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Syntax in a native language still continues to develop in adults: Honorification judgment in Japanese ☆

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Abstract

Native languages (L1s) are tacitly assumed to be complete and stable in adults. Here we report an unexpected individual variation in judgment of L1 regarding Japanese sentences including honorification, and further clarify its neural basis with functional magnetic resonance imaging (fMRI). By contrasting an honorification judgment task with a spelling judgment task, the lower performance group showed more extensive activation in the left inferior frontal gyrus than did the higher performance group. Moreover, activation in the left dorsal and ventral triangular parts negatively correlated with the performance of the honorification judgment task. This modulation pattern demonstrates that cortical activations recruited for sentence processing depend on individual performances even in L1.
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1. Introduction

Previous neuroimaging studies have clarified the cortical activations selective to syntactic processing (Embick, Marantz, Miyashita, O'Neil, & Sakai, 2000; Friederici, Opitz, & von Cramon, 2000; Hashimoto & Sakai, 2002; Suzuki & Sakai, 2003), but no individual differences have been reported for such activation related to the processing of native languages (L1s). If L1s are already complete and stable in adults, as is widely assumed to be true, then there might be no individual differences regarding its competence. However, more complex aspects of language processing may reveal individual variation even in the performance of L1s. In the present study with native Japanese speakers, we focus on "honorification" in the Japanese language, defined in a narrow sense excluding so-called beautification (e.g., "*o-kane*" and "*o-tera*") and polite expression (Shibatani, 1990). The honorific expressions are commonly used to show respect to honored persons, but whose actual usage is rather complicated. For example, in the sentence "*anata-ga watasi-o o-maneki-ni-naru*" [*you*-Nom (nominative case) *I*-Acc (accusative case) *invite*-SH (subject honorifics); "*you invite me*"], SH in the form of *o*-V-*ni*-*naru* (V, verb) should be used because an honored person "*anata*" ["*you*"] is a subject. In contrast, in the sentence "*watasi-ga anata-o o-maneki-suru*" [*I*-Nom *you*-Acc *invite*-OH (object honorifics); "*I invite you*"], OH in the form of *o*-V-*suru* should be used because the same honored person "*anata*" ["*you*"] is now an object. These

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sentences are based on a fixed agreement between the case of an honored person and the form of honorifics (SH or OH), and thus crossed combinations become grammatically incorrect (“**anata-ga watasi-o o-maneki-suru*” and “**watasi-ga anata-o o-maneki-ni-naru*”). Because honorification is mainly used on formal occasions and thus optional (“*anata-ga watasi-o maneku*” without SH and “*watasi-ga anata-o maneku*” without OH are acceptable), we expect an individual variation in its actual performance as well as in the associated responses of brain regions responsible for this linguistic processing.

It is known in linguistics that the structural requirement for sentences regulates the application of the formal syntactic operation, which includes a mechanism called “Agree” as its core. The syntactic operation is provided by universal grammar and thus predicted to be available to every human language (Chomsky, 2000). Its actual application is, on the other hand, subject to cross-linguistic parametric variation, depending on the availability of the relevant syntactic features in the lexicon (Fukui & Sakai, 2003). Thus, one important purpose of the present experiment is to see whether Japanese speakers, whose grammar does *not* generally employ an agreement rule for case, number, and gender, are nonetheless capable of carrying out such syntactic computation properly once the relevant feature is provided by honorification. This last point has been a subject of debate; while some linguists regard Japanese honorification as an example of purely semantic/pragmatic processing controlled by social factors, others have proposed that honorification actually involves syntactic computation in addition to semantic/pragmatic factors [(Boeckx & Niinuma, 2004; Gunji, 1987; Harada, 1976; Ivana & Sakai, 2007) for syntactic account for Japanese honorification, and (Bobaljik & Yatsushiro, 2006) for criticism of such account].

Besides semantic/pragmatic processing and syntactic computation, Japanese honorification involves morphological processing. The honorific prefixes *o* and *go* are added to a noun in order to express respect toward the person related to the noun. Only one of two honorific prefixes is allowed for a noun and most native speakers acquire this knowledge. For example, “*tikara*” [“*power*”] takes the honorific prefix of *o* (“*o-tikara*/**go-tikara*”), whereas “*rikai*” [“*understanding*”] takes the honorific prefix of *go* (“*go-rikai*/**o-rikai*”). This prefix choice depends on morphological knowledge of idiosyncratic word class membership of the noun stem (Sino-Japanese versus Yamato vocabulary). This distinction is also complicated (e.g., “*o-ningyou*/**go-ningyou*” [“*doll*”]), partly because the property of being Sino-Japanese or Yamato is not always predictable simply from inspection of the stem (Ito & Mester, 2003). In addition to this purely word-internal morphological knowledge, the honorific forms SH and OH have distinct morphosyntactic features as well; SH consists of three morphemes (*o*, *ni*, and *naru*), whereas OH consists of two morphemes (*o* and *suru*). By exchanging the morpheme *ni*, normal/anomalous pairs of honorific forms can be created (“*o*-V-*ni-naru*/**o*-V-*naru*” and “*o*-V-*suru*/**o*-V-*ni-suru*”). Here, *naru* obligatorily governs a -*ni* (dative) marked complement, while *suru* equally obligatorily governs an accusative (or bare) complement. Processing of this type of knowledge is again independent of honorification, because light verbs (*naru* and *suru*) can take a noun phrase without honorification (e.g., “*byoki-ni-naru*” [“*get sick*”], “*byoki*(-*o*)-*suru*” [“*have sickness*”], and “*byoki-ni-suru*” [“*cause sickness*”]) (Ivana & Sakai, 2007). To elucidate cortical activations elicited by the syntactic operation in Japanese honorification, a control condition for these two types of morphological and morphosyntactic computation on honorific forms should be properly established. We thus employed honorification (HO) and morphological/morphosyntactic (MO) judgment tasks, in which the participants detected an anomaly in a short sentence (Table 1). We also tested a semantic (SE) judgment task to characterize any cortical activation related to sentence meaning, together with a spelling (SP) judgment task to control visual and motor factors as well as automatic linguistic processes.

In our previous studies, we proposed that the left inferior frontal gyrus (IFG), including the lateral premotor cortex (LPMC), the triangular part of the IFG (F3t), and the opercular part of the IFG (F3op), specialize in syntactic processing, whereas the orbital part of the IFG (F3O) subserves sentence comprehension (Sakai, 2005). If honorification simply reflects semantic processing, then the activation would be limited to the left F3O and temporal regions. However, if honorification is related to syntactic processing, then the left LPMC and F3t/F3op would be significantly activated. Conversely, the left F3O and temporal regions would be activated in the SE task, since explicit semantic processing is required by the task. The present paradigm will thus be useful for elucidating multiple linguistic processes involved in sentence processing.

2. Materials and methods

2.1. Participants

In this study, 44 native speakers of Japanese (aged 18–38 years, 12 females) participated in the experiment. All participants showed right-handedness (laterality quotients: 60–100) by the Edinburgh inventory (Oldfield, 1971). None had a history of neurological or psychiatric disease. Informed consent was obtained from each participant after the nature and possible consequences of the studies had been explained. Approval for these experiments was obtained from the institutional review boards of the University of Tokyo, Komaba.

2.2. Stimuli

We prepared 144 sentences for the present study (see Table 1 for examples). A basic stimulus set consisted of 24 normal Japanese sentences with honorification, which were one of four sentence types: [S-*ga* N-*de*/*ni* O-*o* *o*-V-*ni-naru*], [S-*ga* O_1-*ni* O_2-*o* *o*-V-*ni-naru*], [S-*ga* N-*de*/*kara*

Table 1
Examples of stimuli used in the honorification (HO), morphological/morphosyntactic (MO), semantic (SE), and spelling (SP) judgment tasks

Tasks	Normal sentences	Anomalous sentences
HO	*anata-ga watasi-ni booru-o o-nage-ni-naru* *you*-Nom *I*-Dat *ball*-Acc *throw*-SH *'you throw a ball to me'*	*anata-ga watasi-ni booru-o o-nage-suru* *you*-Nom *I*-Dat *ball*-Acc *throw*-OH *'you throw a ball to me'*
MO	*watasi-ga anata-ni go-iken-o o-kiki-suru* *I*-Nom *you*-Dat HP-*opinion*-Acc *ask*-OH *'I ask your opinion'*	*watasi-ga anata-ni o-iken-o o-kiki-suru* *I*-Nom *you*-Dat HP-*opinion*-Acc *ask*-OH *'I ask your opinion'*
SE	*sensei-ga denwa-de gakusei-o o-home-ni-naru* *teacher*-Nom *telephone*-PP *student*-Acc *praise*-SH *'the teacher praises the student on the phone'*	*sensei-ga booru-de gakusei-o o-home-ni-naru* *teacher*-Nom *ball*-PP *student*-Acc *praise*-SH *'the teacher praises the student on the ball'*
SP	*gakusei-ga sensei-ni o-kaban-o o-moti-suru* *student*-Nom *teacher*-Dat HP-*bag*-Acc *bring*-OH *'the student brings the teacher his bag'*	*gakusei-ga sensei-ni o-kaban-o o-timo-suru* *student*-Nom *teacher*-Dat HP-*bag*-Acc *bring*-OH *'the student brings the teacher his bag'*

Abbreviations used: Nom, nominative case; Dat, dative case; Acc, accusative case; PP, postposition; HP, honorific prefix; SH, subject honorifics; OH, object honorifics. Errors are underlined.

O-*o o*-V-*suru*], and [S-*ga* O_1-*ni* O_2-*o o*-V-*suru*] (S, subject; N, noun; O_1, indirect object; O_2, direct object; V, verb; -*ga*, nominative marker; -*de*/-*ni*/-*kara*, postpositions meaning "*by means of*", "*to*", and "*from*", respectively; -*o*, accusative marker; -*ni*, dative marker). We also included another set of 24 normal sentences without honorific expressions, so that the participants paid full attention to words other than honorific forms.

By modifying the basic set of sentences, we created four different types of anomalous sentences for the HO, MO, SE, and SP tasks (24 each; Table 1), which had the same lexical materials and differed only regard to the types of errors. HO errors were made by exchanging the SH and OH forms. MO errors were made either by exchanging the honorific prefixes (*o*-N/*go*-N) or by using morphosyntactically incorrect forms of SH and OH (**o*-V-*ni-suru*/**o*-V-*naru*). SE errors were made by exchanging nouns between two sentences, so that there was a contextually inappropriate noun in a sentence. SP errors were made by exchanging two adjacent letters in a word. The stimulus presentation and behavioral data collection were controlled using the LabVIEW software and interface (National Instruments, Austin, TX). Each sentence was shown in yellow letters in the *hiragana* and *kanji* writing system against a dark background. For fixation, a red cross was always shown at the center of the screen.

2.3. Tasks

In the functional magnetic resonance imaging (fMRI) sessions, the HO, MO, SE, and SP tasks were conducted in a block design with twelve runs; each run consisted of 24 sentences (6 sentences × 4 tasks). In each block, normal and anomalous sentences were included in the proportion of 3:3, 2:4, or 1:5 in a pseudo-randomized manner. In order to reduce any effects related to task order, we used four sequences for each run: SP–HO–SE–MO and SE–MO–SP–HO alternatively for one-half of the participants, as well as SP–MO–SE–HO and SE–HO–SP–MO alternatively for the other half of the participants. In each trial, the name of each task was presented for 400 ms, followed by a sentence presented for 4300 ms. Participants covertly read sentences and judged whether or not it was a correct sentence, responding by pushing one of two buttons. Before the fMRI sessions, the participants received a short training session outside the scanner.

2.4. fMRI data acquisition and analyses

The participants were in a supine position, wearing earplugs and an eyeglass-like MRI-compatible display (resolution, 800 × 600; VisuaStim XGA; Resonance Technology, Northridge, CA), and their heads were immobilized with padding inside the radio-frequency coil. The fMRI scans were conducted using a 1.5 T MRI system (STRATIS II, Premium; Hitachi Medical Corporation, Tokyo, Japan). Using a gradient-echo echo-planar imaging sequence (repetition time, 5 s; echo time, 50.5 ms; flip angle, 90°; field of view, 192×192 mm^2; resolution, 3×3 mm^2), 16 horizontal slices were scanned, each 6 mm thick and having a 1 mm gap.

Data analyses were performed using SPM2 statistical parametric mapping software (Wellcome Department of Imaging Neuroscience, London, UK). The functional volume data were realigned in multiple runs and we removed runs that included data with a translation of >2 mm in one of the three directions and a rotation of >1.4°. The data were normalized to the standard brain, resampled every 3 mm using bilinear interpolation, and smoothed with an isotropic Gaussian kernel of 9 mm full-width at half-maximum. Low-frequency noise and global changes in activity were further removed. In order to investigate task-specific effects, random-effects analyses (one sample *t*-test) were performed. In each comparison, thresholds were established in statistical parametric maps at the uncorrected $p < .0001$ for the voxel level. Statistical significance of correlation between the behavioral data and the signal changes was further tested using Spearman rank correlation, which is resistant to outliers, i.e., high leverage points. Mean signal changes at an activation focus under each condition were estimated using a 5-s shifted block for the hemodynamic delay.

3. Results

3.1. Behavioral results

The accuracy of the HO, MO, SE, and SP tasks was $78.4 \pm 16.1\%$, $81.2 \pm 11.7\%$, $93.4 \pm 4.8\%$, and $95.0 \pm 4.7\%$ (mean ± SD, $n = 44$), respectively, and the reaction times (RTs) of each task were 2957 ± 458 ms, 2867 ± 424 ms, 2623 ± 384 ms, and 2389 ± 450 ms, respectively. According to an analysis of variance (ANOVA), there were significant main effects of task on both accuracy ($F(3,172) = 28$, $p < .0001$) and RTs ($F(3,172) = 16$, $p < .0001$). According to post hoc Tukey–Kramer tests, the accuracy of the HO task was significantly lower than those of the SE and SP tasks ($p < .05$), and the RTs of the HO task were significantly longer than those of the SE and SP tasks ($p < .05$). Similarly, the accuracy of the MO task was significantly lower than those of the SE and SP tasks ($p < .05$), and the RTs of the MO task were significantly longer than those of the SE and SP tasks ($p < .05$). However, both the accuracy and the RTs of the HO and MO tasks, as well as the accuracy of the SE and SP tasks, showed no significant difference.

Because there were large individual differences in the behavioral data of the HO and MO tasks, we examined the correlation between the performance of the HO and MO tasks. We found that the accuracy of the HO and MO tasks was significantly correlated ($r = .70$, $p < .0001$) (Fig. 1A). The RTs of these tasks were also significantly correlated with each other ($r = .87$, $p < .0001$). We further analyzed the distinct types of the MO task separately, namely the morphological (*o* and *go*) and morphosyntactic (*ni-naru* and *suru*) types. There was a significant correlation between the accuracy for the two types of the MO task ($r = .36$, $p = .02$). Moreover, the accuracy of the HO task significantly correlated with that for the morphological type ($r = .35$, $p = .02$), and even more clearly with that for the morphosyntactic type ($r = .73$, $p < .0001$). Therefore, the capability of processing honorification was also related to more fundamental performances of both morphological and morphosyntactic computation.

All participants were then divided into two groups at the 84% accuracy level (the median) of the HO task: *low* and *high* performance groups. An ANOVA on the accuracy (task × group) showed a significant interaction ($F(3,168) = 21$, $p < .0001$), whereas there was no interaction on the RTs ($F(3,168) = .2$, $p = .88$). According to paired *t* tests, there was a significant difference in the accuracy of the HO and MO tasks for both groups, but in opposite directions (Fig. 1B); the difference in RTs of the HO and MO tasks was significant for the low performance group alone (Fig. 1C). The behavioral results also indicated that the HO and MO tasks were more demanding than the SE and SP tasks for both groups.

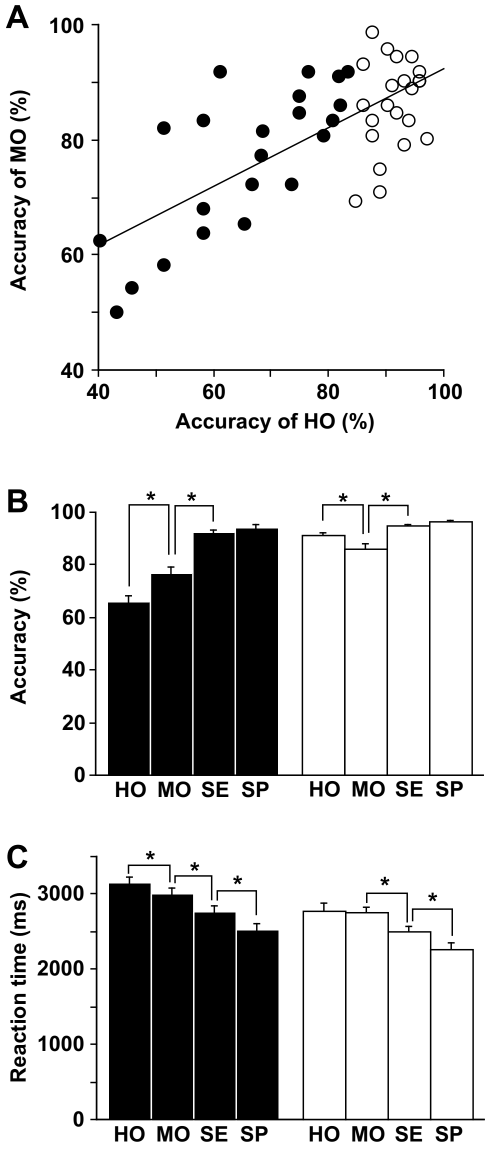

Fig. 1. Behavioral data. (A) Significant correlation between the accuracy of HO and MO. (B) Accuracy (means ± *SEM*) of each task in the low and high performance groups. Filled and open circles/bars denote the low and high performance groups, respectively. (C) RTs of each task in the low and high performance groups. $^*p < .05$ (paired *t*-test).

3.2. The task-selective activations in the left IFG

To elucidate any task-selective activations, the contrasts of HO–SP, MO–SP, and SE–SP were examined in each group (Fig. 2 and Table 2). In the contrast of HO–SP, we observed a marked difference in activated regions between the low and high performance groups. The low performance group showed significant activations mostly localized in the left IFG, including the left LPMC, dorsal F3t (dF3t), ventral F3t (vF3t), and F3O (Fig. 2A). In the same contrast for the high performance group, the left IFG activation was greatly reduced and only the left LPMC was significantly activated within the left IFG, together with the left parietal region and the cerebellum

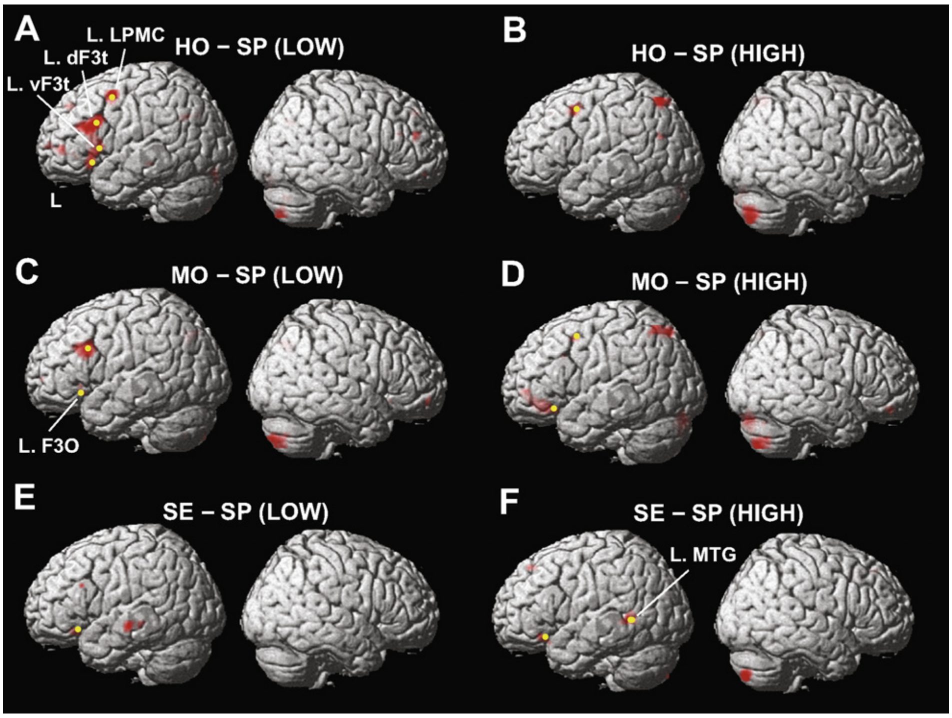

Fig. 2. Task-selective effects in the low and high performance groups. (A) The contrast of HO–SP in the low performance group. Note the significant activation in the left IFG. (B) The contrast of HO–SP in the high performance group. (C) The contrast of MO–SP in the low performance group. (D) The contrast of MO–SP in the high performance group. (E) The contrast of SE–SP in the low performance group. (F) The contrast of SE–SP in the high performance group. Note the selective activation in the left MTG.

(Fig. 2B). The contrast of MO–SP for the low performance group showed significant activation in the left dF3t, left F3O, and the right cerebellum (Fig. 2C). The same contrast in the high performance group showed significant activation in the left LPMC and left dF3t, together with the left parietal region and the cerebellum (Fig. 2D). It is interesting to note that the activation patterns for the *high* performance group were similar between HO–SP and MO–SP, whereas those for the *low* performance group were more focal in MO–SP than in HO–SP. On the other hand, the contrast of SE–SP resulted in similar activation patterns for both the low and high performance groups, such that the left F3O and the left middle temporal gyrus (MTG) showed significant activation.

To further elucidate the task-selective activations in the left IFG, the signal changes at the local maxima of the left LPMC, dF3t, and vF3t (yellow[1] dots in Fig. 2A) were compared among the tasks and groups (Fig. 3). In the left LPMC (−39, 3, 51), the signal change in the HO task was significantly larger than that of the SE task for the low performance group ($p = .001$, paired *t*-test). For the high performance group, the signal change in the MO task was significantly larger than that of the SE task ($p < .005$) (Fig. 3A). In the left dF3t (−42, 18, 27), the signal change in both the HO and MO tasks was significantly larger than that of the SE task ($p < .0005$ and $p = .01$, respectively) for the low performance group (Fig. 3B). In the left vF3t (−57, 15, 9), the signal change in the HO task was significantly larger than that of the SE task ($p < .05$) for the low performance group (Fig. 3C). Among these three regions, the signal change in the HO task for the low performance group was significantly larger than that for the high performance group ($p < .05$). To summarize, both the HO and MO tasks activated the left IFG in the low performance group, and this effect was stronger in the HO task than in the MO task.

3.3. The left dF3t and vF3t activations selectively modulated by the accuracy of HO

To investigate whether individual differences in performance modulated cortical activations, regression analyses were performed using all participants' data regardless of the low and high performance groups. A significant negative correlation between the signal change in HO–SP and the accuracy of the HO task was observed in the left dF3t, vF3t, and other regions ($Z > 3.25$, uncorrected $p < .001$) (Table 3). According to Spearman rank correlation tests, the negative correlation between the accuracy of the HO task and the signal change in HO–SP at each local maximum of the left dF3t ($r_s = -.37$, $p = .015$) and vF3t ($r_s = -.51$, $p = .0008$; Fig. 3D) was significant, whereas the RTs of the HO task were not significantly correlated with the signal change (Table 4). In contrast, no significant correlation was observed between the accuracy of

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[1] For interpretation of the references to color in this text, the reader is referred to the web version of this article.

Table 2
Activated regions for each task in the low and high performance groups

Brain regions	BA	Side	x	y	z	Z	x	y	z	Z
			Low				High			
HO–SP										
LPMC	6/8	L	−39	3	51	5.5	−45	9	48	4.6
dF3t	45	L	−42	18	27	4.8				
		R	45	30	24	3.7				
vF3t	45	L	−57	15	9	4.3				
F3O	47	L	−42	36	−3	3.8				
F2O	47	R	45	51	−12	3.8				
F2	46	L	−42	51	3	4.3				
		R	42	42	21	4.5				
F2/F1	10	L	−33	60	6	3.9				
F1	8	M	−6	42	42	4.5	−6	30	45	3.8
MTG	21/22	L	−57	−30	−9	3.9				
Angular g	39	L	−39	−60	33	4.2	−51	−66	24	3.9
Inferior parietal g	7	L					−30	−66	57	4.8
Precuneus	19	M	0	−69	33	4.3	0	−66	54	4.7
Cerebellum		M	−6	−84	−15	4.4	−9	−87	−30	3.9
		R	24	−75	−48	4.6	36	−78	−39	5.1
MO–SP										
LPMC	6/8	L					−39	9	48	4.2
dF3t	45	L	−51	18	27	5.2	−48	18	33	3.8
vF3t	45	L	−51	24	−3	3.8				
F3O	47	L	−42	24	−9	4.2	−45	42	−6	4.7
F2O	47	R	39	54	−9	3.9	42	45	−15	4.5
F2	10	L	−36	57	3	3.8	−39	51	3	4.3
F1	8	M					−3	21	57	3.9
Insula		R	39	21	−9	3.8				
Inferior parietal g	7	L					−21	−72	54	4.5
Precuneus	19	M	−3	−69	42	4.3				
Cerebellum		M	0	−66	−45	4.3				
		M	9	−84	−27	3.8	12	−84	−27	5.0
		R	30	−84	−42	5.2	30	−75	−48	5.2
SE–SP										
dF3t	45	L	−54	21	27	3.9				
F3O	47	L	−27	27	−12	4.2	−45	30	−12	4.2
F1	8	L					−12	36	48	4.1
MTG	21/22	L	−51	−18	−9	4.1	−63	−51	3	4.3
		L	−51	−33	−6	3.9				
Cerebellum		R					33	−78	−45	5.3

Stereotactic coordinates (*x, y, z*) in the MNI space are shown for each activation peak of *Z* values. The threshold was set at uncorrected $p < .0001$ for voxel level. *Abbreviations used:* BA, Brodmann's area; L, left hemisphere; R, right hemisphere; M, Medial; g, gyrus; LPMC, lateral premotor cortex; dF3t, dorsal triangular part of IFG; vF3t, ventral triangular part of IFG; F3O, orbital part of IFG; F2, middle frontal gyrus (MFG); F2O, orbital part of MFG; F1, superior frontal gyrus; MTG, middle temporal gyrus.

the MO task and the signal change in MO–SP. Because of this HO task-selective modulation of activations in the left dF3t and vF3t, we can exclude the possibility that the activations reflected any general cognitive factors including task difficulty.

3.4. The contribution of other left frontal and temporal regions in the tasks

In the left F3O (−42, 24, −9) (a yellow[1] dot in Fig. 2C), the signal changes for the HO, MO, and SE tasks were all significantly larger than that of the SP task for both the low and high performance groups (Fig. 4A). This result suggests that the F3O activation was equally enhanced by these three tasks involving sentence comprehension, which was in contrast to task-selective syntactic processing. In the left MTG (−63, −51, 3) (a yellow[1] dot in Fig. 2F), on the other hand, the signal change in the SE task was significantly larger than that in the HO and MO tasks for the high performance group ($p < .05$), and the low performance group also showed similar tendency (Fig. 4B). This result suggests that the MTG activation was selectively required by the SE task involving explicit semantic processing.

4. Discussion

The present study demonstrated that both the HO and MO tasks activated the left dF3t more in the low performance group than in the high performance group, and that

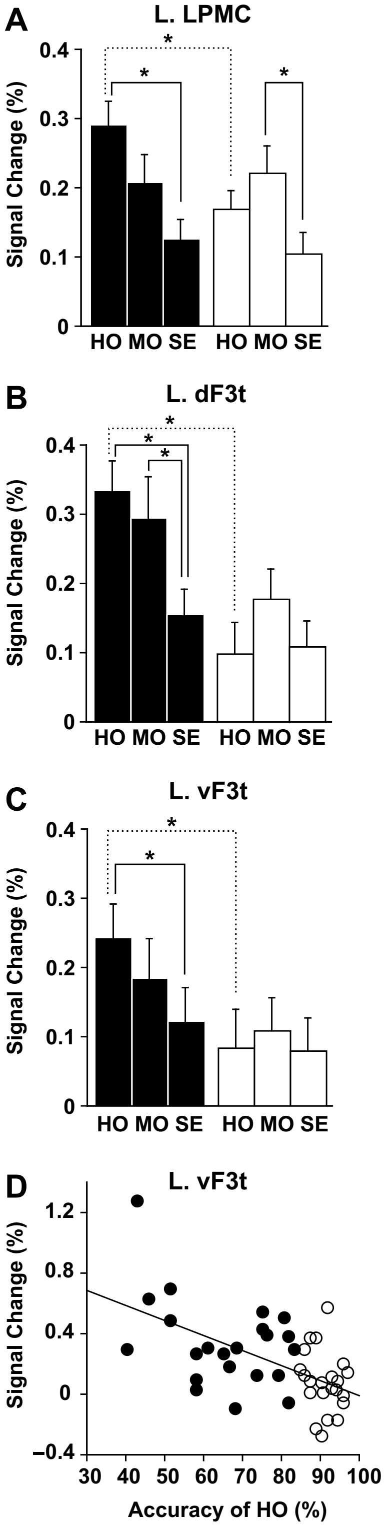

Fig. 3. Signal changes in the left LPMC, dF3t, and vF3t. Taking the SP task as a reference, the percent signal changes (means ± *SEM* of participants in each group) in the HO, MO, and SE tasks are shown for the left LPMC (A), dF3t (B), and vF3t (C) at the local maxima shown in Fig. 2A and Table 2. (D) Significant correlation between the accuracy of the HO task and the signal change in HO–SP at the local maximum of the left vF3t shown in Table 3. Filled and open bars denote the low and high performance groups, respectively. $^*p < .05$ (paired *t*-test).

Table 3
The negative correlation between the signal change of HO–SP and the accuracy of HO

Brain regions	BA	Side	*x*	*y*	*z*	*Z*
dF3t	45	L	−54	18	30	3.3
vF3t	45	L	−57	18	3	3.4
		R	45	24	24	3.4
F2	46	R	39	42	21	3.6
ITG	20/21	R	39	−57	−3	3.9
Fusiform g	37	R	33	−75	−3	3.4
Lingual/calcarine	18	R	21	−48	0	3.4
Cerebellum		M	−9	−63	−42	3.7

Stereotactic coordinates (*x, y, z*) in the MNI space are shown for each activation peak of *Z* values. ITG, inferior temporal gyrus.

Table 4
The correlation between the signal change of the left frontal regions and the behavioral data

	Accuracy		RTs	
	HO	MO	HO	MO
L. dF3t	$r_s = -.37^*$	$r_s = -.26$	$r_s = .16$	$r_s = -.08$
L. vF3t	$r_s = -.51^{**}$	$r_s = -.21$	$r_s = .23$	$r_s = -.14$

The signal changes in the left dF3t and vF3t were calculated at the local maxima shown in Table 3. In these regions, the signal change in HO–SP negatively correlated with the accuracy of the HO task, but the signal change in MO–SP did not significantly correlate with the accuracy of the MO task. $^*p < .05$, $^{**}p < .001$ (Spearman rank correlation test).

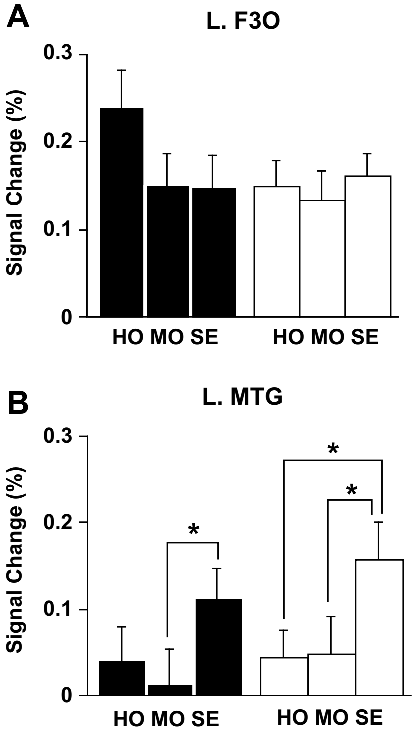

Fig. 4. The signal changes of the left F3O and left MTG. (A) The signal changes at the local maximum of the left F3O shown in Fig. 2C and Table 2. (B) The signal changes at the local maximum of the left MTG shown in Fig. 2F and Table 2. $^*p < .05$ (paired *t*-test).

the HO task elicited significant responses in extensive left IFG regions (the left LPMC, dF3t, and vF3t) when compared with other tasks. Moreover, the activations in the left dF3t and vF3t were negatively correlated with the accuracy of HO. In contrast, the left F3O activation represents processing for sentence meaning, which is consistent with our previous proposal (Sakai, 2005). These results were striking in three ways. First, the neuroimaging data suggested that syntactic computation is indeed involved in the processing of honorification. Since the same basic set of sentences was used for all of the four tasks, the direct comparisons between two tasks eliminated any automatic syntactic processes that were sensitive to phrase structure building or grammatical function assignment. We suggest the involvement of an agreement rule at some abstract levels in the HO task, though the actual applications of the Agree operation should be further examined in the future study, thereby comparing the Agree operation with other syntactic operations. Second, adults exhibit individual differences regarding performances even in L1 syntax, which indeed modulate cortical activations in specific regions. Third, the lower activations in the left dF3t and vF3t may correspond to the higher proficiency in applying the syntactic operation associated with honorification. Taking these results together, they provide the first direct evidence that the individual variation in proficiency of L1 syntax is specifically related to the left IFG function.

In contrast to the performance in second languages (L2s), that in L1 is by definition at the native-level of perfection, and there is little individual variation in its performance. However, the present results demonstrated that even for native speakers there exists a grammatical feature, i.e., honorification, which is difficult to acquire and exhibit individual differences in performance. It is also striking to note that distinct activation patterns can be observed for the low and high performance groups. The enhanced activations of the left LPMC, dF3t, and vF3t for the HO task in the low performance group are consistent with previous fMRI studies, as mentioned above. These enhanced activations cannot be explained by task difficulty in general, since the contrast of MO–SP did not show such extensive activations, in spite of similar performances for the HO and MO tasks when compared with the SP task (Fig. 1). This result provides further support for our previous finding of selective activations in the left LPMC and dIFG, which were demonstrated by direct contrasts between syntactic decision and recency memory tasks (Hashimoto & Sakai, 2002).

Left F3O activation was observed consistently in the HO, MO, and SE tasks, suggesting that this activation subserves the sentence comprehension involved in these tasks. This result is consistent with that of our previous studies (Homae, Hashimoto, Nakajima, Miyashita, & Sakai, 2002; Homae, Yahata, & Sakai, 2003), which clarified selective activation in this region for a sentence comprehension task. Furthermore, another fMRI study has demonstrated that the left MTG was more activated in anomalous sentences than in normal sentences (Suzuki & Sakai, 2003), which is consistent with our finding with SE–SP. The left MTG activation in the present paradigm may reflect enhanced semantic processing for explicitly judging semantically normal/anomalous sentences.

Our recent fMRI study using English past tense verbs has demonstrated that activations in the left dF3t (−51, 24, 24) and the left F3t/F3O (−48, 21, −3) are negatively correlated with the distinct factors of proficiency level and language task demands in L2, respectively (Tatsuno & Sakai, 2005). In the present study, the left dF3t and vF3t activations were also negatively correlated with the accuracy of the HO task even in L1 (Fig. 3D, Table 4). Moreover, this significant modulation was observed for the HO task alone, indicating that activation in these regions was more clearly sensitive to syntactic processing of honorification than to morphological and morphosyntactic processing. There are at least two possibilities for explaining such marked individual variation in L1. First, the honorific expressions are fully acquired in a rich social environment encountered at matured ages (Cook, 1996), which are thus later than the hypothetical "sensitive period" for L1 and L2. Second, individual variation actually exists in every faculties of L1, but the ceiling effects of high performances might mask the most individual differences in L1 capability, except for morphology, morphosyntax, and syntactic computation reveled in the present study. The direction of future research should be thus the elucidation of the neural and computational mechanisms of L1 and L2 acquisition, as well as their developmental changes under the influence of education and socialization.

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