the figure, but only Japanese words were presented during the experiment.
2. Methods

2.1. Participants

We recruited 33 native speakers of Japanese (16 women and 17 men). Their mean age (±standard deviation) was 21.15 ± 1.61 years. At the time of the experiment, all participants were undergraduate or graduate students at Tohoku University. All participants were right-handed, as determined using the Edinburgh Handedness Inventory Questionnaire (Oldfield, 1971), and all had normal or corrected-to-normal vision, as well as normal hearing; they also had no history of psychiatric or neurological illness. We determined the work experience of the participants (i.e., total months of full- and part-time work) using a questionnaire adapted from a previous study concerning honorific use (Nakagawa, 2012). Because all participants were undergraduate or graduate students at the time of this experiment, their part-time jobs outside the university (e.g., waiter, cashier, or school tutor) were likely to require them to use appropriate honorific expressions toward people in various social classes. These part-time jobs also offered the participants opportunities to master honorific expressions through real-life social interactions. Before the experiment was conducted, written informed consent was obtained from all participants. This study was approved by the Institutional Review Board of the Graduate School of Medicine and Graduate School of International Cultural Studies of Tohoku University, Japan.

2.2. Materials

We devised a socio-pragmatic judgment task that involved auditory sentences and visual stimuli (depictions of the interlocutors, see Fig. 1). The study used a 2 × 2 factorial design comprising two factors, each with two levels: social status (speakers of lower [L] and higher social status [H]) and conventionality (conventional [C] and unconventional [U]). Four sentence conditions (LC, LU, HC, andHU) were constructed, as shown in Table 1.

We used speakers and addressees with distinct social status (i.e., student vs. professor; office worker vs. company president). The sentences involved speakers of lower social status speaking to addressees of higher social status (or vice versa) in various situations. To create sentence stimuli, we selected 85 verbs and 85 nouns from a Japanese corpus, the NINJAL-LWP for BCCWJ. Using these verbs and nouns, we created 170 honorific sentences, with respectful and humble expressions, uttered by speakers of lower social status. To ensure that the created honorific sentences matched the social conventions of honorific usage, we performed a sentence-norming experiment with 12 native Japanese speakers who did not participate in the fMRI experiment. The participants were instructed to rate the appropriateness of each sentence on a five-point Likert scale, ranging from 1 (not at all) to 5 (very much). Thus, 80 highly rated honorific sentences (i.e., 3–5 points) were selected for the LC condition.

To control the semantic meaning, the same 80 verbs and nouns from the LC condition were used to create 80 conventional sentences uttered by higher social status individuals for the HC condition. Through mismatches between the two types of honorific verb forms (respectful and humble) and social properties of subject nouns (e.g., I and President) in the sentences in the LC condition, 80 unconventional sentences were created for the LU condition. Finally, sentences for the LU condition (polite expressions) were created by replacing the polite verb forms of sentences in the HC condition with the respectful and humble verb forms (Table 1). Table 1 shows example exchanges between a student and professor. In the LC condition, conventional honorific sentences were expressed by a student toward a professor, as follows: a) when the subject pronoun represented the student, the humble verb form (o-verb-itashimasu) was used, and b) when the subject noun referred to the professor, the respectful verb form (o-verb-ninarimasu) was applied. In the LU condition, a) when the subject pronoun represented the student, the mismatched respectful verb form was used, and b) when the subject noun referred to the professor, the mismatched humble verb form was used. In the HC condition, the professor used conventionally polite expressions with the polite verb form (verb-masu) toward the student, without distinguishing the subject of the sentence (a and b). In the HU condition, a) the professor used the humble form when the subject pronoun represented the professor, and b) the professor used the respectful form when the subject pronoun represented the student, in an unconventional manner with respect to addressing an individual of lower social status. The sentences for the four conditions are shown in Table 1; the contents of the sentences were counterbalanced across conditions.

All sentences were recorded at a natural speech rate by four native Japanese speakers who had a standard Japanese accent; recording was performed using a recording device (ICD-SX2000; Sony, Tokyo, Japan). Each speaker was given a list of sentences that included both conventional and unconventional expressions produced by speakers with distinct social status (i.e., student vs. professor; office worker vs. company president). The two male speakers recorded sentences produced by a student and company president; the two female speakers recorded sentences produced by an office worker and professor. All four speakers were in their thirties. All auditory sentences were recorded as 16-bit detail sound files sampled at 44.1 kHz; they were normalized to a mean of 75 dB via SoundEngine software. The mean durations of the sentences were 3.65, 3.48, 3.03, and 3.69 s for the LC, LU, HC, and HU conditions, respectively. Note that the mean duration of the sentences in the HC condition was shorter than in the other three conditions, because it was difficult to control the lengths of syntactic structures in the non-honorific conventional condition. The visual stimuli of interlocutors were created and presented concurrently with the auditory sentences. An image of the speaker was placed in the bottom left corner, accompanied by a sound-symbol, while an image of the addressee was placed in the upper right corner against a black background. The titles of the speakers and addressees were indicated by Japanese characters and aligned below the respective images (Fig. 1).
2.3. Procedure

We implemented the socio-pragmatic judgment task in an event-related fMRI design, using E-prime 3.0 software (Psychology Software Tools, Inc., Pittsburgh, PA, USA) running on a Windows PC. The auditory sentences were presented synchronously with the visual stimuli (images of the interlocutors). During fMRI scanning, the image stimuli were back-projected onto a screen and viewed by participants through a mirror inside the scanner. Auditory sentences were simultaneously delivered with visual stimuli via optical magnetic resonance imaging-compatible headphones with active noise cancellation (OptaActive, Mazor, Israel). All participants completed 10 practice trials before the fMRI experiment. Participants were instructed to judge the appropriateness of each auditory sentence after listening to it. Each visuo-auditory stimulus pair was presented for 6 s after inter-stimulus intervals that varied randomly from 2 to 6 s (Fig. 1). Participants’ responses were recorded using a response pad. The right forefinger and middle finger indicated “conventional” and “unconventional” judgments, respectively. The stimuli were divided into two sets; each set contained 160 sentences. Conventional and unconventional versions of each sentence were recorded by the same speakers. Two sentence lists were created, to avoid participants hearing sentences with identical meanings being expressed by the same speaker. In each set, the number of sentences was counterbalanced between conventional and unconventional expressions by speakers of lower and higher social status. Each participant received a single set of stimuli divided into two scanning sessions, with a break in the middle. Each scanning session lasted 13 min and 6.27 s.

2.4. Data acquisition

Imaging data were acquired using an Achieva 3.0-T MRI system (Philips, Eindhoven, The Netherlands). Functional images were obtained via gradient echo-planar imaging with the following parameters: echo time = 30 ms, flip angle = 80°, slice thickness = 3.5 mm, slice gap = 0.5 mm, field of view = 190 mm, matrix = 64 × 64, and voxel size = 3 × 3 × 4 mm. Thirty-two axial slices covering the entire brain were obtained at 2-s intervals. In total, 406 vol were acquired for each participant during each session. Subsequently, a T1-weighted structural image (thickness = 1 mm, field of view = 224 mm, matrix = 224 × 224, repetition time = 1800 ms, and echo time = 3.2 ms) was acquired for each participant; this image served as a reference for anatomical correlates.

2.5. Data preprocessing

Preprocessing was performed using Statistical Parametric Mapping software (SPM12, Welcome Department of Imaging Neuroscience, London, UK) in the MATLAB environment (MathWorks, Natick, MA, USA), and involved the following steps. First, all functional volumes for each participant were time-corrected with the 16th slice as a reference, and then spatially realigned to the first echo-planar imaging volume. Second, the anatomical T1 image was co-registered to the mean functional image, which had been produced during the process of realignment and then normalized to Montreal Neurological Institute space. Afterward, for spatial normalization of all echo-planar imaging scans into the Montreal Neurological Institute space, deformation field parameters were obtained from the normalized anatomical T1 image. Finally, all echo-planar images were spatially smoothed by application of an isotropic Gaussian kernel (full width at half maximum = 8 mm).

2.6. Data analysis

Brain imaging data were analyzed by using SPM12 with a conventional two-level analysis. In the first-level analysis, within the general linear framework, functional imaging data were analyzed to model the hemodynamic responses of the correct trials under the four experimental conditions (LC, LU, HC, and HU). We predicted that brain activity would be highest when listeners finished listening to each sentence. Therefore, we focused on the time at the end of the auditory stimulus for the hemodynamic response function modeling. Additionally, the error trials and six movement parameters (three translations and three rotations) were modeled as regressors of no interest. The error trials were those in which the participants responded incorrectly or missed the response window (mean = 9.92% of trials per participant, standard deviation = 6.81%). Notably, all participants responded after listening to the auditory sentences; therefore, no trials were discarded because of a premature response.

For the second-level (random effect) group analysis, the contrast images of the four conditions generated during first-level analysis were entered into a flexible factorial analysis of variance, implemented in SPM12 with a 2 (social status: lower [L] and higher [H]) × 2 (conventionality: conventional [C] and unconventional [U]) within-group design. Furthermore, each participant’s mean reaction time and accuracy rate were modeled for each task condition as covariates, to negate any potential influence of time and task difficulty variation among conditions. The statistical threshold was set at voxel-level p < 0.05, with whole-brain family-wise error correction for multiple comparisons. Activation peak coordinates were reported in Montreal Neurological Institute space, and activated brain regions were identified using the automated anatomical labeling atlas in SPM12 (Tzourio-Mazoyer et al., 2002).

In the flexible factorial analyses, we focused on the main effect of social status (L vs. H), main effect of conventionality (C vs. U), and interaction between social status and conventionality. First, to examine the effect of the speaker’s social status, we compared brain activation during the processing of sentences expressed by the speaker of lower social status (L) with that during the processing of sentences expressed by speakers of higher social status (H), using the contrast [L (LC + LU) > H (HC + HU)]. We predicted that the cognitive processing of honorifics, which requires a computation of syntactic agreement, would occur mediated by social cues of lower social status speakers. Hence, brain activation related to syntactic agreement processing should be greater when comprehending expressions by speakers of lower versus higher social status. Second, to examine brain areas associated with the recognition of
conventional or unconventional expressions, we compared brain activation between the conventional (C) and unconventional (U) conditions using the contrasts \([C (LC + HC) > U (LU + HU)]\) and \([U (LU + HU) > C (LC + HC)]\). The analysis of unconventional relative to conventional expressions would reveal brain activation in association with honorific agreement violation, irrespective of speaker type. Furthermore, these analyses were also designed to assess differential brain activation between conventional (pragmatically appropriate) and unconventional (pragmatically inappropriate) expressions. Third, to examine the interaction effect between social status and conventionality, we investigated brain areas sensitive to speaker properties and violation of honorific rules by using the contrast \([(LU > LC) > (HU > HC)]\). This analysis was designed to investigate the cognitive demand associated with the processing of honorific violations, as mediated by speaker-related social cues.

**Fig. 2.** Effect of speakers of lower social status on brain activation \([L > H]\). Brain areas showing greater activation in association with the processing of honorific expressions produced by speakers of lower social status (LC and LU conditions) versus higher social status (HC and HU conditions). Each area’s peak activation in each condition (LC, HC, LU, and HU) is shown relative to baseline. Error bars indicate the standard error of the mean. The statistical threshold was set at voxel-level \(p < 0.05\), with whole-brain family-wise error correction for multiple comparisons. IFG: inferior frontal gyrus; Tri: pars triangular; Oper: pars opercularis; dmPFC: dorsal medial prefrontal cortex.
In addition to these analyses, to identify the effects of language experience on the involved brain areas, we performed a single regression analysis at the whole-brain level for each sentence condition (LC, LU, HC, and HU) with the total working time of each participant. For all analyses, an initial voxel-level threshold of uncorrected \( p < 0.001 \) was used. For a priori analysis of the bilateral inferior parietal lobules (IPLs) and left IFG, small-volume corrections were performed for multiple comparisons. The regions of interest were selected based on previous findings, which have shown that bilateral IPLs are sensitive to perceived social status (e.g., Chiao et al., 2009); moreover, individual variations have been observed among native speakers of Japanese in the degree of activation of the left IFG associated with honorific agreement processing (Momo et al., 2008). The Wake Forest University PickAtlas toolbox (Maldjian et al., 2003) was used to create anatomical masks through automated anatomical labeling (Tzourio-Mazoyer et al., 2002). The statistical threshold was set at voxel-level \( p < 0.05 \), after family-wise error correction within a priori regions of interest.

3. Results

3.1. Behavioral results

All participants had \( >80\% \) accuracy in all conditions: LC, 93.1\% \( \pm \) 6.5\%; HC, 98.4\% \( \pm \) 3.1\%; LU, 84.2\% \( \pm \) 15.2\%; and HU, 87.3\% \( \pm \) 12.8\%. The mean response times in all conditions were as follows: LC, 761 \( \pm \) 372 ms; HC, 693 \( \pm \) 288 ms; LU, 822 \( \pm \) 387 ms; and HU, 668 \( \pm \) 392 ms. Repeated-measures analysis of variance of accuracy and response time were performed with the two factors of speaker’s social status (lower or higher) and conventionality (conventional or unconventional). With respect to accuracy, there were significant main effects of conventionality \( [C > U] (F_{(1, 32)} = 29.7, p < 0.001) \) and social status \( [L > H] (F_{(1, 32)} = 7.9, p = 0.008) \). There was no significant interaction effect between social status and conventionality \( (F_{(1, 32)} = 0.51, p = 0.48) \). With respect to reaction time, there was a significant main effect of social status \( [L > H] (F_{(1, 32)} = 6.19, p = 0.018) \). The main effect of conventionality was not statistically significant \( [C > U] (F_{(1, 32)} = 0.21, p = 0.652) \). There was no significant interaction effect between social status and conventionality \( (F_{(1, 32)} = 1.8, p = 0.19) \).

3.2. Imaging results

First, when sentences uttered by speakers of lower social status were contrasted with those of speakers of higher social status \( [L > H] \), significantly greater activation was found in the following brain areas: the left IFG (pars opercularis and pars triangularis), bilateral insular cortex, and dmPFC. To confirm the activation patterns across conditions, we extracted parametric estimates for each condition across participants, i.e., the peak voxels in activated brain areas. Increased activation was observed in the LC and LU conditions as compared to in the HC and HU conditions (Fig. 2 and Table 2). Notably, there was no significant activation in the \( [H > L] \) contrast, although this was not included in our initial targeted analysis.

Second, the \( [C > U] \) contrast (i.e., the effect of conventionality) produced significant activation of the bilateral anterior temporal lobe (ATL). Specifically, activation of the left ATL included the anterior parts of the left middle temporal gyrus, while activation of the right ATL mainly included the anterior portion of the right middle temporal gyrus. Contrary to the hypothesis, no activation was found in the \( [U > C] \) contrast (Fig. 3 and Table 3). Furthermore, there was no significant interaction between social status and conventionality.

Finally, with respect to the effect of language experience, small-volume correction in the a priori region of interest showed a significant positive correlation between left IPL activity in the LC condition and the participant’s experience of honorific use in the workplace (indexed by the total amount of full- and part-time work in months). For illustrative purposes, the parameter estimates of the peak voxel in the left IPL was extracted and plotted against the total working time (Fig. 4 and Table 4). No correlations were found between the total working time and IPL activity in other three conditions (LU, HC and HU). Moreover, there was no correlation between total working time and a priori region of interest in the left IFG in any of the four conditions.

4. Discussion

This study investigated the neural correlates of the Japanese honorific agreement processing mediated by socio-pragmatic rules of honorific use (e.g., honorifics used by an interlocutor of lower social status), and the effect of language experience in social contexts on

| Region                               | MNI coordinates | T-value (F(1, 32)) | Cluster size |
|--------------------------------------|-----------------|--------------------|--------------|
| Left inferior frontal gyrus (pars triangularis) | -46, 34, 4     | 5.32               | 59           |
| Left inferior frontal gyrus (pars opercularis) | -54, 16, 28    | 5.37               | 29           |
| Left insula                          | -32, 24, -6    | 5.14               | 62           |
| Right insula                         | 34, 20, 44     | 4.95               | 16           |
| Medial prefrontal cortex             | 6, 20, 24      | 4.08               | 16           |

*Note: For each brain area, the Montreal Neurological Institute (MNI) coordinate space, peak T-value, and size of the cluster are shown for all 33 participants. The statistical threshold was set at a voxel-level of \( p < 0.05 \), with whole-brain family-wise error correction for multiple comparisons.*
the underlying brain mechanisms. Specifically, we measured brain activation when participants performed a socio-pragmatic judgment task that involved conventional and unconventional sentences expressed by speakers of lower and higher social status. Three major findings emerged from this study. First, the condition involving speakers of lower social status induced significant activation in the left IFG, dmPFC, and bilateral insular cortex, regardless of agreement violation. This strong involvement of the left IFG is consistent with our hypothesis that information indicating lower social status of a speaker serves as social cues triggering honorific agreement processing. Second, no significant effect on activation of unconventionality was found. However, greater activation of the bilateral ATLs was observed during the processing of conventional compared with unconventional expressions. This suggests that ATLs may have roles in the integration of semantic and pragmatic information. Third, the neural response in the left IPL during the processing of conventional honorific sentences was positively correlated with participants’ experience of honorific use in the workplace (i.e., total amount of working time). This suggests that experiences of honorific use affect the brain activity related to perceptions of social status during honorific processing. The following sections discuss these main findings in detail.

### 4.1. Processing Japanese honorifics: social cues mediate syntactic agreement processing

Greater activation of the left IFG, insula, and dmPFC was seen when listeners processed honorific expressions from speakers of
lower social status than when they processed such expressions from speakers of higher social status, irrespective of conventionality (honorific agreement violation). This finding was consistent with our prediction that lower social status of a speaker would act as a social cue triggering honorific agreement processing. When the speaker had a lower social status, participants checked and retrieved the agreement between the subject noun and verb form based on syntactic rules. Specifically, for sentences that contained humble expressions, in which the subject noun refers to a speaker of lower social status (i.e., a student or office worker), listeners could retrieve the humble verb form (o-verb-itashimasu). Similarly, the respectful verb form (o-verb-ninarimasu) could be retrieved when the subject noun referred to an addressee of higher social status (i.e., professor or president) for sentences that contained respectful expressions. This process differs from the processing of sentences by speakers of higher social status, which may require semantic-pragmatic analysis. With respect to polite expressions in the HC condition, listeners may simply need to check for consistency between a speaker and the polite verb form; this ensures establishment of a proper semantic-pragmatic representation. With respect to honorific expressions by addressees of higher social status in the HU condition, listeners could infer pragmatic meanings (e.g., irony) from these expressions. These findings may explain why syntactic-related brain activation was not higher for unconventional relative to conventional expressions, even though the HU condition also contains honorific expressions.

Previous neuroimaging findings have shown that the left IFG has a crucial role in the syntactic agreement processing elicited by violation of honorific agreement (Momo et al., 2008). In the present study, we observed greater left IFG activation in response to both correct and violating sentences expressed by speakers of lower social status, but no significant interaction was observed. It is important to clarify the differences between the current study and the previous fMRI study concerning violation of Japanese honorifics (Momo et al., 2008). In the previous study, linguistic agreement cues for honorific processing (e.g., humble or respectful verb forms) triggered agreement processing. In their task, sentences with violations were constructed by exchanging a respectful verb form with a humble one when the subject of the sentence was a second-person pronoun (potentially referring to an individual of higher social status). Furthermore, their participants performed a grammatical judgment task with visually presented sentences. Therefore, syntactic agreement processing presumably occurred when the listeners detected mismatches between subject noun and honorific verb forms. In our study, social cues (rather than linguistic cues) triggered honorific agreement processing in the left IFG. Our participants were asked to judge the conventionality of utterances based on social norms or socio-pragmatic rules. This constrained the listeners’ expectations of honorific use; it cued them to check the agreement between the social properties of subject nouns and the honorific verb forms used in the utterances. From this perspective, our finding provides new evidence that social cues have a crucial role in Japanese honorific agreement processing.

Table 4

| Region                      | MNI Coordinates | T-value | Cluster size |
|-----------------------------|-----------------|---------|--------------|
| Left inferior parietal lobe | –34, –60, 40    | 4.19    | 42           |

Note. The statistical threshold was set at voxel-level $p < 0.05$, with small-volume correction for multiple comparisons.

Fig. 4. Effect of language experience. Results of correlation analyses between brain activation in the LC condition and the total amount of full- and part-time work (months). The left panel depicts significant activation in the left inferior parietal lobe (IPL). The right panel shows the mean parameter estimates of the peak voxel in the left IPL ($–34, –60, 40$) for the LC condition plotted against the total amount of working time for each participant (a representative graph of a positive correlation). The statistical threshold was set at voxel-level $p < 0.05$, with small-volume correction for multiple comparisons (family-wise error rate).
Fig. 2 compares activation patterns of the left IFG among the four conditions; the findings showed that processing both correct and incorrect honorifics in the lower conditions (LC and LU) led to greater activation compared with processing in the higher conditions (HC and HU). Importantly, greater activation of the left IFG in the LC and LU conditions was presumably unrelated to differences in utterance length or the presence of honorifics; reduced activation of this region was observed in the HU condition that contained honorific expressions. These findings support our interpretation that social cues related to the lower social status of a speaker trigger syntactic agreement processing, mainly for sentences in the LC and LU conditions. Moreover, similar activity in both the correct and incorrect L conditions (no significant differences between LC and LU) may be related to the less frequent use of honorific agreement by young native speakers; such use is generally acquired until late adolescents through workplace contexts. Therefore, listeners in the current study who were in their early 20s with limited work experience must closely analyze the agreement between subject nouns and verb forms, regardless of violations.

Our results are consistent with the findings of recent neuroimaging studies showing that left IFG activation is associated with cue-based syntactic processing (Henderson et al., 2016; Jakuszeit et al., 2013; Matchin et al., 2017; Santi & Grodzinsky, 2012; Söderström et al., 2018). For example, Santi and Grodzinsky (2012) observed activation of the left IFG when their participants were able to use preceding syntactic cues to process filler-gap sentences (e.g., “[filler Which paper] did the tired student submit [gap –] after reviewing [p.gap –/it?]”). An ERP study conducted by Söderström et al. (2018) also examined whether participants used Swedish tonal information as cues to determine either the most likely syntactic structure before hearing it. For instance, concerning the sentence “Rut hävdar att kaktet inte intog/intog inte tåget” (“Rut claims that the kaktet not occupied/occupied not the train”), the text up to the syllable -t in kaktet can be pronounced either with a low clause-initial tone to signal a subordinate clause structure, or a high tone to signal the main clause structure. However, the low tone is a more reliable cue than the high tone to predict that the sentence would be a subordinate clause. Compared with the high tone, Söderström et al. (2018) found that low-tone sentences were associated with a predictive effect of negative left-lateralized pre-activation, promoted by the left IFG, and left anterior insula. Furthermore, Jakuszeit et al. (2013) showed that patients with IFG lesions did not exhibit an ERP response to an early negative signal (an indication of earlier syntactic prediction) during the processing of subject-verb agreement violation. Our study provides additional evidence that the left IFG is activated during the processing of honorific agreement triggered by social cues. Future research needs to combine ERP and fMRI techniques to identify both precise temporal brain activity and brain regions underlying honorific agreement processing. For example, it could be examined whether the ERP component of negative left-lateralized pre-activation and left IFG activation appears prior to the input of honorific verbs when social cues are controlled.

In this study, along with the left IFG, greater activation was observed in the dmPFC and bilateral insular cortex in conditions that involved speakers of lower versus higher social status. Activation of these areas may have reflected efficient processing of salient social information, which is important for honorific agreement processing. Functionally, the medial prefrontal cortex (mPFC) has been identified as a critical area for mentalizing (i.e., perspective taking), as well as for understanding and predicting others’ thoughts and intentions (Amodio & Frith, 2006; Bzdok et al., 2013). The insular cortex is presumably associated with the processing of prosodic or acoustic information (Oh et al., 2014), socially and affectively salient information (Chen et al., 2014), and low-versus-high-imposition requests (see Vergis et al., 2020).

The dmPFC and bilateral insular cortex have also been reported to function in the processing of salient socio-prosodic cues for comprehension of speakers’ communicative intentions (Jiang et al., 2018; Rigoulot et al., 2014). For example, Jiang et al. (2018) found that the mPFC and insula were involved in the interpretation of speech in terms of pragmatic-emotional intentions, with the speaker’s identity and voice serving as salient social cues. Moreover, an ERP study by Rigoulot et al. (2014) showed that listeners used speakers’ speech prosody (e.g., a sincere or insincere tone) when answering the question “What did you think of my presentation?” with “I found it really interesting.” to interpret whether their responses constituted compliments or “white lies”. They found significant effects of prosody on P600 ERP components in comparisons of sincere and insincere tones; these components arose from the insula. In the current study, the social status associated with voice and personal information was essential for the comprehension of honorific sentences. Thus, the dmPFC and insula were associated with the processing of salient acoustic information, which facilitated honorific sentence processing. Taken together, the findings of this study suggest that the left IFG, mPFC, and bilateral insula may be jointly involved in processing honorific agreement on the basis of speaker-related social information.

4.2. Effects of expression conventionality

Contrary to our expectation, there was no significant activation during the processing of unconventional expressions relative to the processing of conventional expressions. Instead, greater activation of the bilateral ATLs was found when the participants processed conventional expressions relative to unconventional expressions, irrespective of speaker type. Our finding suggests that pragmatically appropriate expressions (i.e., social conventions or normative polite verbal behavior) are processed or represented in the ATLs.

In the social domain, the ATLs have been suggested to function as a semantic hub for integration or convergence of various features of general social-semantic or conceptual knowledge about objects, facts, and people, and for successful retrieval of words related to familiar semantic experiences (Lambon Ralph et al., 2010; Meyer et al., 2010; Patterson et al., 2007). The ATLs have also been recognized as a crucial region for the perception of stimuli that contain socioemotional information (Olson et al., 2013; Ross & Olson, 2010). Several fMRI studies have shown that ATLs mediate pragmatic implicature and comprehension of indirect speech; these processes require the integration of message-level semantic meaning and social scenarios to understand an interlocutor’s communicative intentions (Feng et al., 2017; Jang et al., 2013). For example, Jang et al. (2013) found that the bilateral ATLs were activated during the processing of literally irrelevant but pragmatically implied meanings (e.g., “Is the teacher in his office now?”; the moderately implicit answer is “The teacher’s car is outside the office.”; and the highly implicit answer is “No black car is outside the office.”). Jang
et al. suggested that the ATLs integrate literal and situational information when people aim to understand pragmatically implied meanings. In the current study, the ATLs may have integrated linguistic forms, meanings, and semantic knowledge, such as personal or factual information related to the speakers’ title/role (e.g., professor or student).

It is important to consider why, in this study, no significant brain activation was observed during the processing of unconventional expressions relative to conventional expressions. One possibility is that the participants might have misinterpreted the unconventional honorific use by speakers of higher social status (HU) with respect to pragmatic meaning (e.g., over-respectfulness, irony, or sarcasm) during conventional judgment tasks. This processing of pragmatic meaning could differ from the processing of honorific agreement violation by a speaker of lower social status (syntactic agreement processing). For example, honorific agreement violation by speakers of higher social status may lead to a pragmatic interpretation of irony or sarcasm toward the addressees, with substantial individual differences in the interpretations. Our results may also suggest that listeners did not invest any cognitive effort into pragmatic interpretation, because they lacked social contextual information to support the processing of pragmatic meaning. Such complex pragmatic-related processing was observed by Jiang et al. (2013). Using an ERP method, they observed distinct patterns of neural activity in response to mismatches of less respectful and respectful second-person Chinese pronouns with the expected speakers (lower or higher social status). A P600-like response was found when processing the over-respectful use of pronouns by speakers of higher social status addressing of lower social status individuals. This effect differed from the neural response seen during the processing of disrespectful use of the second pronoun by a speaker of lower social status (N400). Further investigations are needed to examine the effects of honorific agreement violation by a speaker of higher social status, or in different social contexts, on pragmatic processing (e.g., over-respectfulness or impoliteness).

Notably, Fig. 3 shows deactivation of the bilateral ATLs in the four conditions. This pattern is different from the results in Fig. 2 (involving speakers of lower social status), which showed higher activation in the three activated brain regions compared with baseline. Deactivation of the ATLs has been frequently reported in studies of social, semantic, and pragmatic aspects of language processing (Binder, 2012; Kuperberg et al., 2003; Schilbach et al., 2008). Although all task conditions showed deactivation of the ATLs in this study, greater differences were observed between the C and U conditions (greater activation in the former condition). Nonetheless, these differences may support our interpretation that the ATLs function in the integration of social and linguistic information to form pragmatically appropriate meanings or concepts (e.g., respectfulness, humbleness, and politeness).

### 4.3. Effects of language experience on honorific processing

In this study, we observed a positive correlation between inter-subject variability in the total amount of working time and brain activation in the left IPL during the processing of conventional honorific utterances. This suggests that language experience in the workplace context affects the neural processing of honorifics. Previous studies have shown that the left IPL is associated with perceptions of social status or hierarchies (Chiao et al., 2009). We speculate that the individuals with greater work experience might be more sensitive to social hierarchy information during the processing of honorific sentences. Considering its socio-pragmatic function, honorific speech is primarily used in formal contexts when workers interact with guests and superiors. Individuals likely use social hierarchy information to process honorifics when they have acquired more experience in the workplace. The recognition of social hierarchy is essential to the development of honorifics. Thus, it is difficult to distinguish between social hierarchy processing and honorific processing. This issue requires further investigation. Nevertheless, the present study extends previous literature by showing that the processing of honorifics in L1 is modulated by social experiences and reflects differential neural responses in the left IPL.

### 5. Limitations, future studies, and conclusion

There were two limitations to this study. First, although the usage of honorifics was influenced by the social status and hierarchical relationships between speakers and addressees, it was also influenced by other social factors, such as the level of social solidarity and familiarity. Future studies are needed to investigate how language is processed in diverse social and pragmatic situations. Second, a subjective measure (i.e., self-reported working time) was used to test participants’ experience in using honorifics. Future studies should use objective measures to examine the use of pragmatic expressions and related pragmatic knowledge. Despite these two limitations, the present study provides new evidence that socio-pragmatic factors (i.e., an interlocutor’s social status) may affect the processing of syntactic agreement in the brain. In particular, our findings show that the left IFG, bilateral insular cortex, and dmPFC play an important role in honorific agreement processing based on a speaker’s social status. Moreover, the current study is the first to identify a relationship between language experience and activation of the left IPL during the processing of Japanese honorifics. We hope that this study promotes neurocognitive understanding of the syntactic processing mediated by socio-pragmatic factors.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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